AM1A • 08:00
Coherent Adaptive Optical System, Joseph Marron1; Raytheon, USA.
An adaptive optical system in which coherent images are processed to determine wavefront error and the error is corrected by applying the inverse to a deformable mirror is discussed.

AM1B • 08:00
High-Speed Super-Resolution Microscopy for Biological Imaging, Anna Bezyadina1; Junxiang Zhao1; Joseph Ponsetto1; Yang Xia1; Xiang Zhang1; Zhaowei Liu1; Electrical and Computer Engineering, Univ. of California, Berkeley, USA. We report an efficient strategy using extremely low-cost materials. Due to the excellent thermal insulation, a record thermal efficiency of ~88% was obtained under one sun without concentration, corresponding to the evaporation rate of 1.28 kg/(m² h).

AM1B.2 • 08:15
Broadband Polarization-Insensitive Absorption in Solar Spectrum Enhanced by Magnetic Polaritons, Nan Zhang1; Wenshan Cai2; Shumin Xiao1; Nan Zhang1; Xie Zhang1; Borui Chen1; Jun Gao1; Xiang Liu1; Diana Aqa1; Suhua Jiang2; Zongfu Yu2; Qiaoqiang Gan1; Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, Dept. of Chemistry, USA; Dept. of Electrical and Computer Engineering, Univ. of Wisconsin, USA. We report an efficient strategy using extremely low-cost materials. Due to the excellent thermal insulation, a record thermal efficiency of ~88% was obtained under one sun without concentration, corresponding to the evaporation rate of 1.28 kg/(m² h).

AM1B.3 • 08:30
Highly Reproducible-Organometallic Halide Perovskite Microdevices Based on Top-Down Lithography, Nan Zhang1; Shuai Wang1; Wenshan Cai1; Shumin Xiao1; Qinhai Song1; State Key Lab on Tunable Laser Technology, Ministry of Industry and Information Technology Key Lab of Micro-Nano Optoelectronic Information System, Shenzhen Graduate School, Harbin Inst. of Technology, China; School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA. Herein we fabricate highly reproducible-organometallic-halide-perovskite based devices, various device shapes that are hard to directly synthesize, unique properties and an improved photo-detector have been successfully achieved. The advances will shed light on the practical applications.

SM1C • 08:00
Versatile Sources of High-order Harmonics for Multiple Applications, Anne L’Huillier1; 1Lund Univ., Sweden. This tutorial will introduce the physics of high-order harmonic generation and attosecond pulses and give an orientation of the performances and main applications of current HHG sources.

SM1C.1 • 08:00
Invited
High-Speed Super-Resolution Microscopy for Biological Imaging, Anna Bezyadina1; Junxiang Zhao1; Joseph Ponsetto1; Yang Xia1; Xiang Zhang1; Zhaowei Liu1; Electrical and Computer Engineering, Univ. of California, San Diego, USA; Physics, Univ. of California, Berkeley, USA. We used new super resolution imaging method, localized plasmonic structure illumination microscopy (LPSIM), to observe biological specimens’ movement. This approach allows biologically friendly video rate imaging with wide field of view and 50nm resolution.

FM1D.1 • 08:00
Invited
Cost-effective and Efficient Solar Vapor Generation Using Thermally Isolated Black Paper, Zhejun Liu1; Zongfu Yu2; Qiaoqiang Gan1; Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, Dept. of Chemistry, USA; Dept. of Electrical and Computer Engineering, Univ. of Wisconsin, USA. We report an efficient strategy using extremely low-cost materials. Due to the excellent thermal insulation, a record thermal efficiency of ~88% was obtained under one sun without concentration, corresponding to the evaporation rate of 1.28 kg/(m² h).

FM1D.2 • 08:15
Broadband Polarization-Insensitive Absorption in Solar Spectrum Enhanced by Magnetic Polaritons, Nan Zhang1; Wenshan Cai2; Shumin Xiao1; Nan Zhang1; Xie Zhang1; Borui Chen1; Jun Gao1; Xiang Liu1; Diana Aqa1; Suhua Jiang2; Zongfu Yu2; Qiaoqiang Gan1; Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, Dept. of Chemistry, USA; Dept. of Electrical and Computer Engineering, Univ. of Wisconsin, USA. We report an efficient strategy using extremely low-cost materials. Due to the excellent thermal insulation, a record thermal efficiency of ~88% was obtained under one sun without concentration, corresponding to the evaporation rate of 1.28 kg/(m² h).

SM1C.2 • 08:30
Quantitative Label-free Imaging of Live-cell Adhesion Using Photonic Crystal Enhanced Microscopy (PCEM), Yue Zhao1; Ji Sun Choi1; Thibault Manir1; Hopeong Yu1; Brendan Leary1; Brian T. Cunningham1; 1Univ of Illinois at Urbana-Champaign, USA; Research Park, UIUC, USA. To quantify live-cell adhesion, a photonic crystal biosensor surface with an extracellular matrix coating is monitored within a PCEM instrument to dynamically image changes in attached cell mass-density during live-cell attachment, spreading, and drug response.
Quantum Many-body Physics with Multi-mode Cavity QED

FM1E • 08:00
Invited
Macroscopically Visible Quantum Interference Due to Strong Interactions in Colliding BECs, Rachel E. Wooten¹, Mackillo Kira¹
Center for Ultrafast Optical Science, Univ. of Michigan, USA. We report our observation of a novel form of nonequilibrium phase transition, the condensation of supermode-density-wave-polaritons, by placing a BEC of atoms inside a multimode optical cavity.

FM1F • 08:15
Quantum Many-body Physics with Multi-mode Cavity QED, Benjamin Lev¹, Stanford Univ., USA. We report our observation of a novel form of nonequilibrium phase transition, the condensation of supermode-density-wave-polaritons, by placing a BEC of atoms inside a multimode optical cavity.

FM1G • 08:10
Parity-time Symmetry in Metamaterials

FM1H • 08:00
FM1H.1 • Plasmonic and Dielectric Metasurfaces and Metamaterials

Andrea Alù is the Temple Foundation Endowed Professor #3 at the University of Texas at Austin. His research interests span nano-optics, photonics, electromagnetics and acoustics. He is an OSA, APS, IEEE, SPIE Fellow and recipient of several awards, including the NSF Waterman award and the OSA Lomb medal.

FM1H.2 • 08:15
Achromatic Metamaterials over 60 nm Bandwidth in the Visible, Zhujun Shi¹, Moham-madreza Khorasaninejad¹, Wei-Ting Chen¹, Alexander Y. Zhu¹, Vyshakh Sanjeev¹, Aun Zaidi¹, Federico Capasso¹, Harvard Univ., USA; 2Univ. of Waterloo, Canada. We demonstrate achromatic metamaterials with a constant focal length over 60 nm bandwidth (λ = 490 nm to 550 nm). We also design metasurfaces with reverse chromatic dispersion, opposite to that of a Fresnel lens.

FM1H.3 • 08:30
Broadband Achromatic Metasurface Lenses, Sajad Shrestha¹, Adam Overvig¹, Nanfang Yu¹, Columbia Univ., USA. We experimentally demonstrated broadband achromatic metamaterial surface lenses that show ±3% focal distance error over a wavelength range of ~400 nm in the near-infrared. Converging and diverging metasurface lenses with different numerical apertures have been realized.
08:00–10:00
SM11 • Ultrafast Modelocked Oscillators
President: Thomas Sudmeyer; Université de Neuchâtel, Switzerland

SM11.1 • 08:00
High-precision Modelocked Thin-disk Oscillators: Latest Progress and Future Prospects, Clara J. Saraceno1,2, Ruhr Universität Bochum, Germany. High-power ultrafast thin-disk oscillators have made tremendous progress in the last decade, creating a path towards compact high-power systems from the XUV to the THz domain. We will review most recent progress and future trends.

SM11.2 • 08:30
10-GHz Straight-Cavity SESAM-Mode-Locked Yb:CALGO Laser Operating in the Normal Dispersion Regime, Aline Sophie Mayer1, Christopher R. Phillips1, Ursula Keller1, ETH Zurich, Switzerland. We demonstrate a 10-GHz SESAM-modelocked Yb:CALGO laser delivering 240 fs at 0.64 W from a straight cavity containing a fanout-apodized-PPLN crystal, which provides solid-modelocking via cascaded second-order nonlinearities and a defocusing-lens effect suppressing Q-switching-damage.

SM11.3 • 08:30
Superior Terahertz Generation using Plasmon-Enhanced Sub-bandgap Photoconductive Antenna, Afshin Jooshesh1, Thomas E. Darcie1, Reuven Gordon1; 1Univ. of California, Los Angeles, USA; 2School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore. We demonstrate high quantum yield broad photoluminescence emission of ultrathin sub-nanometer CdSe nanoplatelets at 1570 nm excitation.

SM1J • THz Photonic Oscillators
President: Iwao Kawayaran; Osaka Univ., Japan

SM1J.1 • 08:00
Modulation of Terahertz Polarization on Picosecond Timescales using Polymer-Encapsulated Semiconductor Nanowires, Sarwat A. Baig1, Jessica L. Boland2, Djamshid Damy1, Hoe Tan1, Chennupati Jagadish1, Michael B. Johnston2, Hannah Joyce1; 1Univ. of Cambridge, UK; 2Univ. of Oxford, UK; 3Australian National Univ., Australia. We exploit the photoconductivity of semiconductor nanowires to achieve ultrafast broadband modulation of THz pulses. A modulation depth of -8 dB was achieved by a polarizer consisting of 14 layers of nanowires encapsulated in polymer.

SM1J.2 • 08:15
Terahertz Power Enhancement by Improving Metal Adhesion Layer of Plasmonic Photocductive Sources, Deniz Turan1, Sofia Carolina Corzo Garcia1, Enrique Castro Camus1, Mana Jarrahi1, 1Univ. of California, Los Angeles, USA; 2Centro de Investigaciones en Óptica, Mexico. Impact of metal adhesion layer on performance of plasmonic terahertz sources is investigated. Up to 50% terahertz power enhancement is achieved when using Cr adhesion, compared to Ti adhesion used in existing plasmonic terahertz sources.

SM1K • Materials for Quantum Optics
President: Takehiko Tawara; NTT Basic Research Labs, Japan

SM1K.1 • 08:00
New Color Centers in Diamond for Long Distance Quantum Communication, Nathalie de Leon1; 1Princeton Univ., USA. We have developed new methods to stabilize SiV+ in diamond, and observe T1>1 minute at 4K, and >90% of its emission into its zero phonon line, making it a promising single atom quantum memory.

SM1K.2 • 08:30
Anomalous Spectral Characteristics of Ultrathin sub-nm Colloidal CdSe Nanoplatelets, Sumanta Bose1,2; 1Univ. of Victoria, Canada. We demonstrate eight times larger THz field emission with twice the bandwidth for a plasmon-enhanced low-temperature grown GaAs photoconductive antenna in comparison with a commercial InGaAs device at 1570 nm excitation.

SM1L • High-power, High-energy Fiber Sources
President: Darren Hudson; Macquarie Univ., USA

SM1L.1 • 08:00
High Power Narrow Linewidth Micro-Structured Fiber Amplifiers, Benjamin Pulford1, Cody Mart2, Iyad Dajani1, Thomas Ehrenreich1, Roger Holten2, Craig Robin2; 1Air Force Research Lab, USA; 2Univ. of Arizona, USA; 3Leidos, USA; 4Keeble, USA; 5Lockheed Martin, USA. An acoustic and gain tailored photonic crystal fiber (PCF), and a hybrid microstructured fiber, were used to demonstrate near diffraction limited output powers of 1160W and 820W, respectively, with spectral linewidths <1GHz.
SM1M.1 • 08:00
Silicon Chip-Based Quantum Random Number Generator, Yoshitomo Okawachi1, Mengjie Yu1, Kevin Luke2, Daniel O. Carvalho2, Michel Lipson1, Alexander L. Gaeta1.

We present the experimental demonstration of an Omni-Resonant Optical Micro-Cavity, Soroush Shabahangi1, Hasan E. Kondakci1, Massimo Villinger1, Joshua Perlstein1, Ayman F. Abouraddy1, CREOL, Univ. of Central Florida, USA. By simultaneously phase-matching an angularly multiplexed 50-nm-wide spectrum, we render a Fabry-Perot microcavity having 0.7-nm-wide resonances ‘omni-resonant’, such that it continuously resonates across multiple bare-cavity FSRs.

SM1M.2 • 08:15
A Nonlinear Enhanced Microresonator Gyroscope, Jonathan M. Silver1, Leonardo Del Bino1, Pascal Del’Haye1, National Physical Lab, UK. We present the experimental demonstration of a nonlinear enhanced gyroscope using counterpropagating light in a microresonator. This could enable the realization of integrated optical Sagnac sensors with enhanced sensitivity via the Kerr nonlinearity.

SM1M.3 • 08:30
1.25-Gb/s All-Optical NAND/AND Logic Gates in a Hydrogenated Amorphous Silicon Waveguide, Kangmei Li1, Amy Foster1, John Hopkins Univ., USA. We demonstrate 1.25-Gb/s all-optical NAND/AND logic gates in a hydrogenated amorphous silicon waveguide via four-wave mixing Bragg scattering with only 85-mW peak pump powers in the waveguide.

SM1N.1 • 08:00
Experimental Demonstration of an Omni-Resonant Microcavity, Soroush Shabahangi1, Hasan E. Kondakci1, Massimo Villinger1, Joshua Perlstein1, Ayman F. Abouraddy1, CREOL, Univ. of Central Florida, USA. By simultaneously phase-matching an angularly multiplexed 50-nm-wide spectrum, we render a Fabry-Perot microcavity having 0.7-nm-wide resonances ‘omni-resonant’, such that it continuously resonates across multiple bare-cavity FSRs.

SM1N.2 • 08:15
Silicon Microring with Ferrofluid Cladding, Abdelkrim El Amili1, Mário C. Souza2, Felipe Vallini1, Newton C. Frateschi1, Universite, Denmark. We experimentally investigate a ferrofluid-clad silicon microring resonator-based magnetic field sensor. The device presents relatively high loaded quality factors (~ 6,000) and resonance shifts of 185 pm in response to 110 Oe strong magnetic field.

SM1N.3 • 08:30
Towards Ultra-High Q Microresonators in High-Index Contrast AlGaAs-On-Insulator, Minhao Pu1, Ayman N. Kamel1, Erik Stassen1, 1CREOL, Univ. of Central Florida, USA; 2Materials Science and Engineering Dept., Univ. of Central Florida, USA. We experimentally demonstrate a ferrofluid-clad silicon microring resonator-based magnetic field sensor. The device presents relatively high loaded quality factors (~ 6,000) and resonance shifts of 185 pm in response to 110 Oe strong magnetic field.

SM1O.1 • 08:00
Tri-color Optical Transmitter with Embedding 28-GHz Millimeter-wave Carrier for 5G Mobile over Fiber, Huai-Yung Wang1, Yu-Chieh Chi1, You-Wei Chen1, Gong-Ru Lin1, Graduate Inst. of Photonics and Optoelectronics, and Dept. of Electrical Engineering, National Taiwan Univ., Taiwan. Data throughput enhanced tri-color optical transmitter with single-mode modulation for 28-GHz millimeter-wave over fiber link in 50-km-long SMF is demonstrated to achieve QAM-OFDM baseband data rates of 16-Gba/s optical and 12-Gba/s 3-m wireless communications.

SM1O.2 • 08:15
High Efficiency 36-50 GHz Millimeter-wave Down-Conversion Utilizing a Wideband Tunable Optoelectronic Oscillator Based on Stimulated Brillouin Scattering, Yuanfeng Xu1, Xiaofeng Peng1, Yuxiang Chen1, Cheng Zhang1, Lin Zhu1, Wewei Hu1, Zhangyun Chen1, Peking Univ., China. A novel high-efficiency 36-50GHz millimeter-wave down-conversion system utilizing an optoelectronic oscillator based on stimulated Brillouin scattering is demonstrated. 35-49GHz signals are down-converted to 1GHz IF with -35.72dB conversion-efficiency and without optical or electronic amplifiers.

SM1O.3 • 08:30
Gigahertz tuning of on-chip RF photonic delay line, Yang Liu1,2, Amol Choudhary1,2, David Marpaung2,3, Benjamin J. Eggleton2,3. 1The Univ. of Sydney, Australia, 2Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), Australia. We demonstrate a technique that enables three-fold enhancement of time delay and seamless delay switching for RF signals at gigahertz speed from optical ring resonators on an integrated Si3N4 chip, solely by optical power control.
Executive Ballroom 210A
CLEO: Applications & Technology

AM1A • A&T Topical Review on Advances in Laser-based Remote Sensing I—Continued

AM1A.3 • 09:00
Standoff Detection of Isotopes in a NH3 Chemical Plume, Mark C. Phillips1, Brian Brumfield1, Pacific Northwest National Lab, USA. We perform standoff detection of 15NH3 and 14NH3 at a 10 Hz rate in a chemical plume with varying concentration using an external cavity quantum cascade laser swept over the range 930-1065 cm-1.

AM1A.4 • 09:15
Multi-Wavelength Laser Transmitter for the Two-Step Laser Time-of-Flight Mass Spectrometer, Anthony W. Yu1, Steven X. Li1, Nanyang Technological Univ., Singapore; 2National Univ. of Singapore, Singapore. We are developing a multi-wavelength laser for the two-step laser time-of-flight mass spectrometer (LZMS). The LZMS is designed to detect hydrocarbons in organically-doped analog minerals, including cryogenic Ocean World-relevant ices and mixtures for future astrobiology missions.

AM1B • Photovoltaics—Continued

AM1B.4 • 08:45
Electrosprayed TiO2 Nanoporous Hemispheres Arrays for Enhanced Efficiency of Perovskite Solar Cells, Shaoyang Ma1, Tao Ye2, Lei Wei1, (Nanyang Technological Univ., Singapore; 2National Univ. of Singapore, Singapore. We demonstrate the enhanced performances of perovskite solar cells based on electrosprayed TiO2 nanoporous hemisphere (NHs) arrays. The optimized PCE is 19.3% with a Jsc of 23.8mA/cm2, V oc of 1.14V and FF of 0.71.

AM1B.5 • 09:00
Photovoltaics as a Branch of Optoelectronics:Solar Cells, Heat Engines, Electroluminescent Refrigerators, Eli Yablonovitch1, T. Patrick Xiao2, ‘Univ. of California Berkeley, USA. The photovoltaic cell and the LED are really the reciprocal of one another. The slogan: “A great solar cell has to be a great LED” has led to all the new solar cell efficiency records. Very efficient light emitting diodes (LED's) surprisingly, do actually become cold as they operate, since LED light carries away entropy. This refrigeration requires superb LED efficiency, which is enabled by 2d photonic crystal patternning, for luminescence extraction.

AM1C • Plasmonic Biosensors—Continued

AM1C.3 • 08:45
Ultrasound Detection with Surface Plasmon Resonance on Fiber End-facet, Xiu Zhang1, De Cai1, Xiaolong He1,5, Sung-Liang Chen1, Xueding Wang1, Tian Yang1, State Key Lab of Advanced Optical Communication Systems and Networks, Key Lab for Thin Film and Microfabrication of the Ministry of Education, Shanghai Jiao Tong Univ., China; X’u Yuan Biotechnology Company, China; 2Dept. of Biomedical Engineering, Univ. of Michigan, USA. A surface plasmon resonance cavity on an optical fiber end-facet is designed and demonstrated for ultrasound detection. A noise equivalent pressure of 25 KPa over 20 MHz, almost omni-directional response and stable performance are reported.

AM1C.4 • 09:00
Monolayer WS, Enhanced High Sensitivity Plasmonic Biosensor based on Phase Modulation, Qingling Ouyang1,2, Nishtha Panwar1, Shuwen Zeng1, Xiuling Wang1, Li Jiang1,2, Xuan-Quyen Dinh1,2, Beng Kang Tay1,2, Philippe Coquet1,4, Ken-tye Yong1,2, School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore; 2CINTRA CNRS/NTU/THALES, Singapore; 3State Key Lab of Modern Optical Instrumentation, Centre for Optical and Electromagnetics Research, Zhejiang Univ., China; 4EMN, CNRS UMR 8520, France. A monolayer WS, enhanced surface plasmon resonance biosensor is proposed. We theoretically and experimentally demonstrate that the sensitivity could reach to 3.5×10⁴ deg/RIU, which was 300% higher than that of the conventional configuration.

AM1C.5 • 09:15
On-chip detection of immune-cell secretion using a circular nanoplasmonic interferometer array, Xie Zeng1, Yifeng Qian1, Yongkang Gao1, Hang Li1, Sushil Kumar1, Qiaoqiang Gan1, Xuanhong Cheng1, Filipbert Bartoli1, Lethigh Univ., USA; 2The State Univ. of New York at Buffalo, USA; 3Alcatel-Lucent Bell Labs, USA. The MPM-9 protein secreted by THP1 cells was detected using an on-chip circular nanoplasmonic interferometer array. Sensitive dynamic analysis of MPM-9 in the supernatant was demonstrated, suggesting the device a potential for cell function analysis.

SM1C • Plasmonic Biosensors—Continued

SM1C.3 • 08:45
Ultrasound Detection with Surface Plasmon Resonance on Fiber End-facet, Xiu Zhang1, De Cai1, Xiaolong He1,5, Sung-Liang Chen1, Xueding Wang1, Tian Yang1, State Key Lab of Advanced Optical Communication Systems and Networks, Key Lab for Thin Film and Microfabrication of the Ministry of Education, Shanghai Jiao Tong Univ., China; X’u Yuan Biotechnology Company, China; 2Dept. of Biomedical Engineering, Univ. of Michigan, USA. A surface plasmon resonance cavity on an optical fiber end-facet is designed and demonstrated for ultrasound detection. A noise equivalent pressure of 25 KPa over 20 MHz, almost omni-directional response and stable performance are reported.

FM1D • Attosecond Science—Continued

FM1D.2 • 09:00
Observing the Ultrafast Buildup of a Fano Resonance in the Time Domain, Andreas Kaldun1,2, Alexander Blättermann1, Veit Stood1, Stefan Donsa1,2, Hui Wei1, Renate Pazourek1, Stefan Nagele1, Christian Ott1,2, Chi-Dong Lin1, Joachim Burgdörfer1, Thomas Pfeifer1,2, ‘Max-Planck-Institut für Kernphysik, Germany; 3PULSE Inst. for Ultrafast Energy Science, SLAC National Accelerator Lab, USA; 4Inst. for Theoretical Physics, Vienna Univ. of Technology, Austria; 5Dept. of Physics, Kansas State Univ., USA; 6Center for Quantum Dynamics, Universität Heidelberg, Germany. First experimental observation of the time-dependent build-up of an asymmetric Fano resonance achieved by using a tunable temporal gate to interrupt the autoionization process of a correlated two-electron excited state in He with a strong laser field.

FM1D.3 • 09:15
Investigating Impulsive Strong Field Perturbation of Molecular Rydberg States with XUV Transient Absorption, Chen-Ting Luo1, Nathan Harkema1, Arvinder Sandhu1, ‘Univ. of Arizona, USA. We probe the laser induced modification of XUV initiated molecular polarization using attosecond transient absorption. Spectral evolution is used to investigate the vibrationally resolved dynamics. We also simulate the spectrogram under impulsive laser perturbation.
Using a high-brightness Univ., Germany. QFT is efficiently realized with trapped Yb+ between three effective spins, a coherent range magnetic gradient induced coupling are measured close to the quantum limit.

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We introduce a general set of conditions for observing reverse pump dependence in lasers and other counterintuitive phenomena, which demonstrate that any irreducible system with patterned gain and loss can exhibit such exotic behaviors.

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We report a high-efficiency Amplitude-Phase Modulation of emissivity in the mid-infrared is experimentally realized using thin-film phase-transition material SmNiO 3. Designs of variable emissivity coatings based on metasurfaces integrated with SmNiO 3 are also reported.
Femtosecond Yb:YAG Laser Modelocked Using Intracavity SHG, Veselin S. Aleksandrov1,2, Luben S. Petrov1, Nickolai Belashenko1, Ivan C. Buchvarov1,3, Sofia Univ. St. Kliment Ohridski, Bulgaria; 2IPh Photonics Ltd., Bulgaria; 3ITMO Univ., Russia. A femtosecond Yb:YAG laser mode-locked using intracavity SHG is demonstrated. Stable operation is achieved with pulse duration of 660 fs, output power of 0.8 W at repetition rate of 110 MHz.

SM1J.4 • 08:45
Highly Efficient Photoconductive Terahertz Generation through Photonic Trapping, Norbert Modsching1,2, Christian Kränkel2, Thomas Sudmeyer1,3, Institut de Physique, Université de Neuchâtel, Switzerland; 2Inst. of Laser-Physics, Univ. of Hamburg, Germany. We discuss different configurations of KLM thin-disk lasers based on Yb:LuO. We achieve shorter pulses than previously demonstrated for this gain material in the thin-disk configuration and up to 11.0 W in 184-fs pulses.

SM1K.3 • 08:45
Frequency-Domain Measurement of Spontaneous Emission Lifetime in Rare-Earth-Doped Gain Media, Enri S. Magden1, Patrick T. Callahan1, Nanxi Li2, Katia Shutykova1, Alfonso Ruocco1, Neetesh K. Singh1, Ming Xing1, Diederik Vermeulen1, Jonathan Bradley2, Gerald Leake2, Douglas Caulbaugh3, Leslie Kolodziejski3, Franz Kaehtner1,2, Erich P. Ippen1, Michael Watts1. A Q-switched modelocked Holmium doped YAG waveguide laser is reported. With a Graphene saturable absorber the repetition rate of 110 MHz is achieved, with a mode-locked repetition rate of 5.9 GHz.

SM1K.4 • 09:00
Quantum Nano-photonic Devices Based on Rare-earth Ions, Andrei Pashov1, Applied Physics, Caltech, USA. We present a highly efficient photonic crystal cavities for terahertz generation. This oscillator operates at room temperature and has a gain of 55 dB based on the fundamental principle of injection-seeded THz parametric generator/detector.

SM1L.4 • 09:00
A Kilo-Watt all-fiber distributed-pumping oscillator, Jianju Cao1, Yu Yu1, Hanyuan Ying1, Zhiyang Pan1, Zefeng Wang1, Jinbao Chen1, National Univ of Defense Technology, China. An all-fiber distributed-pumped oscillator with 1.14-kW output power was demonstrated. Laser gain competition was used to suppress parasitic lasing and an output power of 80 W was generated at 2130 nm with 50% optical efficiency.

SM1L.5 • 09:15
Single-mode 60-µm-core multiple-cladding-resonance photonic bandgap fiber laser with ~1kW output power, Guancheng Gu1, Fantiing Kong1, Thomas Hawkins1, Maxwell Jones1, Joshua Parsons1, Monica T. Kalichevsky-Dong2, Benjamin Pullford1, Iyad Dajani1, Stephen Palese3, Eric Cheung4, Liang Dong1, Clemson Univ., USA; 2Nufern, USA; 3Air Force Research Lab, USA; 4Raytheon Space & Airborne Systems, USA; 5Northrop Grumman Aerospace Systems, USA. We report the effectiveness of multiple-cladding-resonance photonic bandgap fiber for suppressing mode instability by demonstrating pump-limited single-mode output power of ~1 kW in a 60-µm-core fiber, a record for any fiber lasers at this core diameter.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

Marriott Salon III

Marriott Salon IV

Marriott Salon V & VI

CLEO: Science & Innovations

SM1M • Integrated Nonlinear Photonic Platforms—Continued

SM1M.4 • 08:45
All-optically induced quasi phase matching in SiN waveguides for second harmonic generation enhancement, Davide Grassani1, Adrien Billat1, Martin Pfeiffer1, Syvatoslav Kharitonov1, Tobias J. Kippenberg1, Camille-Sophie Bres1; EPFL, Switzerland. We report more than 30dB second harmonic generation enhancement in SiN waveguide by all-optical writing of a persistent $\chi^{(2)}$ grating. Phase matching peaks are observed for different writing wavelengths.

SM1N • High-Q Micro-cavities and Applications—Continued

SM1N.4 • 08:45
Transversely Coupled Fabry-Perot Resonators in SOI, Md. Ghulam Saber1, Zhenping Xing1, Eslam El-Fiky1, David Patel1, Luhua Xu1, Nicolas Abadia1, David V. Plant1; McGill Univ., Canada. We experimentally demonstrate transversely coupled Fabry-Perot resonators using sidewall Bragg gratings and loop mirrors as reflectors in silicon-on-insulator platform. The resonators have channel spacing of ~50 GHz, extinction ratio of ~12 dB and Q-factor of ~15350.

SM1O • RF Photonics—Continued

SM1O.4 • 08:45
Silicon Optical-Phased-Array Prototypes Using Electro-Optical Phase Shifters, Che Zhao1, Haiyang Zhang1, Zhong Zheng1, Chao Peng1, Weiwei Hu1; ‘Peking Univ., China. High-speed silicon optical-phased-array (OPA) prototypes are achieved using electro-optical phase shifters with quick response (4.2 ns) and small footprint (500 μm / 2π), 11.1° (1D) and 7.4° × 3.7° (2D) beam steering is observed.

SM1N.5 • 09:00
Post processing resonance trimming of a silicon micro-ring resonator using Flash memory technology, Mei Y. Grajower1, Noa Mazurski1, Joseph Shappir 1, Uriel Levy1; Hebrew Univ. of Jerusalem, Israel. A new post processing approach for resonance trimming of a micro-ring resonator is presented. The approach is based on charge trapping in thin layer of silicon nitride as done in Flash memories device.

SM1M.5 • 09:00 Invited
Nonlinear Optical Frequency Conversion in Aluminum Nitride Photonic Circuits, Hong Tang1; Electrical Engineering, Yale Univ., USA. I will discuss the development of high efficiency optical frequency converters based on AlN nonlinear photonic circuits, including visible-to-IR conversion leveraging AlN's $\chi^{(2)}$ nonlinearity and microwave driven noiseless in-band frequency conversion at single photon levels.

SM1N.5 • 09:15
On-chip beam positioning sensor via frequency locked cascaded ring resonators, Alex Naaman1, Liron Stern1, Uriel Levy1; The Hebrew Univ. of Jerusalem, Israel. We present a novel technique for on-chip beam positioning, based on tracking the thermo-optic driven spectral resonance shifts between two cascaded microring resonators vs. the position of an NSOM tip which illuminates the structure.

SM1O.5 • 09:00
Compressed Sensing of Sparse RF Signals Based on Silicon Photonic Microwavities, Hongcheng Sun1, Bryan T. Bosworth1, Brian C. Grubel1, Michael Kassay1, Mark A. Foster1, Amy Foster1; The Johns Hopkins Univ., USA. We demonstrate accurate reconstructions of sparse radio frequency signals using silicon photonic microwavities to generate the pseudorandom pattern. A compression ratio of 8% is achieved for 24 patterns.

SM1O.6 • 09:15
Silicon microring weight banks for multivariate RF photonics, Alex Tait1, Thomas Ferrera de Lima1, Ellen Zhou1, Allie X. Wu1, Matt Chang1, Mitchell A. Nahmias1, Bhavin J. Shastri1, Paul R. Prucnal1; Princeton Univ., USA. Microring weight banks enable novel analog processing approaches in silicon photonics. Incorporating statistical techniques, they can implement wideband dimensionality reduction. We demonstrate principal component analysis of three 1GHz signals in a microring weight bank.
AM1A.6 • 09:45
Adaptive Perfect Coherent Absorber for Photoacoustic Spectroscopy, Mohammadreza Ghasemkhani1, Alexandre R. Albrecht1, Eric Lee1, Denis Seletsky1, Mansoor Sheik-Bahae1; 1Univ. of New Mexico, USA; 2Dept. of Physics and Center for Applied Photonics, Univ. of Konstanz, Germany. Using adaptive coupled Fabry-Perot cavities, we have utilized the concept of perfect coherent absorbers in a compact and sensitive photoacoustic spectrometer. Normalized noise-equivalent absorption (NNEA) coefficient of $-1 \times 10^{-10}$ cm$^{-1}$ W Hz$^{-1/2}$ is measured.

AM1B • Photovoltaics—Continued

SM1C • Plasmonic Biosensors—Continued

FM1D • Attosecond Science—Continued
Robert McConnell, Rajeev Ram, Jeremy limited, focused beams. We discuss our addressing of atomic ions with diffraction-within planar ion traps can enable scalable quantum information processing.

We measure the ultrafast nonlinear dynamics of two-layer graphene sheets, Jennifer M. Reed, Manuel R. Ferdinandus, Kathleen Brockdorf, Shin Mou, Augustine Urban. We measure the ultrafast nonlinear dynamics of two-layer graphene. One instantaneous electronic and three noninstantaneous free carrier responses are observed. Measurements indicate a large saturable absorption effect due to Pauli blocking.

Fast tunable terahertz absorber based on a MEMS-driven metamaterial, Mingkai Liu, Mohammad Susli, Dilusha Silva, Gino Putrino, Hemendra Kala, Shuting Fan, Michael Cole, Lorenzo Farace, Vincent Wallace, Willie J. Padilla, David A. Powell, Mariusz Martyniuk, Ilya Shadrivov, “Nonlinear Physics Centre, Australian National Univ., Australia; 2School of Electrical, Electronic and Computer Engineering, Univ. of Western Australia, Australia; 3School of Physics, Univ. of Western Australia, Australia; 4Dept. of Electrical and Computer Engineering, Duke Univ., USA. We design, fabricate and experimentally study ultra-thin tunable terahertz absorbers based on MEMS-driven metamaterials. We demonstrate giant tuning of resonant absorption, with practical modulation speeds that can be useful for terahertz detection and imaging applications.

On-resonance chiral metamaterial for chiroptical sensing at the molecular level, Hamed Shams Mousavi, Sajanlal R. Panikkar, Valappil, Ali A. Eftekhar, Mostafa El-Sayed, Ali A. Adibi, “Georgia Inst. of Technology, USA. We present a novel three-dimensional chiral metamaterial design for chiroptical spectroscopy. Utilizing the chiral light-matter interaction between the designed metamaterial and molecule that is chiral in the same wavelength range, we demonstrate chiroptical sensing at the molecular level.
SM1.6 • Ultrafast Modelocked Oscillators—Continued

SM1.6 • 09:30  Invited
Generation of 220 fs, 20 W pulses at 2 µm from Kerr-lens mode-locked Ho:YAG thin-disk oscillator, Jinwei Zhang1, Ka Fai Mak1, Sebastian Gröblmeier1, Dominik Bauer1, Dirk Sutter2, Vladimir Pervak2, Ferenc Krausz1,2, Oleg Pronin1; ‘Max-Planck-Inst. of Quantum Optics, Germany; ‘Ludwig-Maximilians-Univ. Munich, Germany; ‘TRUMPF Laser GmbH and Co. KG, Germany. We report the first mode-locked Ho:YAG thin-disk oscillator delivering 220-fs pulses at 20-W average power and 2090-nm central wavelength. The output parameters constitute the highest average power of any mode-locked oscillator around 2 µm.

SM1J • THz Photonic—Continued

SM1J.6 • 09:30 Complete Wavefront Control of Single-Cycle THz Pulses via Optical Pulse Envelope Manipulation, Bradley Smith1, John Whittaker1; ‘Univ. of Michigan, USA. The generation of THz pulses by tilted and curved optical pulse-fronts is modeled from first-principles — agreeing with initial experimental results. We also propose a novel method to rapidly vary the tilt of optical pulse-fronts.

SM1K • Materials for Quantum Optics—Continued

SM1K.5 • 09:30 Improving Photoluminescence Collection from Nitrogen Vacancy Ensembles in Diamond via Surface Texturing, Samuel M. Parks1, Richard Grote1, David Hopper1,2, Lee Basset1; ‘Univ. of Pennsylvania, USA; ‘Dept. of Physics, Univ. of Pennsylvania, USA. We demonstrate a 60% increase in collected photoluminescence from nitrogen-vacancy ensembles in single-crystal diamond by surface texturing. Enhancements of up to a factor of 23 are predicted for optimized texturing and collection.

SM1L • High-power, High-energy Fiber Sources—Continued

SM1L.6 • 09:30 Transverse-Mode Instability Mitigation using Photonic-Lantern Adaptive Spatial Mode Control, Juan Mantoya1,2, Chris Aleshrie1, Christopher Hwang1, Dale Marts1, Niyom Lue1, Andrew Benedick1, Tso-Yee Fan1, Dan Riper2; ‘Massachusetts Inst of Tech Lincoln Lab, USA. We report on mitigating transverse mode instability using a photonic-lantern all-fiber-based adaptive spatial mode control (ASMC) system. We demonstrate control of polarization, phase, and amplitude to combat optical disturbances.

SM1K.6 • 09:45 Quantum Photonic Wavelength Conversion and Modulation using Low Loss Aluminum Nitride, Gong Zhang1, Jianguo Huang1, Wee Ser1, Weibo Guo1, Yidong Chong2, Jiangbin Gong1, Leong Chuan Kwek1, Al Qun Liu1; ‘School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore; ‘School of Physical and Mathematical Sciences, Nanyang Technological Univ., Singapore; ‘Dept. of Physics and Centre for Computational Science and Engineering, National Univ. of Singapore, Singapore; ‘Centre for Quantum Technologies, National Univ. of Singapore, Singapore. An AlN photonic chip for quantum wavelength convention and modulation is designed and fabricated. The waveguide has low loss down to 1.2 dB/cm. Fast switching using Pockels effect and second harmonic generation is achieved.

SM1L.7 • 09:45 Tunable, All-Fiber, Continuous Wave Oscillator in the E-band Operating on the 4F3/2 to 4I13/2 transition in Neodymium, Leily S. Kiani1, Jay Dawson1, Paul H. Pax1, Graham S. Allen1, Victor V. Khitrov1, Derek R. Drachenberg1, Michael J. Messerly1, Nick Schenkel1, Matthew J. Cook1, Robert P. Crist1; ‘Lawrence Livermore National Lab, USA. We demonstrate 80 nm of tuning in the 1400 nm range with 116 mW maximum output power in an Nd3+ doped fiber oscillator with distributed spectral filtering.
SM1M • Integrated Nonlinear Photonic Platforms—Continued

SM1M.6 • 09:30
Enhanced Effective Second-order Nonlinearities in Si-rich SIN Thin Films, Hing-Hsi Lin1, Raja Sharma1, Mu-Han Yang1, Matthew W. Puckett1, Christian D. Wurm1, Felipe Vallin1, Yeshiahu Fanman1; 1Electrical and Computer Engineering, Univ. of California, San Diego, USA. We develop Sr-rich SiN thin films exhibiting large effective second-order nonlinearity ($\chi^{(2)}$) as high as 22.7 pm/V by combining the nonlinear contribution from pre-existing $\chi^{(2)}$ in SiN and from the electric-field induced second-harmonic (EFISH) effect.

SM1M.7 • 09:45
Silicon photonic crystal cavity enhanced second-harmonic generation from monolayer WSe2, Taylor K. Fryett1, Kyle Seyler1, Jiajiu Zheng1, Xiaodong Xu1, Arka Majumdar1; 1Univ. of Washington, USA. We demonstrate a silicon photonic crystal cavity enhanced second-harmonic generation (SHG) in tungsten diselenide. The observed SHG is enhanced by a factor of ~200 compared to a bare monolayer on silicon.

SM1N • High-Q Micro-cavities and Applications—Continued

SM1N.7 • 09:30
Subwavelength Grating Racetrack Resonator Based Ultrasensitive Refractive Index Sensor, Liyun Huang1,2, Hai Yan1, Xiaoqian Xu1, Swapnajit Chakravarty1, Nameei Tang1, Huiping Tian1, Ray T. Chen1,2; 1Dept. of Electrical and Computer Engineering, The Univ. of Texas at Austin, USA; 2State Key Lab of Information Photonics and Optical Communications, School of Information and Communication Engineering, Beijing Univ. of Posts and Telecommunications, China. Omega Optics Inc, USA. An ultrasensitive transverse magnetic mode subwavelength grating racetrack resonator with a sensitivity of 429.7 nm/RIU and a detection limit of 3.71 x 10^-4 RIU is demonstrated experimentally.

SM1N.8 • 09:45
The Switchable EIT-like and Fano Resonances in Microring-Bragg Grating Based Coupling Resonant System, Zecen Zhang1, Ting Hu1, Xiaodong Qiu1, Xin Guo1, Mohamed S. Rouifed1, Chongyang Liu1, Hong Wang1; 1School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore. A microring-Bragg grating based coupling resonant system is experimentally demonstrated to generate switchable EIT-like and Fano transmissions for the first time. The resonance state is dependent on the relation between coupling coefficient and round-trip-intensity-attenuation.

SM1O • RF Photonics—Continued

SM1O.7 • 09:30
Highly selective and reconfigurable Si3N4 RF photonic notch filter with negligible RF losses, Yang Liu1,2, David Marpaung1,2, Amol Choudhary1,2, Benjamin J. Eggleton1, 1The Univ. of Sydney, Australia; 2Centre for Ultrahigh bandwidth Devices for Optical System (CUDOS), Australia. We present an integrated RF photonic notch filter on a Si3N4 chip, with tunable bandwidth (150-300 MHz), high rejection (>50 dB), tuning range of 1-12GHz and negligible RF insertion loss, using resonators’ unique phase responses.

SM1O.8 • 09:45
Microwave frequency-doubling based on a coupling-modulated silicon ring resonator, Yiming Zhong1, Linjie Zhou1, Yanyang Zhou1, Uyang Xie1, Minjuan Wang1, Jianping Chen1; 1Shanghai Jiao Tong Univ., China; 2Univ. of California, Santa Barbara, USA. We demonstrate microwave signal generation with frequency doubling using a coupling-modulated silicon ring resonator at critical coupling. The average electrical harmonic suppression ratio is around 20dB (29dB) for 5dBm (10dBm) input microwave power.
Shiming Zhu 1, Sune R. Svanberg 1,2; 
Research Center, USA; 2Analytical Services
Zhao1, Ming Lian 1, Zheng Duan 1, Yiyun Li 1,
using a Novel Mobile System,
Guangyu of Atmospheric Atomic Mercury in China
Differential Absorption Lidar Monitoring
Upendra Singh1,2, Tamer Refaat1,2, Mulugeta Petros1,2, Syed Ismail1,2; NASA Langley Research Center, USA; 2Analytical Services and Materials Inc, USA. Challenges towards development and demonstration of an airborne 2-μm triple-pulse integrated path differential absorption (IPDA) lidar for simultaneous measurements of carbon dioxide and water vapor column measurements from air and space-borne platform will be presented.

Invited
AM2B • Mid-IR Sensors and Emitters
President: To be Determined
New Sources and Sensors for Mid- to Far-IR Optical Sensing, Ian Ku, Daoshan Jung2, Sukriti Dev1, Narsee Yoon1, Leland J. Nordin1, Anthony J. Hoffman1, Minjoo Lee, Dan Wasserman1, ‘Univ. of Texas at Austin, USA; 2Elctrical and Computer Engineering, Univ. of Illinois Urbana Champaign, USA. The mid- to far-IR wavelength ranges offer unique opportunities to engineer a wide range of light matter interactions. We will present new optical and optoelectronic devices and materials leveraging these interactions for next generation optical systems.

AM2A.2 • 11:00
Differential Absorption Lidar Monitoring of Atmospheric Atomic Mercury in China using a Novel Mobile System, Guangyu Zhao1, Ming Lian1, Zheng Duan1, Yiyun Li2, Shiming Zhu2, Sun R. Svanberg1,2; South China Normal Univ., Sweden; 2Lund Univ., Sweden. Mercury is a severe pollutant in China. A novel mobile laser spectroscopy lab was constructed and used in differential absorption lidar mapping in major Chinese cities, a heavily polluted mining area and an archeological site.

AM2B.2 • 11:00
Narrow-Linewidth Oxide-Confined Heterogeneously Integrated Si/III-V Semiconduc-
tor Laser, Wang Huolei1, Dongwun Kim1, Mark Harfouch2, Naresh Satyani2, George Rakuljic2, Amnon Yariv1,2; Dept. of Applied Physics and Materials Science, California Inst of Technology, USA; 2Dept. of Electrical Engineering, California Inst. of Technology, USA. We demonstrate a narrow-linewidth heterogeneously integrated silicon/III-V laser based on the oxide-confinement method. The laser achieves an output power of 4 mW and a linewidth of 28 kHz with a threshold current of 62 mA and a side mode suppression ratio of 50 dB at 1574 nm.

AM2A.1 • 10:30
Active Optical Remote Sensor for Carbon dioxide and Water Vapor Measurement from an Air and Space-borne Platform, Upendra Singh1,2, Tamer Refaat1,2, Mulugeta Petros1,2, Syed Ismail1,2; NASA Langley Research Center, USA; 2Analytical Services and Materials Inc, USA. Challenges towards development and demonstration of an airborne 2-μm triple-pulse integrated path differential absorption (IPDA) lidar for simultaneous measurements of carbon dioxide and water vapor column measurements from air and space-borne platform will be presented.

AM2B.1 • 10:30
New Sources and Sensors for Mid- to Far-IR Optical Sensing, Ian Ku, Daoshan Jung2, Sukriti Dev1, Narsee Yoon1, Leland J. Nordin1, Anthony J. Hoffman1, Minjoo Lee, Dan Wasserman1, ‘Univ. of Texas at Austin, USA; 2Elctrical and Computer Engineering, Univ. of Illinois Urbana Champaign, USA. The mid- to far-IR wavelength ranges offer unique opportunities to engineer a wide range of light matter interactions. We will present new optical and optoelectronic devices and materials leveraging these interactions for next generation optical systems.

AM2A • A&T Topical Review on Advances in Laser-based Remote Sensing II
President: Fabio Di Teodoro; Raytheon, USA

SM2C • Biomedical Spectroscopy and Cell/Particle Analysis
President: Andreu Llobera; Centre Nacional de Microelectronica, Spain

SM2C.1 • 10:30
Applications of Laser Spectroscopy to Meet Challenges in Medicine, Katarina Svanberg1,2; 1Lund Laser Centre, Sweden; 2Center for Optical and Electromagnetic Research, China. Laser based spectroscopic techniques can be used in the detection and therapy of human diseases. Examples from oncology, orthopedics and pediatrics as well as from the field of food quality control will be given.

Katarina Svanberg is an M.D. and a Ph.D. and holds a professorship in Oncology at Lund University, Sweden as well as at South China Normal University in Guangzhou, China. Her main research interest concerns light interaction in tissue in biomedical optics and photonics for applications in the clinic.

SM2C.2 • 10:30
Time-Resolved X-ray Absorption Spectroscopy with a Water-Window High-Harmonic Source, Yoann Perrin1, Jean-Pierre Wolf2, Hans Jakob Woerner1; 1ETH Zurich, Switzerland; 2Universite de Geneve, Switzerland. Femtosecond X-ray absorption spectroscopy is demonstrated at the carbon K-edge (290 eV) and sulfur L-edges (180-240 eV) and applied to study the photodissociation of CO2 and SF5 by element-specific core-to-valence transitions.
FM2E.1 • 10:30
Spatially Multimode Holographic Quantum Memory for Single and Multiple Photons Generation, Michal Dabrowski1, Radoslaw Chrapkiewicz1,2, Wojciech Wasilewski1,2, Faculty of Physics, Univ. of Warsaw, Poland; 2Stanford Univ., USA. We experimentally demonstrate μs-lifetime holographic quantum memory for single photon and up to 60 photons, based on Raman interaction in warm rubidium-87 vapors. Such a multimode memory could practically enhance rates of single and multiple photons generation.

FM2E.2 • 10:45
Q Lad: A Noise-Free Quantum Memory for Broadband Light at Room Temperature, Joshua Nunn1, Krzysztof T. Kaczmarek1, Patrick M. Ledingham1, Benjamin Brecht1, Amir Feizpour1, Guillaume S. Thekkadath2, Ian A. Walmsley1; 1Faculty of Physics, Univ. of Warsaw, Poland; 2Stanford Univ., USA; 3Physics, Univ. of Oxford, UK; 4National Research Council, Canada. We implement a low-noise, broadband quantum memory for light via off-resonant two-photon absorption in warm atomic vapors. We store heralded single photons and verify that the retrieved fields are anti-bunched.

FM2E.3 • 11:00
Storage of Ultra-Broadband Pulses in Hot Atomic Barium Vapor, BIN FANG1, Shuai Dong1, Seth Meiselman1, Offir Cohen1, Virginia O. Lorenz1; 1Physics, Univ. of Illinois at Urbana-Champaign, USA; 2Physics, Univ. of Delaware, USA. We demonstrate the potential for an ultra-broadband quantum memory in hot atomic barium vapor using an off-resonance Raman interaction. It may enable storage of THz-bandwidth photons for high-speed quantum information processing in the telecom range.

FM2F.1 • 10:30
Invited
Engineered Nonlinearities in Transparent Conducting Oxides, Marcello Ferrera1, Matteo Clerici1, Nathaniel Kinsey1, Clayton DeVault1, Jonngbum Kim1, Enrico Caroli1, Luca Caspani2, Amir Shaltout1, Daniele Faccio1, Vladimir M. Shalaev1, Andrea Boltasseva1, Heriot-Watt Univ., UK; 2Virginia Commonwealth Univ., USA; 3Univ. of Glasgow, UK; 4Purdue Univ., USA; 5Univ. of Strathclyde, UK. Towards the fabrication of all-dielectric nanophotonic devices with tunable capabilities, we combined interband and intraband nonlinearities in aluminum-doped zinc oxide thin films thus enlarging the material bandwidth and gaining ultra-fast control over the transmitted spectrum.

FM2G.1 • 10:30
Invited
Photonic Topological Insulators in Two and Three Dimensions, Alexander B. Khanikaev1, City College of New York, USA. Magneto-electric coupling is shown to give rise to topological surface states in 2D and 3D systems with electromagnetic duality. The ability to control magneto-electric coupling locally enables reflectionless routing of electromagnetic states along arbitrarily shaped pathways.

FM2H.1 • 10:45
Label-free Detection of Nucleic Acid Composition within DNA Strands using Surface-enhanced Raman Spectroscopy, Lindsay Freeman1, Lin Pang1, Yehiaahu Fanman1, 1Univ. of Califomia, San Diego, USA. We demonstrate label-free detection of the composition of a single strand of DNA using surface-enhanced Raman spectroscopy in which DNA is linearized to plasmonic surfaces and hundreds of Raman spectra are acquired and statistically analyzed.

FM2H.2 • 11:00
Active Metasurface Sensors for High Sensitivity Detection of the Concentration and Mid-Infrared Spectral Fingerprints of Biomolecules, Zhaoyi Li1, Yibo Zhu1, James C. Hone1, Qiao Lin1, Nanfang Yu1; 1Columbia University, USA. We report biosensors based on tunable graphene plasmonic metasurfaces that enable high sensitivity detection of both the concentration and mid-infrared spectral fingerprints of human anti-body immunoglobulin (IgG).
Franz Kaertner1,2; all-inline scheme for relative timing measurement.

We introduce an optical method of regenerative mode-locking. A novel method of regenerative mode-locking, directly stabilized solitons in silicon-nitride microresonators, Chengying Bao1, Andrew Weiner1, Yi Xuan1, Daniel Leaird1, Minghao Qi2; Purdue Univ., USA. We investigate soliton generation dynamics with the influence of thermal effects. Either soliton annihilation or survival can occur in different trials with the same tuning method, and a spontaneous route to soliton formation is observed.

Reduction of a Chip-scale CPM Laser Using COEO Multi-tone Injection Locking, Ricardo Bustos Ramirez1, Michael Plasck1, Kirintra Bagnell1, Ashish Bhardwaj1, James Ferrara1, Gloria Hoefler2, Ming C. Wu3, Peter J. Delfyett1; 1CREOL, The College of Optics & Photonics, USA; 2Infinera Corporation, USA; 3Electrical Engineering and Computer Science, Univ. of California at Berkeley, USA. A fully stabilized, self-referenced 750-MHz Yb fiber laser frequency comb, the device could continuously generate the optical frequency comb. The device could continuously generate the optical frequency comb. The device could continuously generate the optical frequency comb. The device could continuously generate the optical frequency comb.

High-Dynamic-Range Relative Arrival Time Measurement for Accurate and Precise Parametric Waveform Synthesis, Giulio Maria Rossi1,2, Roland E. Marz1,2, Yudong Yang1,2, Oliver Muecke1,2, Ricardo Bustos Ramirez3, Michael Plasck1, Kirintra Bagnell1, Ashish Bhardwaj1, James Ferrara1, Gloria Hoefler2, Ming C. Wu3, Peter J. Delfyett1; 1CREOL, The College of Optics & Photonics, USA; 2Infinera Corporation, USA; 3Electrical Engineering and Computer Science, Univ. of California at Berkeley, USA. We reported the low-loss Ge-on-GaAs platform for mid-infrared spectral region is reported. Mid-infrared spectral region is reported. Mid-infrared spectral region is reported. Mid-infrared spectral region is reported.

Ultra-low Noise All-inorganic Perovskite CsPb2Br5 Microplate with Superior Crystallization, Enhanced Stability, and Various Optical Properties, Thomas R. Schibli1, 2, Kaoru Minoshima1,2, Alfred Leitenstorfer1; 1Karlsruhe Institute of Technology, Germany; 2ERATO MINOSHIMA Intelligent Optical Synthesizer Project, Japan Science and Technology Agency, Japan; 3Physics, Univ. of Colorado at Boulder, USA. We developed a microwave-referenced optical frequency synthesizer based on a fully stabilized, self-referenced 750-MHz Yb fiber laser frequency comb. The device could continuously generate the optical frequencies and the tuning speed reaches 60 GHz/s.
**Marriott Salon III**

**SM2M.1 • 10:30**

**Topology Optimization in Nonlinear Nanophotonics: from Frequency Conversion to Exceptional Points**, Alejandro Rodriguez, "Princeton Univ., USA. We exploit topology optimization to design complex nanophotonic structures (new kinds of micropillars, photonic-crystal slabs, and waveguides), with applications to efficient nonlinear frequency conversion and dual-polarization, dual-wavelength, and highly degenerate zero-index metamaterials and exceptional points.

**SM2M.2 • 11:00**

**Waveform Dynamics in Air-slot Photonic Crystal Optomechanical Oscillators**, Jiagu Wu, Shu-Wei Huang, Yangjun Huang, Hao Zhou, Mingbin Yu, Guoqiang Lo, DimLee Kwong, Shukai Duan, Cheewei Wong, "Southwest Univ., College of Electronic and Information Engineering, China; "Univ. of California, Los Angeles, Fang-Lu Mesoscopic Optics and Quantum Electronics Lab, USA; "Univ. of Electronic Science and Technology of China, School of Communication and Information Engineering, China; "STAR Inst. of Microelectronics, Singapore. We study experimentally and theoretically the use of photonic crystal nano-cavity to generate a broad range of waveforms, mediating by Drude electron-hole plasma in silicon, and coming from the dynamical states at varying operating conditions.

**SM2M.3 • 11:00**

**Fabrication of All-Glass Toroidal Microresonators for Photothermal Imaging**, Kandandar A. Knapper, Erik H. Horak, Kevin D. Heylman, Randall H. Goldsmith, "Chemistry, Univ. of Wisconsin - Madison, USA. The fabrication of all-glass toroidal microresonators and their demonstration as a powerful platform for ultra-sensitive photothermal imaging and spectroscopy is described.

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**Marriott Salon IV**

**SM2N.1 • 10:30**

**Adiabatic frequency conversion in an ultra-high-Q silica microcavity using the Kerr effect**, Wataru Yoshiki, Yoshihiro Honda, Tomohiro Tetsutomo, Takasumi Tanabe, "Keio Univ., Japan. We experimentally demonstrate adiabatic frequency conversion in an ultra-high-Q silica toroid microcavity using the Kerr effect. We show that the amount of conversion, conversion time width, and number of conversions can be freely controlled.

**SM2N.2 • 10:45**

**Demonstration of all-optical tunable buffering using coupled ultra-high-Q silica microcavities**, Wataru Yoshiki, Yoshihiro Honda, Tomohiro Tetsutomo, Kentaro Furusawa, Noriko Sekeine, Takasumi Tanabe, "Keio Univ., Japan; "Advanced ICT Research Inst., National Inst. of Information and Communications Technology, Japan. We describe the first experimental demonstration of all-optical tunable buffering with coupled silica toroid microcavities. We prove that a 10-ns optical pulse can be buffered for 20 ns thanks to the microcavities' ultra-high Q factor.

**SM2N.3 • 11:00**

**A C-band Push-pull Dual-ring Silicon Photonic Modulator for 20 km SSMF transmission without CD compensation**, Rui Li, David Patel, Eslam El-Fiky, Allrez Samani, Zhenping Xing, Luhua Xu, David V. Plant, "McGill Univ., Canada. We experimentally present a C-band push-pull dual-ring silicon photonic modulator operating at 60 Gb/s in B2B configuration. Without CD compensation, 23 Gb/s transmission over 20 km of SSMF with measured BER below $3.8 \times 10^{-3}$ is demonstrated.

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**Marriott Salon V & VI**

**SM2O.1 • 10:30**

**An Integrated Racetrack Colliding-Pulse Mode-Locked Laser with Pulse-Picking Modulator**, Ashish Bhardwaj, James Ferrari, Ricardo Bustos Ramirez, "Michael Plaschka, Gloria Hoefler, Vikrant Lal, Fred Kish, Peter J. Delfyett, Ming C. Wu, "Infinera Corporation, USA; "CREOL, College of Optics and Photonics, Univ. of Central Florida, USA; "Dept. of Electrical Engineering and Computer Science, Univ. of California at Berkeley, USA. We present a novel racetrack colliding-pulse mode-locked laser with external pulse-picking and optical amplification monolithically integrated on InP. Optical pulses with FWHM of 2.36 ps are observed under hybrid mode-locking at 10 GHz repetition rate.

**SM2O.2 • 10:45**

**Over 10-Gbit/s Pulsed RZ-OOK Wave-length and Format Switching in Two-Photon-Absorption-Free SiC Waveguide**, Bo-Ji Huang, Chu-Lun Wu, Chih-Hsien Cheng, Jung-Hsuan Lin, Hua-Yung Wang, Cheng-Ting Tsai, Yu-Chieh Chi, Gung-Ru Lin, "National Taiwan Univ., Taiwan. All-optical wavelength and format conversion of pulse return-to-zero on-off-keying data in two-photon-absorption-free carbon-rich silicon carbide ring waveguide with enhanced nonlinear Kerr switching effect at 12 Gb/s is demonstrated with an extinction ratio of 20 dB.
The OSIRIS-REx Laser Altimeter, Cameron Dickinson 4, Timothy Haltigin 5, Daly1, Oliver Barnouin2, Catherine Johnson3, Michael Westberg 1, Gerard Wysocki 1; 1Princeton, USA. A cavity attenuated phase shift Faraday rotation spectrometer has been developed for oxygen detection near 762 nm. The system incorporates a high-finesse cavity for sensitivity enhancement and achieves minimum detectible polarization rotation of 2×10⁻⁹ rad/√Hz.

AM2B.3 • 11:15
InN Nanopillar Photodetector with Enhanced Infrared Response Using Indium-Tin Oxide Nanorods, Lung-Hsing Hsu 2, Yuh-Jen Cheng 2, Peichen Yu 1, Hao-chung Kuo 2, Chen Chung Lin 1; National Chiao-Tung Univ, Taiwan; Academia Sinica, Taiwan. Enhanced infrared photosresponse is observed in InN pillars/ITO rods photodetectors fabricated by LP-MOCVD and oblique-angle electron beam evaporation. The enhanced IR portion photocurrent as high as 19% can be measured via AM1.5G solar simulated spectra.

AM2B.4 • 11:30
Cavity attenuated phase shift Faraday rotation spectroscopy, Charles L. Patrick 1, Jonas Assmann 1, Niklas Staacke 1, Joachim Sacher 1; 1Univ. of Texas at Austin, USA. We report a study of self-modulation of laser plasma wakefields, at densities around 50.8±10.1 um. A probe that captured the structure of a GeV proton pulse at 1530 nm high power tunable diode laser source, leading to 2.5 TW peak power. This laser opens the way for high brightness soft X-ray attosecond pulses.

AM2B.5 • 11:45 Invited
The OSIRIS-REx Laser Altimeter, Michael Daly 1, Oliver Barnouin 2, Catherine Johnson 3, Cameron Dickinson 4, Timothy Haltigin 5, Dante Lauretta 2; 1Princeton, USA; 2York Univ, Canada; 3Univ. of British Columbia, Canada; 4MDA, Canada; 5Canadian Space Agency, Canada; 6Univ. of Arizona, USA. The OSIRIS-REx Laser Altimeter (OLA) is a scanning laser altimeter onboard the NASA mission to the near-Earth asteroid 101955 Bennu. We will describe the operation and unique capabilities of the instrument for an asteroid mission.

AM2B.6 • 12:00
FPGA Locking to Acetylene (C2H2) Hyperfine Structure, Fatemeh Yazdandoust 1, Herve Tatenguem Fankem 2, Tobias Milde 3, Marc Strohwaltd 4, Alvaro Jimenez 5, Christian Assmann 6, Niklas Staacke 7, Joachim Sacher 8; 1Sacher Lasertechnik GmbH, Germany. A 1530 nm high power tunable diode laser system with FPGA locking to acetylene hyperfine structure is presented. The system is locked to the hyperfine structure of the R5 state of acetylene with excellent long term stability.

AM2C.3 • 11:30
Interband Cascade LEDs with Split Active Stages, William W. Bewley 1, Chul Soo Kim 2, Mijn Kim 2, Chadwick L. Canada 3, Michael J. Warren 1, Charles L. Herring 1, Stephanie Tomasulo 1, Igor Vurgaftman 1, Jerry R. Meyer 3; 1Naval Research Lab, USA; 2Sotera Defense Solutions, USA; 3ASEE Fellow Residing at Naval Research Lab, USA. Midwave infrared ICLEDs with split active stages positioned at antinodes of the optical electric field are shown to generate up to 1.86 mW of output power and 0.3% wallplug efficiency in CW operation at 25°C.

AM2C.4 • 12:00
Withdrawn.
**FM2E • Atomic Ensemble and Bulk Crystal Quantum Memories—Continued**

**FM2F • Engineering Nonlinear Materials—Continued**

**FM2G • Photonic Topological Insulators—Continued**

**FM2H • Plasmonic and Nanophotonic Sensors, Switches, & Photodetectors—Continued**

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**Monday, 10:30–12:30**

**CLEO: QELS-Fundamental Science**

**Executive Ballroom 210E**

**FM2E.4 • 11:15**
Highly Efficient and Long-lived Optical Quantum Memory with Cold Atoms, Young-Wook Cho, G. T. Campbell, J. L. Everett, J. Bernu, D. Higginbottom, M. T. Cao, J. Geng, N. P. Robotham, and H. Lam; Centre for Quantum Information, Office of Quantum Science, The Australian National Univ., Australia; Department of Quantum Science, The Australian National Univ., Australia. We report a highly efficient and long-lived optical quantum memory via the gradient echo memory (GEM) technique in cold atoms. The efficiency is as high as 67% with the e−1 coherence time of 1 ms. The ability of quantum storage is verified using heterodyne tomography of small coherent states.

**FM2E.5 • 11:30**
A Quantum Light-Matter Beam splitter in Diamond, Duncan England, Kent Fisher, Jean-Philippe MacLear, Khabat Heshami, Philip Bustard, Kevin Resch, Ben Sussman; Centre for Quantum Information, National Research Council, Canada; *Inst. for Quantum Computing, Univ. of Waterloo, Canada; Department of Physics, Univ. of Ottawa, Canada. A quantum memory can be viewed as a light-matter beam-splitter, mapping a photon to a superposition of the output mode and stored mode. We use this mechanism to demonstrate non-classical one-photon and two-photon interference.

**FM2F.3 • 11:15**
Electro-optically Tunable Optical Nonlinearity of Graphene-covered SiN waveguides, Koen Alexander, Muhammad Mohsin, Utsav Dave, Lei Abdullah shiramin, Stephane Clemen, Daniel Neumayer, Bart Kuyken, Dries van Thourhout; Photonics Research Group, INTEC, Ghent Univ., Belgium; Center for Nano- and Biophotonics (NB-Photonics), Ghent Univ., Belgium; Advanced Microwavelectronic Center Aachen, AAO GmbH, Germany. Electro-optical tunability of the optical nonlinearity of graphene is demonstrated on a SiN platform using four-wave mixing. The nonlinearity of graphene-covered waveguide more than doubles when tuning E to the vicinity of h/2.

**FM2F.5 • 11:45**
Comparison of surface and bulk contributions to SHG in metatoms made of centrosymmetric materials, Daniel Timbrell, Jian Wei You, Yuri Kivshar, Nicola C. Panos, Univ. College London, UK; Australian National Univ., Australia. We analyze the contributions of surface and bulk effects to second-harmonic generation from crosses made of centrosymmetric dielectric and metallic materials and demonstrate that bulk and surface effects in dielectric structures can be comparable.

**FM2G.4 • 11:30**
Temporal Defects in Photonic Topological Insulators, Christina I. Jong, Fabian Letischer, Michael Fleischhauer, Georg von Freymann; Physics Dept. and Research Center OPTIMAS, Univ. of Kaiserslautern, Germany; Graduate School Materials Science in Marz, Germany; Fraunhofer-Instit. for Physical Measurement Techniques (IPM), Germany. We experimentally study time-dependent defects in a waveguide model of a topological insulator. Backscattering is not observed, but in contrast to static defects, edge modes propagate through the defects.

**FM2G.5 • 11:45**
Realization of Photonic Anomalous Floquet Topological Insulators, Lukas Maczewsky, Julia Zeuner, Stefan Nolte, Alexander Szameit; Friedrich-Schiller-Universität Jena, Germany; Phys. Inst.,Universität Rostock, Germany. We realize the first observation of a photonic anomalous Floquet insulator in the waveguide regime. In contrast to the common understanding, the system exhibits topological edge modes despite vanishing Chern number of all bands.

**FM2H.4 • 11:30**
Sub-picosecond All-Optical Switching of Tamm Plasmons in Photonic Crystals, Boris Atanasovski, Vladimir Bessonov, Andrey Fedyanin, Lomonosov Moscow State Univ., Russia. Photoinduced change in metal permittivity leads to a spectral shift of the Tamm plasmon resonance excited in a photonic crystal/metal sample. Proper selection of a probe wavelength allows observing a 200 fs-long reflectance modulation.

**FM2H.6 • 11:45**
GaAs/AlGaAs Core-shell Ensemble Nanowire Photodetectors, Fasti Li, Lying Tan, Jiuyuan Li, Jing Ma, Lan Fu, Hark Hoe Tan, Chenmupta Jagadish; Harbin Inst. of Technology, China; The Australian National Univ., Australia. We report the growth of GaAs/AlGaAs core-shell nanowire ensembles grown on p- and n-doped GaAs substrates respectively and the fabrication of these nanowire photodetectors. The I-V characteristics and spectral responsivity of these detectors were investigated by comparison.

**FM2H.7 • 12:00**
Actively-Tunable Plasmonic Metasurfaces Using a Phase-Change Material, Andrew Boyce, Jon Stewart, Virginia Wheeler, Marken Mikkelsen; Electrical and Computer Engineering, Duke Univ., USA; Center for Metamaterials and Integrated Plasmonics, Duke Univ., USA; Dept. of Physics, Duke Univ., USA; U.S. Naval Research Lab, USA. We demonstrate active tuning of the absorption resonance of a plasmonic metasurface by integrating VO2, a phase change material. Thermal switching of the resonance yields shifts close to the metasurface’s linewidth.
SM2M • Nonlinear Dynamics and Harmonic Generation—Continued

SM2M.3 • 11:15
Polarization Chaos in Nonlinear Optical Fibers Induced by a Reflective Delayed Loop, jacopo morosi1,2, Akram Akrout1, Antonio Picozzi2, Mann Gilles1, Massimiliano Guasoni2, Julien Fatome3, 4Dipartimento di Elettronica, Informazione e Bioingegneria (DEIB), Politecnico di Milano, Italy; 5Laboratoire Interdisciplinaire Carnot de Bourgogne (LICB), Universit'e Bourgogne Franche-Comt'e, France; 6Optoelectronics Research Centre, Univ. of Southampton, UK. We demonstrate that the nonlinear interaction in an optical fiber between an incident beam and its backward delayed replica leads to a chaotic dynamics of its output polarization state enabling a powerful scrambling process.

SM2M.4 • 11:30
Linearizing Nonlinear Optics, Bruno E. Schmidt1, Philippe Lassonde2, Guilomrt Ernotte1, Matteo Clerici1, Roberto Morandotti1, Heide Ibrahim1, Francois Legare2; 1Tokai Univ., Japan; 2NTT Device Technology Labs, Inc., Canada; 3INRS-EMT, Canada; 4Univ. of British Columbia, Canada. We propose enabling a new generation of optical systems enabling unconventional control of light flow.

SM2M.5 • 11:45
Bandwidth Control of Near Infrared Frequency Combs in High-Order Sideband Generation, Darren C. Valovcin1, Hunter Banks1,2, Shaun Mack1, Art Gossard3, Loren PF, Mark S. Shenker3,4,5, USCS Physics, USA; 1Inst. for Terahertz Science and Technology, USA; 2Materials, Univ. of California, Santa Barbara, USA; 3Electrical Engineering, Princeton, USA; 4US Navy Research Lab, USA. Optical excitation of excitons in semiconductor quantum wells driven by intense, monochromatic terahertz fields results in several-hundred MHz-wide frequency combs. Appropriate scaling of the driving field and frequency result in predictable comb bandwidths.

SM2M.6 • 12:00
Efficient multi-stage frequency mixing in multiple QPM device for optical carrier processing, Masaki Asobe1,2, Akram Akrout1,3, Koji Enbutsu2, Takeshi Umeki2, Takeshi Nakamura1, Koji Erbutsu2, Takeshi Umeki1, Tohoku Univ., Japan; 4NTT Device Technology Labs, NTT Corporation, Japan. The multi-stage frequency mixing opens up the possibility of optical carrier processing. We propose efficient carrier phase recovery of multi-level phase modulated signal using new configuration. We also demonstrated data transmission using multiple carriers.

SM2N • Whispering Gallery Mode Micro-cavities—Continued

SM2N.4 • 11:15
Tunable Split-Disk Whispering Gallery Mode Resonators, Tobias M. Sigle1, Michael Remmel1, Sarah Kraemer1, Heinz Kalt1; 1Institute of Applied Physics, Karlsruhe Inst. of Technology,Germany Polymeric doped disk resonators, split in two halves, are structured on a flexible elastomer substrate by direct laser writing. A controlled substrate deformation enables precise resonance tuning verified by reversible shifts of the lasing modes.

SM2N.5 • 11:30
Whispering Gallery Mode Resonators for Functional Devices, Lan Yang1,2,3; 1Washington Univ. in St Louis, USA. I will discuss fundamental physics, such as parity-time symmetry and exceptional point (EP), in whispering-gallery-mode (WGM) resonators, which can be used to achieve a new generation of optical systems enabling unconventional control of light flow.

SM2N.6 • 12:00
Isolators and Circulators Based on Kerr Nonreciprocity in Microresonators, Leonardo Del Bino1,2, Jonathan Silver1, Xin Zhao1,2, Sarah L. Stebbings1, Pascal Dehaye1, National Physical Lab (NPL), UK; 2Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK; 3School of Electronic and Information Engineering, Beihang Univ., China. We demonstrate nonreciprocal light propagation in microresonators based on Kerr-effect-mediated symmetry breaking between counterpropagating light. In proof-of-principle experiments, we realize isolators and circulators with more than 20 dB isolation.

SM2O • Modulators—Continued

SM2O.4 • 11:30
Monolithically Integrated CMOS Nanophotonic Segmented Mach-Zehnder Transmitter, Andi Mahendra1,2, Douglas Gill1, Chi Hung1, Jason Ono1,2, Benjamin Lee1, Tam Huynh1, Jonathan Proesel1, Nicolas Dupuis1, Philip Leong1, Benjamin Eggleton1, William Green1; 1School of Electrical and Information Engineering, The Univ. of Sydney, Australia; 2Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS) at School of Physics at The Univ. of Sydney, Australia; 3IBM Thomas J. Watson Research Center, USA. We present a monolithic segmented Mach-Zehnder transmitter, fully integrated in a 90 nm CMOS process. The transmitter exhibits a link sensitivity of -14.1 dBm optical modulation amplitude (OMA) at bit error rate (BER) = 10^-12 at 12.5 Gbps.

SM2O.5 • 11:45
Ultra-Broadband Mach-Zehnder Hybrid Electro-Optic Polymer/Sol-Gel Silica Waveguide Modulators, Yasuhiro Enami1,2, Atsushi Seki1, Shin Masuda1, Jingdong Luo1,2, 1National Physical Lab (NPL), UK; 2Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK. We present a monolithic segmented Mach-Zehnder transmitter, fully integrated in a 90 nm CMOS process. The transmitter exhibits a link sensitivity of -14.1 dBm optical modulation amplitude (OMA) at bit error rate (BER) = 10^-12 at 12.5 Gbps. We report on on-chip electro-optic tuning with integrated in-plane microelectrodes for optical systems enabling unconventional control of light flow.

SM2O.6 • 12:00
Integrated lithium niobate microresonators with in-plane microelectrodes for electro-optic tuning, Min Wang1, Yingxin Xu2, Zhiwei Fang3, Jintian Lin1, Wei Fang2, Ya Cheng1, 1Shanghai Inst of Optics and Fine Mech, China; 2Zhejiang Univ., China. We report on on-chip electro-optic tuning of high-Q lithium niobate microresonator with integrated in-plane microelectrodes fabricated by femtosecond laser. Due to the compact spatial arrangement, high electro-optical tuning coefficient of 3.41 pm/V was demonstrated.
### AM2A • A&T Topical Review on Advances in Laser-based Remote Sensing II—Continued

**Title:** Early-stage Plasma Spectra Improvement Using a Field-portable Double-pulse Laser System

**Authors:** Shuo Li, Lei Liu, Aidong Yan, Sheng Huang, Xi Huang, Yongfeng Lu, Kevin Chen

**Affiliations:**
- Univ. of Pittsburgh, USA
- Electrical and Computer Engineering, Univ. of Nebraska-Lincoln, USA

**Abstract:**
A field-portable double-pulse laser system was developed to study early-stage plasma in laser-induced breakdown spectroscopy. Emission spectral quality was significantly improved in terms of enhanced peak emission and reduced background emission.

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### AM2B • Mid-IR Sensors and Emitters—Continued

**Title:** Broadband Terahertz-Light Emission by Current-Injection Distributed-Feedback Dual-Gate Graphene-Channel Field-Effect Transistor

**Authors:** Deepika Yadav, Youssef Tahboub, Gen Tamamushi, Junki Mitsushio, Takayuki Watanabe, Alexander Dubinov, Maxim Ryzhii, Victor Ryzhii, Taichi Otsuji

**Affiliations:**
- Research Inst. of Electrical Communication, Tohoku Univ., Japan
- ECE, Univ. of Texas, USA
- Inst. of Physics of Microstructures, RAS, Russia
- Univ. of Aizu, Japan
- Inst. of Ultra-High-Frequency Semiconductor Electronics, Russia

**Abstract:**
Observed spontaneous THz emission (1-7.6THz) at 100K by current injection in distributed-feedback dual-gate graphene transistor. We saw nonlinear threshold-like behavior w.r.t the current-injection level. Precise DFB cavity design is expected to transcend spontaneous emission to stimulated emission.

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### SM2C • Biomedical Spectroscopy and Cell/Particle Analysis—Continued

**Title:** Single Particle Fluorescence Analysis on Demand on Electro-Optofluidic Chip with Gated Particle Delivery

**Authors:** Md Mahmudur Rahman, Mark Harrington, Matthew A. Stott, Aaron Hawkins, Holger Schmidt

**Affiliations:**
- Univ. of California, Santa Cruz, USA
- Electrical and Computer Engineering, Brigham Young Univ., USA

**Abstract:**
Electronic feedback enables introduction of single microbeads and DNA molecules into a liquid-core waveguide through a micro/nanopore. Subsequent fluorescence detection from a controlled number of individual particles is demonstrated, enabling single particle analysis on demand.

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**12:30–13:30  Lunch Break (on your own) **

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**SC378: Introduction to Ultrafast Optics**

**SC455: Integrated Photonics for Quantum Information Science and Technology New**
FM2E • Atomic Ensemble and Bulk Crystal Quantum Memories—Continued

**FM2E.7 • 12:15**

Designing Quantum Repeaters for Continuous Variable Quantum Communication, William Munro1,2, Fabian Furrer1; 1NTT Basic Research Labs, Japan; 2National Inst. for Informatics, Japan. In this presentation we discuss the design of continuous variable quantum repeaters that can distribute entangled and pure two-mode squeezed states over arbitrarily long distances with a success probability that scales polynomially with distance.

**FM2F • Engineering Nonlinear Materials—Continued**

**FM2F.7 • 12:15**

Dynamical Birefringence: High-order Sideband Generation as a Probe of Berry Curvature, Hunter B. Banks1,2, Darren C. Valovic2,3, Qile Wu2, Shawn Mack3,4, Art Gossard3, Loren Pfeiffer3, Renbao Liu3, Mark S. Sherwin4,5; 1Physics Dept., UCSB, USA; 2Inst. for Terahertz Science and Technology, UCSB, USA; 3Chinese Univ. of Hong Kong, China; 4Naval Research Lab, USA; 5Materials Dept., UCSB, USA; 6Electrical Engineering Dept., Princeton Univ., USA. Continuous optical excitation of electron-hole pairs in quantum wells driven by intense, monochromatic terahertz fields leads to high-order sideband generation, up to 90th order. Manipulations of polarization reveal sensitivity to Berry curvature.

**FM2G • Photonic Topological Insulators—Continued**

**FM2G.7 • 12:15**

Dispersion Topological Darkness, Haomin Song1, Nan Zhang2, Jiyuan Duan2, Zhejun Liu3, Jun Gao2, Matthew H. Singer1, Dengxin Ji1, Alec R. Chee2, Xie Zeng1, Borui Chen4, Suhua Jiang3, Qiaoqiang Gan1; 1Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, USA; 2Technical Center for Industrial Product and Raw Material Inspection and Testing, China; 3Material Science Dept., Fudan Univ., China. We present a complete description of “topological darkness” in a three-dimensional space regarding optical constants (i.e., $n$ and $k$) of effective media, wavelengths and incident angles, which is essential for enhanced light-matter interaction in thin-films.

**FM2H • Plasmonic and Nanophotonic Sensors, Switches, & Photodetectors—Continued**

**FM2H.8 • 12:15**

Plasmonic Nanoantenna based Ultrafast and Broadband Graphene Photodetectors, Semih Cakmakyanap1, Ping Keng Lu1, Mona Jarrahi1; 1Univ. of California Los Angeles, USA. We present broadband photodetection from 800 nm to 20 μm with operation speeds exceeding 50 GHz and responsivity levels as high as 0.6 A/W at 0.8 μm and 11.5 A/W at 20 μm by using plasmonic nanoantennas as photodetector contact electrodes on graphene.

12:30–13:30 Lunch Break (on your own)

SC378: Introduction to Ultrafast Optics  
SC455: Integrated Photonics for Quantum Information Science and Technology New

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### CLEO: Science & Innovations

**SM2I • Ultrafast Pulse Generation—Continued**

**SM2I.8 • 12:15**  
Frequency-halved Orthogonally Polarized Vector Soliton States from a Single Fiber Laser Source, Ahmet E. Akosman¹, Michelle Y. Sander¹²; ¹Electrical and Computer Engineering, Boston Univ., USA; ²Materials Science and Engineering, Boston Univ., USA. An ultrafast pulse train composed of co-generated, consecutive, equal intensity and orthogonally polarized pulses is experimentally shown for the first time in a vector soliton mode-locked fiber laser.

**SM2J • THz Quantum Optics and Metamaterials—Continued**

**SM2J.5 • 12:15**  
Electrically Modulated Nonlinear Terahertz Metamaterials, George R. Keiser¹, Nicholas Karl¹, Qiang Liu¹, Caleb Tullis¹, Houtong Chen¹, Antionette Taylor², Igal Brener², Alex Benz², John Reno³, Daniel M. Mittleman¹; ¹Brown Univ., USA; ²Sandia National Lab, USA; ³Los Alamos National Lab, USA. We present an electrically modulated nonlinear terahertz metamaterial. The device consists of an array of split-ring resonators fabricated on n-type GaAs. Applying a 15V bias to the MM reduces the nonlinear terahertz modulation by ~60%.

**SM2K • Micro and Nanoscale Fabrication—Continued**

**SM2K.7 • 12:15**  
Telecommunications Band Photoluminescence from Hydrogenated Amorphous Silicon Ring Resonators, Michael G. Wood¹, Ryan J. Patton¹, Ronald M. Reano¹; ¹Ohio State Univ., USA. We report enhanced photoluminescence from 1300 nm to 1600 nm wavelength in ring resonators composed of hydrogenated amorphous silicon thin films. Enhancement of up to 5 dB occurs at the resonant modes of the rings.

**SM2L • Multiwavelength and Comb Fiber Sources—Continued**

12:30–13:30  Lunch Break (on your own)

SC378: Introduction to Ultrafast Optics  
SC455: Integrated Photonics for Quantum Information Science and Technology New
SM2M • Nonlinear Dynamics and Harmonic Generation—Continued

SM2M.7 • 12:15
A Two-Photon Shack-Hartmann Wavefront Sensor for The Near-Infrared Wavelength, Fei Xia1, David Sinefeld1, Bo Li1, Chris Xu1; 1Cornell Univ., USA. We present a novel wavefront sensing scheme based on two-photon absorption in a conventional silicon camera for measuring aberrations of pulsed laser beams in the near-infrared wavelengths up to 2.0 µm.

SM2N • Whispering Gallery Mode Micro-cavities—Continued

SM2N.7 • 12:15
Self-Referenced Temperature Sensing with a Lithium Niobate Microdisk Resonator, Rui Luo1, Haowei Jiang1); Hanxiao Liang1, Qiang Lin1; 1Univ. of Rochester, USA; 2Shanghai Jiao Tong Univ., China. We report self-referenced temperature sensing with a high-Q Z-cut lithium niobate microdisk resonator, based on thermo-optic birefringence. We achieved a temperature sensitivity of 0.834 GHz/K and temperature sensing resolution of 0.8 mK.

SM2O • Modulators—Continued

SM2O.7 • 12:15
A Dual-drive PAM-4 Si Mach-Zehnder Modulator for 50Gb/s Data Transmission at 1550nm Wavelength, ChihKuo Tseng1, Jhih-Heng Yeh1, Po-Wei Chen1, Wei-Lun Chung1, Tzu-Yu Yeh1, Kai-Ming Feng1, Meng-Chyi Wu1, Ming-Chang Lee1; 1NTHU, Taiwan. A low-voltage dual-drive push-pull Si Mach-Zehnder modulator is demonstrated to implement an optical 25 Gbaud (50 Gb/s) PAM-4 transmission.

12:30–13:30 Lunch Break (on your own)

SC378: Introduction to Ultrafast Optics
SC455: Integrated Photonics for Quantum Information Science and Technology New

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
AM3A.1 • 13:30
Self-driving Cars and Lidar, Simon Verghese,1 Waymo, USA. Before graduating from X as Waymo, Google’s self-driving car project had been using custom lidars for several years. In their latest revision, the lidars are designed to meet the challenging requirements we discovered in autonomously driving 2 million highly-telereometryed miles on public roads. Our goal is to approach price points required for advanced driver assistance systems (ADAS) while meeting the performance needed for safe self-driving. This talk will review some history of the project and describe a few use-cases for lidars on Waymo cars. Out of that will emerge key differences between lidars for self-driving and traditional applications (e.g., mapping) which may provide opportunities for semiconductor lasers.

AM3A.2 • 14:00
53 Years Tunable Semiconductor Laser – Past, Present and Future, Christoph Raab1, Rudolf Neuhauer2, Stephan Falke3, Christian Nölleke1, Jürgen Stuhler1, Wil- helm Kaenders1. TOPICA Photonics AG, Germany. We present an overview from first external cavity diode lasers to current and future designs. Based on applications the requirements and realizations of tunable diode lasers are shown with respect to their importance to “Quantum Technology” initiatives.

AM3B.1 • 13:30
Laser-Based Sensors for Addressing Climate Change, Michael B. Frish1,2; Physical Sciences Inc., USA. Identifying, measuring, and reducing mankind’s contribution to climate change is an urgent international endeavor. This paper describes our work dedicated towards developing and applying laser sensors to support efforts to reduce greenhouse gas emissions.

AM3B.2 • 14:00
Fiber-Pigtailed Silicon Photonic Sensors for Methane Leak Detection, Chu Teng1, Chi Xiong1, Eric Zhang1, Yves Martin2, Marwan Khater2, Jason Orcutt1, William Green2, Gerhard Wysocki3,4; 1Princeton Univ., USA; 2IBM T. J. Watson Research Center, USA. We present comprehensive characterization of silicon photonic sensors for methane leak detection. Sensitivity of 40 ppmv after 1 second integration is reported. Fourier domain characterization of on-chip etalon drifts is used for further sensor improvement.

AM3C.1 • 13:30
The Importance of Knowing You are Sick: Biophotonics For The ‘Other’ Brain, Mark R. Hutchinson1; School of Medicine, The Univ. of Adelaide, Australia; 2Australian Research Council Centre of Excellence for Nanoscale Biophotonics, Australia. The next frontier in neuroscience is the exploration of the “other brain” or the other 90% of cells of the central nervous system, termed glia. Currently there are no tools available to explore the real-time function of these underappreciated cells. This presentation will explore new opportunities for biophotonics in this space.

AM3C.2 • 14:00
Biophotonics - A Powerful Tool for Non-invasive and Labelfree Cell- and Tissue Screening, Juergen Popp1,2; 1Leibniz Inst. of Photonic Technology, Germany; 2Inst. of Physical Chemistry, Friedrich-Schiller Univ., Germany. In this presentation, we will highlight our recent advances in translating biophotonic approaches with special focus on linear and non-linear Raman spectroscopy towards routine clinical applications with focus on infectious diseases and cancer.

FM3D.1 • 13:30
Multidimensional Attosecond Spectroscopy, Nirit Dudovich1,2; 1School of Medicine, The Univ. of Adelaide, Australia; 2Australian Research Council Centre of Excellence for Nanoscale Biophotonics, Australia. We present an overview of how attosecond pulses can be used to probe the fundamental light-matter interaction in nature. We demonstrate how the liberated electron can control over the timing, phase, and orientation of electron recollisions in high harmonic generation. Employing elliptically-polarized bi-chromatic driving fields, we exert far-reaching control over the enhancement and suppression of different harmonic sets.
Invited Synchronized Spontaneous Downconversion Supplies Scalable Single-Photon Sources, Paul G. Kwiat1, Fumihiro Kaneda1, Fedor Bergmann1, Michelle Victora1; 1Univ of Illinois at Urbana-Champaign, USA. Very efficient sources of pure single photons can be realized by combining optimized, heralded nondeterministic photon sources with spatial or temporal multiplexing. Low-loss synchronization elements can further enhance scalability, enabling various multi-photon quantum information applications.

Invited Direct Observation of Multimode Solitons in Few-Mode Optical Fiber, Zimu Zhu1, Logan Wright1, Demetrios Christodoulides2, Frank W. Wise1; 1School of Applied and Engineering Physics, Cornell Univ., USA; 2The College of Optics and Photonics, Univ. of Central Florida, USA. We experimentally observe Raman shifted multimode solitons in few-mode graded-index fiber. They display spatiotemporal properties that depend on the specific launch conditions. Multimode solitons exhibit energy-volume relations distinct from both single-mode and spatio-temporal solitons.

Joint Experiment Realization of Synthetic Weyl Points In Optical Regime, Hui Liu1, Qiang Wang1,1 Nanjing Univ., China. We demonstrate that generalized Weyl points can exist in a parameter space and we report the first observation of such nodal points in one-dimensional photonic crystals in the optical range.

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Joint Giant optical cross section induced by conical dispersion in photonic crystals, Ming Zhou1, Ling Liu1, Lei Shi1, Jian Zi1, Zongfu Yu1; 1Univ. of Wisconsin - Madison, USA. We show that the optical cross section of a single two-level system embedded in photonic crystals can be enhanced by 4 orders of magnitude near the vicinity of Dirac and Weyl points.

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Joint Probing the Femtosecond Response of Plasmonic Nanoparticles with Strong-field Photoemission, William Putnam1,2, Phillip D. Keatley1, Richard G. Hobbs1,2, Karl K. Berggren1,2; 1Dept. of Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA; 2Dept. of Physics and Center for Ultrafast Imaging, Univ. of Hamburg, Germany; 3Centre for Research on Adaptive Nanomaterials and Nanodevices (CRANN), Advanced Materials and Bio-Engineering Research Centre (AMBER), and School of Chemistry, Trinity College Dublin, Ireland. We illuminate resonant and off-resonant plasmonic nanoparticles with few-cycle laser pulses and measure strong-field photoemission. Recording interferometric autocorrelations with the strong-field photocurrent, we study the response of the nanoparticle near-fields to ultrafast excitation.

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Joint Observation of Spatial Optical Diatomic Drive Acceleration, Yumiao Pei1, Yi Hu1, Cibo Shi2, Daohong Song1, Liqin Tang1, Jingjun Zhou1, Ling Lu2, Lei Shi3, Zongfu Yu1; 1Univ. of Wisconsin - Madison, USA; 2Chinese Academy of Sciences, China; 3Fudan Univ., China. We show that the optical cross section of a single two-level system embedded in photonic crystals can be enhanced by 4 orders of magnitude near the vicinity of Dirac and Weyl points.

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SM3J • Ultrafast Amplifiers
Presider: Alan Fry; SLAC National Accelerator Lab, USA

SM3J.1 • 13:30
Scaling Mid-Infrared Ultrafast Parametric Sources to High Peak and Average Power, Igor Jovanovic1, Univ. of Michigan, USA. Scaling mid-infrared parametric sources to high powers motivates the use of high-performance nonlinear materials transparent beyond ~2 μm. Recent progress in development of parametric amplifiers based on ZnGeP2, associated long-wavelength pumps, and diagnostics is discussed.

SM3J.2 • 14:00
High-Power Optical Parametric Chirped-Pulse Amplifier Operating at 2.2 μm, Justinas Pupeikis1, Lukas Gallmann 1, Hideki beyond ~2 μm. Recent progress in development of high-performance nonlinear materials transparent beyond ~2 μm. Recent progress in development of parametric amplifiers based on ZnGeP2, associated long-wavelength pumps, and diagnostics is discussed.

SM3J.3 • 14:00
CMOS-Compatible ALD Zinc Oxide Coating for On-Chip Second-Order Nonlinear Optical Functionalities, Artur Hermans1,2, Michiel Van Dael1, Clemens Kieninger3, Julien Dendauwen1, Stéphane Clemmen1, Tobias Harter1,2, Artur Hermans1,2, Optical Functionalities, Heinrich Hertz Inst., Germany. We show coherent wireless transmission at carrier frequencies of 0.25 THz and 0.35 THz, relying exclusively on optoelectronic concepts for RF signal generation and coherent reception. In a proof-of-concept experiment, we demonstrate transmission of a BPSK signal at a symbol rate of 1 Gbaud.
SM3M.1 • 13:30
Broadband and Wideband Parametric Gain via Intermodal Four-Wave Mixing in Optical Fiber, Jeffrey Demas1, Gautam Prabhakar1, Tao He1, Siddharth Ramachandran1, Boston Univ., USA; 2School of Optoelectronics, Beijing Inst. of Technology, China. We demonstrate a novel intermodal four wave mixing process by dividing a pump at 1047nm between the LP01 and LP11 fiber modes, leading to simultaneously broadband (28nm at 1550 nm) and wideband (~1 octave) spontaneous parametric gain.

SM3M.2 • 13:45
Visible Raman Generation from Ambient Air in a Nodeless Hollow-Core Fiber, Shoufei Gao1, Yingying Wang1, Pu Wang1, 1Beijing Univ. of Technology, China. A nodeless hollow-core fiber, exposed to ambient air, enables multiline Raman generation from nitrogen, oxygen, water and carbon oxide by a 532 nm picosecond laser for the first time.

SM3M.3 • 14:00
Picosecond Pulse Generation at 1177 nm by SRS in PbWO4, Pumped by a Multi-mJ, Multi-W Sub-nm Laser System, Bozhidar Oreshkov1, Ruijun Lai1, Luben S. Petrov1, Hui Yuan1, Wei Xiong1, Ivan C. Buchvarov1,2, Valentin Petrov3, 1Faculty of Physics, Sofia Univ. St. Kliment Ohridski, Bulgaria; 2School of Opto-Electronic Information Science and Technology, Yantai Univ., China; 3Dept. of Optoelectronics, Beijing Inst. of Technology, China. We report on high energy (~1 mJ), high average power (~0.5 W), sub-500-ps stimulated Raman scattering in a PbWO4, crystal, pumped by a sub-nanosecond Nd:YAG based master-oscillator power-amplifier (MOPA) laser system operating at 500 Hz. We also study the operation performance of fabricated OAM mode generator in experiment.

SM3N.1 • 13:30
Design and Fabrication of 2 um Metasurface-based Orbital Angular Momentum (OAM) Mode Generator Employing Reflective Optical Antenna Array, Yifan Zhao1, Jing Du1, Zhengwen Ruan1, Li Shen1, Shuhui Li1, Jian Wang1, 1Huazhong Univ of Science and Technology, China. A chip-scale reflective metasurface is designed and fabricated for generating 2 um orbital angular momentum (OAM) mode with topological charge of +1 or -1. We also study the operation performance of fabricated OAM mode generator in experiment.

SM3N.2 • 13:45
Extraordinary Optical Transmission of Ultra-Thin Freestanding Plasmonic Membranes, Longli Liu1, Hsin-Yu Wu2, Meng Lu2, 1Dep. of Electrical and Computer Engineering, Iowa State Univ., USA; 2Graduate Inst. of Nanomedicine and Medical Engineering, Taipei Medical Univ., Taiwan; 3Dep. of Mechanical Engineering, Iowa State Univ., USA. We demonstrate a 30 nm-thick freestanding plasmonic membrane that supports mid-infrared surface plasmon resonances. The membrane is perforated using the imprint-and-transfer approach. The device was used to measure the absorption of a thin polymer film.

SM3N.3 • 14:00
Bloch long-range surface plasmon polaritons in metallic stripe waveguides, Norman Feng1, Matteo Menotti1, Ewa Litacka-Skrzek1, Howard Northfield1, Anthony Olivieri1, Niall Tait1, Marco Lisicki1, Pierre Berini1,2, 1Dept. of Physics, Univ. of Pavia, Italy; 2School of Electrical Engineer and Computer Science, Univ. of Ottawa, Canada; 3Dept. of Electronics, Carleton Univ., Canada; 4Centre for Research in Photonics, Univ. of Ottawa, Canada. We propose and demonstrate a thin Au stripe on a truncated 1D dielectric photonic crystal covered with Cypot as a waveguide for Bloch long-range surface plasmon polaritons on-chip Coherent Conversion of Photonic Quantum Entanglement Between Different Degrees of Freedom, Lantian Feng1, Ming Zhang1, Zhi-Yuan Zhou1, Ming Li1, Xiao Xiong1, Le Yu1, Bao-Sen Shi1, Guang-Can Guo1, 1Univ Sci & Tech China, China; 2Zhejiang University, China. We introduce the transverse waveguide-mode degree of freedom to quantum photonic integrated circuits, and demonstrate the coherent conversion of a photonic quantum state between path, polarization and transverse waveguide-mode degrees of freedom on a single chip.

SM3O.1 • 13:30
Quantum Entanglement Between Different Degrees of Freedom, Lantian Feng1, Ming Zhang1, Zhi-Yuan Zhou1, Ming Li1, Xiao Xiong1, Le Yu1, Bao-Sen Shi1, Guang-Can Guo1, 1Univ Sci & Tech China, China; 2Zhejiang University, China. We introduce the transverse waveguide-mode degree of freedom to quantum photonic integrated circuits, and demonstrate the coherent conversion of a photonic quantum state between path, polarization and transverse waveguide-mode degrees of freedom on a single chip.
Recent Progress in Quantum Dot Based Devices: Physics and Applications, Edik U. Rafailov1, Aston Inst. of Photonic Technologies, Aston Univ., UK. The unique properties offered by quantum-dot semiconductor structures allowed for the development of compact CW and ultrashort pulse lasers. In this paper we review recent progress in fabrication of quantum-dot based devices and their applications.

High spectral resolution of overlapping molecular transitions of CH4 and N2O in the mid-infrared region, May Hlaing1,2, Amir M. Khan1,2, Caio S. Azevedo1,2, Seth A. Faye1,2,1. Delaware State Univ., USA. We show novel detection techniques and quantitative metrics of instrument performance of a mid-IR quantum cascade laser-based system using higher harmonic (2f and 4f) detection to resolve overlapping line transitions of methane, nitrous-oxide and water-vapor.

AM3A.3 • 14:30 Invited Recent Progress in Quantum Dot Based Devices: Physics and Applications, Edik U. Rafailov, Aston Inst. of Photonic Technologies, Aston University, UK. The unique properties offered by quantum dot semiconductor structures allowed for the development of compact CW and ultrashort pulse lasers. In this paper we review recent progress in fabrication of quantum-dot based devices and their applications.

AM3B.4 • 14:30 Cryptophane-Cladded Interferometric Waveguide Sensor for Aqueous Methane Detection, Jana Jégereš1, Frehun T. Dullo1, Susan M. Lindecrantz1, Jacqueline M. Boergers1,2, Jarn H. Hansen1, Laura M. Lechuga1, Olav G. Helles1, UIT Norges Arktisk Universitet, Norway; TU Dortmund, Germany; Catalan Inst. of Nanoscience and Nanotechnology (ICN2), CSIC, Spain. A nanophotonic sensor for sensitive detection of methane in water solution is presented. Cryptophane-A doped waveguide cladding provides for methane pre-concentration directly on a chip, resulting in a detection limit of 60 ppm (86 nM).

AM3B.5 • 14:45 High Confinement and Low Loss Si3N4 Waveguides for Miniaturizing Optical Coherence Tomography, Xinwen Yao1, Mohammad A. Tadayon1, Xingchen Ji1,2, Christine P. Hendon1,2, Malcom C. Hill6, Stephen A. Novak4,5, Michael A. Novak4,5, Malcom C. Hill6, Kenneth V. Ramanathan2, Zenghu Chang2, Andrew Chew2, Xiaoming Wu3, Yanchun Yin2, Shima Gholam-Mirzaei2, Dana Browne1, Michael Chin1, Zenghu Chang2, Kenneth Schafer1, Mette Gaarde1, Shambhu Ghimire1. SLAC National Lab, USA; Univ. of Central Florida, USA; Louisiana State Univ., USA. We report a strong carrier-envelope-phase dependence of high harmonics in bulk solids subjected to strong few-cycle laser fields. We discover that harmonics are delayed with respect to each other at the sub-cycle level, yielding an atto-chirp.

AM3C.3 • 14:30 Depth-Resolved Characterization of the In Vivo Tympanic Membrane using Nano-Sensitive Optical Coherence Tomography, Roshan Dououa1, Jenny Won1,2, Guillermo L. Monroy1,2, Ryan Porter1,2, Michael A. Novak1,2, Malcom C. Hill1,2, Stephen A. Novak1,2, Beckman Inst. for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign, USA; Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA; Dept. of Bioengineering, Univ. of Illinois at Urbana-Champaign, USA; Dept. of Pediatrics, Univ. of Illinois at Urbana-Champaign, USA; College of Medicine, Univ. of Illinois at Urbana-Champaign, USA; Dept. of Pediatrics, Univ. of Illinois at Urbana-Champaign, USA. We report nano-sensitive optical coherence tomography (nsOCT) structural changes of the in vivo human tympanic membrane (TM) under normal and infected conditions. nsOCT enables diagnostics which may impact the clinical treatment of middle-ear infection.

AM3C.4 • 14:45 High Confinement and Low Loss Si3N4 Waveguides for Miniaturizing Optical Coherence Tomography, Xinwen Yao1, Mohammad A. Tadayon1, Assema Mohanty1,2, Christine P. Hendon1,2, Michael Lipson1,2, Columbia Univ., USA; Carne Foundation Hospital, USA. We show that this platform can enable the miniaturization of traditionally bulky active OCT components.

SM3C.3 • 14:30 In Vivo/Deep Tissue Imaging—Continued

FM3D.3 • Atto-second Spectroscopy—Continued

FM3D.4 • 14:30 Harmonic Generation in Solids from a Fiber Laser, Kevin F. Lee1, Xiaoyan Ding1, T. J. Hammonds2, Martin E. Fernmann1, Giulio Vampa3, Paul B. Corkum1. IMRA America, Inc., USA; Joint Attosecond Science Lab, Univ. of Ottawa and National Research Council Canada, Canada. We generate up to the seventh harmonic in silicon and zinc oxide from a femtosecond Ti:Sapphire laser at 93 MHz, rather than a multi-stage Ti:Sapphire system as in earlier experiments.
Multi-octave supercontinuum driven by soliton explosion in dispersion-designed antiresonant hollow-core fibers, Michael Zuerch1,2, Rudrakant Sarpal2, Dani Karashov3,4, Andreas Hoffmann1, Teodora Grigorova1, Gregor Sauer1, Alexander Hartung1, Anka Schwuchow2, Jörg Bierlich1, Jens Kelkel2, Markus Schmidt1, Christian Spielmann1,2,3,4; 1Dept. of Chemistry, UC Berkeley, USA; 2Inst. of Optics and Quantum Electronics, Friedrich Schiller Univ., Germany; 3Leibniz Inst. of Photonic Technology e.V., Germany; 4Otto Schott Inst. of Material Research, Friedrich Schiller Univ., Germany. We show two-photon interference. The advantage of photonic crystal platform for scalable quantum photonic devices are highlighted.

Reflection and refraction in artificial photonic gauge fields, Moshe-Ishay Cohen1, Yoakov Lumer1, Hanan H. Herzig Shenfux1, Yonatan Plotnik1, Jonathan Nemirovsky1, Mordchaia Segev1, 1Technion Israel Inst. of Technology, Israel; 2Dept. of Electrical and Systems Engineering, Univ. of Pennsylvania, USA. We study the interface between two artificial gauge fields in a 2D photonic lattice, and find the analogues of Snell’s law and Fresnel coefficients of such interfaces. We demonstrate practical nano-grating configurations for highly directional and monochromatic hard X-ray generation from modestly relativistic electrons. By optimizing the nano-grating to support high field enhancement we show efficient radiation generation at multiple harmonics.

Experimental Demonstration of the Necklace Beam Formation in Engineered Nonlinear Media, Jingbo Sun1, Salih Sahil1, Viktor Walasik1, Eric Johnson2, Alexandra M. Nikiforov1, Natalia L. Ushchum1, 1State Univ. of New York at Buffalo , USA; 2Electrical and Computer Engineering, Clemson Univ., USA. We experimentally investigate the formation, dynamics and stability of complex necklace beams using structured light with different orbital angular momentum propagating in nonlinear nano-collidal suspensions with negative polarizabilities.

Photonic Weyl Point in a 2D Resonator Array with a Synthetic Frequency Dimension, Qian Lin1, Meng Xiao1, Luq Yuan1, Shinhui Fan1, 1Stanford Univ., USA. We propose a realization of Weyl point in two-dimensional arrays of resonators undergoing dynamic modulation. Our system provides an on-chip platform to explore Weyl points under different symmetries and demonstrate topological surface state in synthetic space.

Efficient hard X-ray source enabled by metallic nano-gratings, Gilles D. Rosalen1,2, Liang Jie Wong3, Ido Kaminer1, Nicholas Rivera1, Bjorn Maes4, Marin Soljačić5, 1MIT, USA; 2Singapore Inst. of Manufacturing Technology, Singapore; 3UMONS, Belgium. We propose practical nano-grating configurations for highly directional and monochromatic hard X-ray generation from modestly relativistic electrons. By optimizing the nano-grating to support high field enhancement we show efficient radiation generation at multiple harmonics.

Nano-chirality detection with vortex plasmonic modes, Jordan Hachtel1,2, Roderick Davidson1,2, Matthew Chisholm1, Richard F. Haglund1, Sokrates Pantelides1, Sang-Yeon Cho1, Benjamin Lawrie1, 1Oak Ridge National Lab, USA; 2Vanderbilt Univ., USA; 3New Mexico State Univ., USA. Cathodoluminescence spectroscopy in a scanning transmission electron microscope is used to probe the spatio-spectral response of nanoscale apertured plasmonic vortex generators. Further, we demonstrate that plasmonic vortex modes can probe the chirality of nanoscale materials.
SM3J.3 • 14:15
Generation of a 200-mJ class infrared femtosecond laser by dual-chirped optical parametric amplification, Yuji Fujii, Eiji J. Takahashi, Bing Xue, Katsumi Midorikawa; RIKEN, Japan. Total output energy of 1.4 µJ (signal) and 1.9 µJ (idler) reaches 210 mJ by a dual-chirped optical parametric amplifier (DC-OPA). The obtained IR spectra support 41 fs and 40 fs transform limited durations, respectively.

SM3J.4 • 14:30
Sub-8 fs, 210 µJ Pulses at 100 kHz from a Noncollinear Optical Parametric Amplifier, Federico J. Furch, Achut Giree, Felix Schell, Tobias Wittig, Gunnar Arsholm, Claus Peter Schulz, Marc J. J. Vrakking; 1MaxPlanck-Helmholtz Centre for Materials Research, Potsdam, Germany; 2Dept. of Chemical & Biomolecular Engineering, North Carolina State Univ., USA. We study the performance of a noncollinear optical parametric amplifier delivering more than 100 kHz at a central wavelength of 850 nm. After compression of 7.2 fs with more than 210 µJ are obtained.

SM3J.5 • 14:45
Direct diode pumped Ti:Sapphire ultrafast regenerative amplifier system, Sterling J. Backus, mathew kirchner, Charles Durfee; 1Menlo Systems GmbH, Germany; 2Dept. of Physics, Univ. of Erlangen-Nuremberg, Germany. We report on a cryogenically cooled Ti:sapphire ultrafast regenerative amplifier laser system producing multi-W energies with repetition rates continuously tunable from 50 kHz up to 250 kHz pumped with 450mW fiber coupled laser diodes.

SM3K.4 • 14:15
Laser Annealing of Low Temperature Deposited Silicon Waveguides, Yohann Franze, Antoine F. Runge, Sve Z. Oo, Noel Healy, Gregory Martinez-Jimenez, Ali Z. Khokhar, Antulio Tarazona, Harold M. Chong, Sakel-laris Mailis, Anna C. Peacock; 1Univ. of Southampton, UK. We report the fabrication of low temperature deposited polysilicon waveguides using a laser annealing process. Micro-Raman and XRD measurements reveal the quasi-single crystal-like quality of the material, which exhibits low optical losses of 5.13 dB/cm.

SM3K.5 • 14:30
Effects of Dielectric Cladding on Si Nanophotonics, Yeshashu Fairman; 1Univ. of California San Diego, USA. We discuss effects of dielectric cladings on nanoscale engineered optical nonlinearities for Si nanophotonics applications to modulation and wave mixing of optical fields.

SM3L • Mode Locked Fiber Lasers—Continued

SM3L.4 • 14:30
Novel Robust 2-µm All-PM Thulium/Holmium Based Femtosecond Fiber Laser Oscillator, Heinar Hoogland, Wolfgang Hänsel, Ronald Holzwarth; 1Menlo Systems GmbH, Germany; 2Dept. of Physics, Univ. of Erlangen-Nuremberg, Germany. We report on an all-PM mode locked 2-µm central wavelength figure-9 fiber laser oscillator based on Thulium/Holmium codoped gain fiber supporting femtosecond pulses at MHz-repetition rate.

SM3L.5 • 14:45
Broadband High Energy Breathing Laser at 1.6 µm, Jiqiang Kang, Xiaoming Wei, Kenneth Wong; 1The Univ. of HongKong, China. We demonstrate a broadband high energy breathing fiber laser at 1.6 µm with a robust configuration. It delivers 52.4-nm flat optical spectrum and about 3.9-nJ pulse energy by 220-mW pump power.
SM3M.4 • 14:15
A Compact, Efficient Deep UV Optically Pumped VECSEL, Mikhail A. Yakshin1, Mahmoud Fallahi2, SES, USA; 3College of Optical Sciences, The Univ. of Arizona, USA. We describe a compact and efficient UV laser that is under development. Over 190 mW power at 234 nm wavelength is obtained by harmonic conversion of the intra-cavity doubled output of an optically pumped Yb:YAG VECSEL.

SM3N.5 • 14:30
Graphene metasurface devices for spatial light modulation and imaging, Beibei Zeng1, Akhiles Singh1, Abul Azad1, Aditya Mohite1, Houtong Chen1, Los Alamos National Lab, USA. We demonstrate an ultrathin solid-state modulator employing metasurface/graphene/semiconductor heterostructures, where the optical properties can be efficiently tuned through applying low voltage biases in each pixel, serving as infrared spatial light modulators for imaging and sensing.

SM3N.6 • 14:45
Metasurfaces Based on Nano-Patterned Phase-Change Memory Materials, Shane A. Colburn1, Alan Zhan1, Sanchit Deshmukh1, Jason Myers1, Jesse Frantz1, Arka Majumdar1, Univ. of Washington, USA; 2Stanford Univ., USA; 3U.S. Naval Research Lab, USA. We fabricate nano-patterned films of GeSbTe to make optical metasurfaces of isolated scatterers with the goal of arbitrary electrical reconfigurability, and induce phase changes by heating with a femtosecond pulsed laser.
AM3A.4 • 15:00
Mid-infrared Quantum Cascade Lasers Transferred-printed on Silicon-on-Sapphire, Seungyong Jung1, Jeremy Kind2, Jae Hyun Kim1, Luke J. Mawst2, Mikhail A. Belkin1, Dan Botez2; 1Univ. of Texas at Austin, USA; 2Univ. of Wisconsin-Madison, USA. We experimentally demonstrate transfer-printing of mid-infrared quantum cascade lasers onto a silicon-on-sapphire platform and laser light coupling to a silicon waveguide via an adiabatically tapered mode converter. Transferred devices operate in pulsed mode at room-temperature.

AM3A.5 • 15:15
Coupled-Cavity Lasers for a Low-Power Integrated Coherent Optical Receiver, Shamsul Arafin1, Gordon Morrison2, Milan Mashanovitch2, Leif Johansson1, Larry A. Coldren1; 1Univ. of California Santa Barbara, USA; 2Freedom Photonics LLC, USA. Compact, tunable, low-power consumption coupled-cavity lasers are designed and experimentally demonstrated. Single-mode operation with an SMSR >24 dB and >11 nm tuning range are achieved, being suitable as on-chip local oscillators in low-power integrated optical coherent receivers.

AM3B.6 • 15:15
Plasmonic Nanoantenna Array with Single-Chip Integrated Metal-Organic Framework for Infrared Absorption CO2 Sensing, Alan X. Wang1; 1Oregon State Univ., USA. Surface-enhanced infrared absorption is a spectroscopic technique but unsuitable for gas spectroscopy due to the need for long absorption path lengths. We demonstrate a device using metal-organic framework integrated with plasmonic nanoantennas for CO2 sensing.

AM3B.7 • 15:15
Development of IR2-Hi5 multipass MIR isotope analyzer for plant photosynthesis and respiration study, Zhenyou Wang1, Yan Zhuang1, Andrei Deev1, Sheng Wu1; 1Arrow Grand Technologies, USA. A fast, low-sample-volume mid-infrared isotope ratio analyzer was developed and characterized. It’s employed to demonstrate real-time monitoring the CO2 concentration and carbon isotope fractionation in plant photosynthesis and respiration processes.

AM3C.5 • 15:15
Deep Tissue Coherent Imaging Using Speckle Intensity Correlations Over Object Position, Qiaoen Luo1, Kevin J. Webb1, 1Purdue Univ., USA. Spatial speckle intensity correlation measurements in relation to object position are used to image moving objects embedded inside heavily scattering, centimeter-thick chicken breast tissue.

AM3C.6 • 15:15
Doubling the Sensitivity of Multiphoton Frequency-Domain Fluorescence Lifetime Images, Yide Zhang1, Genevieve Vigil1, Ulrich Huttner1,2, Fabian Langer3, Christoph Schmid1, Stefan Schlauderer1, Stephan W. Koch1,2, Mackillo Kira1; 1Univ. of Marburg, Germany; 2Univ. of Michigan, USA; 3Univ. of Regensburg, Germany. Harmonic sidebands are compared in monolayer vs. bulk WSe2. We find strong Coulomb enhancement of sidebands in monolayer WSe2, when resonant vs. non-resonant 1s-exciton excitations are compared, this is virtually absent in bulk.
counts/s at saturation.

We demonstrate that strain control of hexagonal boron nitride allows spectral tuning of single photon emitters over 6 meV. We predict that elliptically polarized beams undergoing multiple collapsing-defocusing cycles experience a loss of polarization and demonstrate this experimentally by measuring a large increase in fluctuations of nonlinear ellipse rotations for pulses undergoing filamentation.

We present a new optical phase retrieval method using the conical refraction of metal tunnel junctions, which provides a powerful tool for sensing, nonlinear optics, and quantum optics.

We investigate the light generation from crystalline Ag-cubes based metal-insulator-metal tunnel junctions, which brings on-chip ultrafast optical sources one step closer to reality.
SM3J • Ultrafast Amplifier—Continued

Spectral phase instabilities during amplification in Ti:Sapphire, Roland Nagymihály1,2, Peter Jogi1, Adam Borzsonyi1,2, Huabao Cao1, Karoly Osvay1, Emilian Gonitier1, Benoit Bussiere2, Olivier Tcherbakoff1, Pascal D’Oliveira1, Pierre Mary Paul1, Jean-François Hergott1, Commissariat à l’Énergie Atomique, France; 2Amplitude Technologies, France; 3Continuum Inc, Amplitude Laser Group, USA. We present an original compact, 10 kHz Ti:Sa regenerative amplifier design that minimizes existing thermal effects allowing to produce 17 fs pulse duration with a 170 mrad shot to shot residual CEP noise.

SM3J • THz Communications—Continued

Fiber-Coupled, Photoconductive Heterodyne Receiver Operating at Frequencies up to 1 THz, Simon Nellen1, Björn Gloebisch1, Robert Kohlhaas1, Dennis Stanze1, Thorsten Göbel1, James O’Gorman2, Liam Barry2, Martin Schell1, Robert A. Norwood1, Shijie Fu3, Wei Shi3, Zong2, Kort Wiersma2, Arturo Chavez-Pirson2, Nasser Peyghambarian1; 1School of Electrical and Computer Engineering, Cornell Univ., USA; 2Institut d’Optique de Microélectronique et de Nanotechnologie (IEMN), France. A leaky-wave antenna based terahertz (THz) demultiplexer is presented in this paper. It can realize demultiplexing of real-time THz data streams at different carrier frequencies under identical or different data rates.

SM3J • Silicon Photonics—Continued

Telecom Band Plasmonic Enhanced Internal Photoemission Photodetector Based On Deposited Amorphous Silicon, Nir Kaplan1, Meir Y. Grajower1, Noa Mazurski1, Joseph Shapira1, Uriel Levy1; 1The Hebrew Univ. of Jerusalem, Israel. We present a first demonstration of plasmonic enhanced internal photoemission Schottky photodetector implemented by low temperature deposited amorphous silicon for the telecom regime. The detector show responsivity of 53 mA/W.

SM3K • Mode Locked Fiber Lasers I—Continued

Fixed-Point Tuning of a Frequency Comb from a Passively Mode-Locked Soliton Fiber Laser, Ken Kashihawa1,2, Hajime Inaba1,2; 1National Inst. of Advanced Industrial Science and Technology (AIST), Japan; 2JST, ERATO MINOSHIMA Intelligent Optical Synthesizer (IOS), Japan. We report wavelength-dependent pump-induced responses of repetition and carrier-envelope-offset frequencies of a soliton fiber laser comb. Lasing wavelength adjustment can tune a fixed point and design controlling orthogonality between a pump-laser current and another actuator.

SM3K • Silicon Photonics—Continued

Mode-locked operation of a 1150 nm diode-pumped CNT mode-locked Ho3+-doped Fluoride Fiber Laser at 1.2 um, Junfeng Wang1, Xiuxiu Ma1, Jie Zong2, Kort Wiersma1, Arturo Chavez-Pirson2, Robert A. Norwood1, Shijie Fu2, Wei Shi2, Nasser Peyghambarian1; 1College of Optical Sciences, Univ. of Arizona, USA; 2NP Photonics, USA; 3College of Precision Instrument and Optoelectronics Engineering, Tianjin Univ., China. Mode-locked operation of a 1150 nm diode-pumped holmium-doped fluoride fiber laser at 1.2 um based on carbon nanotube saturable absorber is reported. Mode-locked laser at 1192 nm with a repetition rate of 18.47 MHz was obtained.
SM3M • Progress in Optical Frequency Conversion—Continued

**SM3M.7 • 15:00**
**Intracavity Difference-Frequency Mixing of OPO Signal and Idler Pulses in BaGa₄Se₇**, Andrey A. Boyko¹², Nadezhda Y. Kostyukova¹², Valeriy Badikov², Dmitrii Badikov², Vladimir Panyutin², Galina Shevyrdyaeva³, Validas Pasiskevicius³, Andrius Zukauskas³, Georg M. Marchev¹, Dmitry Koller², Valentin Petrov¹; ¹Max Born Inst., Germany; ²Special Technologies, Ltd., Russia; ³Kuban State Univ., Russia; ⁴Royal Inst. of Technology, Sweden; ⁵Novosibirsk State Univ., Russia.

An overall quantum conversion efficiency of 7.8% is achieved by intracavity mixing the signal and idler of a 1.064-µm pumped Rb:PPKTP OPO in BaGa₄Se₇, generating >0.7 mJ pulse energy at ~7 µm and 100 Hz.

**SM3M.8 • 15:15**
**Burst-Mode Pumping for Single-Pulse Parametric Amplification in the Long-Wave IR**, Ignas Astrauskas¹, Edgar Kakis¹, Tobias Flöry¹, Giedrius Andriukaitis¹, Pavel Malevich¹, Tadas Balciunas¹, Audunus Puglys¹, Andrius Baltuska³; ¹Photons Inst., Vienna Univ. of Technology, Austria. We propose and demonstrate a scheme for LWIR pulse amplification based on spatial and spectral demultiplexing of a pulse burst from a 1 µm laser amplifier. This method enables multi-color multi-beam pumping of an OPA without complications intrinsic to coherent pulse combining techniques.

SM3N • Plasmonics and Metamaterials—Continued

**SM3N.7 • 15:00**
**Thermal Homeostasis Device Using Phase-Change Materials**, Shao-Hua Wu¹, Mingkun Chen¹, Luqiang Li¹, Vladimir Baranov², Vladan Jankovic², Phillip Hom², Luke Sweatlock², Michelle Pavone²; ¹Univ. of Southern California, USA; ²NG Next Northrop Grumman Corporation, USA.

We design a thermal homeostasis device that passively regulates temperature 20x better than regular semiconductor materials. The thermal emission changes by a factor of 10 as the material temperature crosses a phase transition.

**SM3N.8 • 15:15**
**Surface-Plasmon Opto-Magnetic Field Enhancement for Magnetization Reversal of On-Chip Nanomagnets**, Aveek Dutta¹, Deeks Dutta¹, Deeksha Shah¹, Bradley Beauchamp¹, Kurtal Roy¹, Vladimir M. Shalaev¹, Ernesto E. Marinero¹, Alexandra Boltasseva¹; ¹Purdue Univ., USA.

We study, computationally, TiN plasmonic resonator coupled to a nanomagnet for magnetic field switching. We find that compared to an isolated nanomagnet under similar illumination conditions, localized surface plasmon resonances in the coupled system generate larger magnetic fields in the nanomagnet.

SM3O • Integrated Quantum Photonics—Continued

**SM3O.5 • 15:00**
**On-Chip Auto-Correlator Using Two-Photon-Absorption Photodiode Array and Counter-Propagating Slow Light**, Keisuke Kondo¹, Toshihiko Baba¹, Hideaki Misono¹, Hiroaki Yamauchi¹, Juntaro Ohya¹; ¹Dept. of Electrical and Computer Engineering, Yokohama National Univ., Japan. We demonstrate an ultra-compact solid-state auto-correlator without delay scanning. We observe counter-propagating slow light pulses in a Si photonic crystal waveguide with a two-photon-absorption photodiode array. Sensitive detection is available for picosecond pulses.

**SM3O.6 • 15:15**
**Electrically Pumped, Waveguide-Coupled Si Light Emitting Diodes**, Sonia M. Buckley¹, Martin Stevens¹, Sae Woo Nam¹, Richard Mirin¹, Jeffrey Shainline¹; ¹NIST, USA. We describe fabrication and testing of LEDs based on emissive defect centers in Si and discuss our progress toward low-temperature on-chip integrated sources and detectors.

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**14:00–17:30 Understanding Unconscious Bias, Winchester Room/Hilton**

**15:30–16:00 Coffee Break, Concourse Level**
16:00–18:00
AM4A • A&T Topical Review on Scientific and Commercial Progress in Semiconductor Lasers II
President: Bojan Resan; Lumentum, Univ. of Applied Sciences, Switzerland

16:00–18:00
SM4C • Optofluidic Components and Systems
President: Aaron Hawkins; Brigham Young Univ., USA

16:00–18:00
SM4D • Nanophotonics, Waveguides, and Microresonators in Sensing
President: Aleksandra Foltynowicz; Umea Univ., Sweden

AM4A.1 • 16:00
Invited
Low Noise Ultrafast Pulse Generation and Signal Processing Using Semiconductor Lasers, Peter J. Delfyett1, A. Ardey1, S. Bhoopalpur1, E. Saralidou1; 1CREOL, The College of Optics & Photonics, USA. This talk covers novel techniques and applications of low noise ultrafast optical pulses and stabilized optical frequency combs. Applications are focused on photonic ultrawide-band signal processing, such as waveform generation and measurement, and matched filtering.

AM4B.1 • 16:00
Invited
In-Vivo Monitoring of Energy Chemistry and Energy Production with High Spatial Resolution, aidong yan1, Paul Ghodrnicki2, Michael Burch2, Shiwoo Lee3, Ming-Jun Li3; 1CREOL, The College of Optics & Photonics, USA; 2National Energy Technology Lab, USA; 3Corning Inc., USA. This talk discusses developments of distributed fiber sensors for real-time and simultaneous monitoring of fuel consumption and resulting temperature/strain variation with sub-cm spatial resolution in reactors such as solid oxide fuel cells during their operations.

SM4C.1 • 16:00
Invited
Optofluidic Chips for Raman Spectroscopy and Optical Trapping, Heidi Ottevaere1, Qing Liu2, Diane De Coster3, Jürgen Van Erps3, Michael Vervaeke1, Hugo Thierry1; 1Vrije Universiteit Brussel, Belgium. We present the modeling, design and fabrication of microfluidic devices incorporating Raman spectroscopy, from which one enables confocal Raman measurements on-chip, as well as optical trapping. In a proof-of-concept demonstration, we measure the Raman spectra of various solutions and investigate the trapping capabilities of the replicated chips.

SM4D.1 • 16:00
Transform-limited dual-comb spectroscopy using free-running waveguide lasers, Nicolas Bourbeau Hebert1, Jean-Daniel Deschênes2, Hugo Bergeron1, George Chen2, Champak Khurmi2, David Lancaster2, Jérôme Genest1; 1Université Laval, Canada; 2Univ. of South Australia, Australia. We present a standalone dual-comb platform based on two mutually stable waveguide lasers integrated in the same glass chip. Residual fluctuations are compensated using an algorithm seeded only by interferograms, which yields transform-limited spectra.

AM4A.2 • 16:30
Invited
Ultrafast Semiconductor Disk Lasers, Ursula Keller1; 1Physics Dept., ETH Zurich, Switzerland. The performance of ultrafast semiconductor disk lasers rapidly advanced over the last decades. There is a strong interest from industry for inexpensive, compact and reliable ultrafast laser sources in the picosecond and femtosecond domain. The aim of this review is to describe the application potential and to give an overview of the current status of modelocked semiconductor disk lasers. Particular focus is placed on the ongoing efforts to achieve shorter pulses with higher peak powers.

AM4B.2 • 16:30
Withdrawn.

SM4C.2 • 16:30
Vertically Embedded Multimode-Interference Waveguide-Based Optical Stretchers for Mechanical Characterization of Cells, Zhanshi Yao1, Andrew W. Poon1; 1Hong Kong Univ. of Sci. and Tech., Hong Kong. We demonstrate an on-chip optical cell stretcher using optical lattices generated from SU8-filled vertically embedded multimode-interference waveguides in a silicon substrate. We extract the shear modulus of ~2 μN/m from swollen rabbit red blood cells.

SM4D.2 • 16:15
Invited
Waveguide Cavities for Absorption Detection of Chemicals, Hans-Peter Loock1; 1Queen’s Univ. - Chemistry, Canada. Fiber optic cavities based on either on fiber loops or identical FBGs are used to detect the optical loss due to trace chemicals based on the cavity ring-down time or the photoacoustic effect, respectively.
Quantum Dot Based Devices for Scalable Heterogeneous III-V / Si₃N₄ Integration for Quantum Photonic Circuits

- FM4F.1 • 16:00
  Rogue waves in red blood cell suspensions, Yuxuan Ren1, Josiah Lamstein1, Trevor S. Kelly1, Chensong Zhang2, Yong Sun3, Claudio Conti4, Demetrios Christodoulides5, Zhihgan Chen2,3,2, San Francisco State Univ., USA; 3Nankai Univ., China; 2Univ. Sapientia, Italy; 1CREO/College of Optics, Univ. of Central Florida, USA. We observe rogue-wave-like events in red-blood-cell suspensions driven by light scattering and Brownian motion. In contradistinction with results from poly styrene bead suspensions, at high powers, the optical nonlinearity leads to altogether different probability distributions.

- FM4F.2 • 16:15
  Deep penetration of light through suspensions of red blood cells, Josh Lamstein1, Rekha Gautam1, Tobias Hansson2, Anna Bezryadina3, Benjamin Wetzel4,5, Roberto Morandotti1,4, Zhihgan Chen1,2, San Francisco State Univ., USA; 2Nankai Univ., China; 3INRS, Université du Québec, Canada; 4Univ. of California, San Diego, USA; 5Univ. of Sussex, UK. We demonstrate nonlinear self-trapping of a light beam in human red blood cell suspensions with varying liquid buffer concentrations, along with a numerical model that features an effective nonlocal nonlinearity to explain our experimental observations.

- FM4F.3 • 16:30
  Second-harmonic focusing by nonlinear turbid media, Feng Li1, Long Xiao1, Yu Ye1, Mengxuan Wang1, Kaiju Cui1, Xue Feng1, Wei Zhang1, Yidong Huang1, Tsinghua Univ., China. We demonstrate second-harmonic focusing of second-harmonic waves, which are generated and scattered from nonlinear turbid media via feedback-based wavefront shaping, is presented, indicating more controllable degrees of freedom for future focusing and imaging through turbid media.

- FM4F.4 • 16:45
  Tailoring Thermal Emission with Epsilon-Near-Zero Media Augmented with Dielectric Rods, Inigo Liberal1, Nader Engheta1,2,3,4,5,6, 1Dept. of Physics & Astronomy, Shanghai Jiao Tong Univ., China; 2Collaborative Innovation Center of Physics (CICIFPSA), Shanghai Jiao Tong Univ., China; 3Planck Inst. for Intelligent Systems, Germany. We theoretically investigate the thermal emission capabilities of epsilon-near-zero (ENZ) bodies containing dielectric rods. Effective enhancement of the wavelength at the ENZ frequency empowers directive and reconfigurable emission patterns, as well as geometry-invariant spectral features.
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<td>16:00-18:00</td>
<td>SM4I • Ultrafast Pulse Combination and Manipulation</td>
<td>Meeting Room 211 B/D</td>
<td>Igor Jovanovic</td>
<td>Univ. of Michigan, USA</td>
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<td>SM4J • THz QCLs and Imaging</td>
<td>Meeting Room 212 A/C</td>
<td>Kimberly Reichel; Brown</td>
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<td>SM4K • Resonant Optics</td>
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<td>SM4L • Mode Locked Fiber Lasers II</td>
<td>Marriott Salon I &amp; II</td>
<td>Andy Chong; Univ. of Dayton, USA</td>
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<td>SM4I.1 • 16:00 Coherent Pulse Stacking Amplification – Extending Chirped Pulse Amplification by Orders of Magnitude</td>
<td>Meeting Room 211 B/D</td>
<td>David P. Burghoff; MIT, USA</td>
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<td>SM4J.1 • 16:00 Flat Comb Generator, Simultaneous Phase-Locking of Quantum Cascade Lasers Using Multi-Frequency THz Source System Composed of MZM-Based Flat Comb Generator, Synchronization of Two Quantum Cascade Lasers</td>
<td>Meeting Room 212 A/C</td>
<td>Jonathan Bar-David; Noa Mazurski; Uriel Levy</td>
<td>Tohoku Univ., Japan</td>
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<td>SM4J.2 • 16:30 Femtosecond Beam Combination Using Diffractive Optic Pairs, Femtosecond 3D Direct Laser Writing, Towards Planar Dielectric Metasurfaces</td>
<td>Meeting Room 212 B/D</td>
<td>Christoph Bacher; Philippe Raslin; Daniel Paardekooper; Thomas Feurer</td>
<td>Univ. Bern, Switzerland</td>
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<td>SM4K.1 • 16:00 Merging Micro- and Nano-Optics, Terahertz Quantum Cascade Laser Frequency Combs, Diffractive Optic Pairs, Femtosecond Beam Combination Using Planar Silicon Nanoantennas which are build by LOCOS technique to fabricate quasi-planar Silicon nanoantennas which are building blocks for future planar metasurfaces.</td>
<td>Meeting Room 212 B/D</td>
<td>Harald W. Giessen; S Thiele; S Rostok; A Herkommer; Almantas Galmasauskas; Yuri Y. Set</td>
<td>W. Giessen; S Thiele; S Rostok; A Herkommer; Almantas Galmasauskas; Yu Y. Set</td>
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<td>SM4K.2 • 16:30 Self-optimization and oscillation state mapping of polarization additive pulse mode-locked fiber lasers, Estimation of transient properties of submicron-probing mode-locked fiber lasers, Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers</td>
<td>Meeting Room 212 B/D</td>
<td>Manuel Ryser; Christoph Bacher; Philippe Raslin; Daniel Paardekooper; Thomas Feurer</td>
<td>Universitats Bern, Switzerland</td>
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<td>SM4L.1 • 16:00 Mode-locked Er-doped Fiber Laser by Pump Modulation beyond Emission Lifetime Limit, 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band, 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band</td>
<td>Meeting Room 212 B/D</td>
<td>Shoko Yokokawa; Masato Yoshida; Yoshihisa Hirooka</td>
<td>Tohoku Univ., Japan</td>
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<td>SM4L.2 • 16:15 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band</td>
<td>Meeting Room 212 B/D</td>
<td>Yu Wang; Sze Y. Set</td>
<td>The Univ. of Tokyo, Japan</td>
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<td>SM4L.3 • 16:30 Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers, Estimation of transient properties of submicron-probing mode-locked fiber lasers, Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers</td>
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**Monday, 16:00–18:00**

**CLEO: Science & Innovations**

**Meeting Room 211 B/D**

- **SM4I • Ultrafast Pulse Combination and Manipulation**
  - **Presider:** Igor Jovanovic; Univ. of Michigan, USA
  - **Presenter:** David P. Burghoff; MIT, USA

**Meeting Room 212 A/C**

- **SM4J • THz QCLs and Imaging**
  - **Presider:** Kimberly Reichel; Brown Univ., USA
  - **Presenter:** Jonathan Bar-David; Noa Mazurski; Uriel Levy

**Meeting Room 212 B/D**

- **SM4K • Resonant Optics**
  - **Presider:** Roberto Paieia; Boston Univ., USA
  - **Presenter:** Harald W. Giessen; S Thiele; S Rostok; A Herkommer

**Marriott Salon I & II**

- **SM4L • Mode Locked Fiber Lasers II**
  - **Presider:** Andy Chong; Univ. of Dayton, USA
  - **Presenter:** Shoko Yokokawa

**SM4I.1 • 16:00 Coherent Pulse Stacking Amplification – Extending Chirped Pulse Amplification by Orders of Magnitude**

- **Presenter:** Almantas Galmasauskas; Yuri Y. Set

**SM4J.1 • 16:00 Flat Comb Generator, Simultaneous Phase-Locking of Quantum Cascade Lasers Using Multi-Frequency THz Source System Composed of MZM-Based Flat Comb Generator, Synchronization of Two Quantum Cascade Lasers**

- **Presenter:** Akira Kawakami; Takahide Sakamoto; Norihiko Sekine; Akiyoshi Kasamatsu; Iwao Hosako

**SM4J.2 • 16:30 Femtosecond Beam Combination Using Diffractive Optic Pairs, Femtosecond 3D Direct Laser Writing, Towards Planar Dielectric Metasurfaces**

- **Presenter:** Christoph Bacher; Philippe Raslin; Daniel Paardekooper; Thomas Feurer

**SM4K.1 • 16:00 Merging Micro- and Nano-Optics, Terahertz Quantum Cascade Laser Frequency Combs, Diffractive Optic Pairs, Femtosecond Beam Combination Using Planar Silicon Nanoantennas which are build by LOCOS technique to fabricate quasi-planar Silicon nanoantennas which are building blocks for future planar metasurfaces.**

- **Presenter:** Harald W. Giessen; S Thiele; S Rostok; A Herkommer; Almantas Galmasauskas; Yuri Y. Set

**SM4K.2 • 16:30 Self-optimization and oscillation state mapping of polarization additive pulse mode-locked fiber lasers, Estimation of transient properties of submicron-probing mode-locked fiber lasers, Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers**

- **Presenter:** Manuel Ryser; Christoph Bacher

**SM4L.1 • 16:00 Mode-locked Er-doped Fiber Laser by Pump Modulation beyond Emission Lifetime Limit, 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band**

- **Presenter:** Shoko Yokokawa

**SM4L.2 • 16:15 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band, 40 GHz, 770 fs Harmonically and Regeneratively FM Mode-Locked Erbium Fiber Laser in L-Band**

- **Presenter:** Yu Wang; Sze Y. Set

**SM4L.3 • 16:30 Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers, Estimation of transient properties of submicron-probing mode-locked fiber lasers, Self-optimization and oscillator state mapping of polarization additive pulse mode-locked fiber lasers**

- **Presenter:** Manuel Ryser; Christoph Bacher

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**Monday, 16:00–18:00**

**Meeting Room 211 B/D**

- **SM4I • Ultrafast Pulse Combination and Manipulation**
  - **Presider:** Igor Jovanovic; Univ. of Michigan, USA

- **SM4J • THz QCLs and Imaging**
  - **Presider:** Kimberly Reichel; Brown Univ., USA

- **SM4K • Resonant Optics**
  - **Presider:** Roberto Paieia; Boston Univ., USA

- **SM4L • Mode Locked Fiber Lasers II**
  - **Presider:** Andy Chong; Univ. of Dayton, USA
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
AM4A • A&T Topical Review on Scientific and Commercial Progress in Semiconductor Lasers II—Continued

AM4A.3 • 16:45 Evaluation of Air Turbulence Impact Based on Wavefront Reconstruction, Wenbo Gao1, Milorad Cujevic1; 1 Univ. of Arizona, USA. We have established and experimentally verified a convenient relation between the wavefront error variance and the phase structure function, which can be readily used to estimate the atmospheric coherence diameter and the refractive-index structure constant.

AM4A.4 • 17:00 Tunable 3D Hybrid Integrated Silicon Photonic External Cavity Laser, Bowen Song1, yuan lu1, sasa Ristic2, jonathan klunk3,1; 1ECE, Univ. of California Santa Barbara, USA; 2McGill Inst. for Advanced Materials, McGill Univ., Canada. A 3D-integrated hybrid silicon laser was demonstrated with tuning range of 30 nm, a side-mode suppression ratio of 34 dB, optical output power of 2 mW, and peak relative intensity noise of -135 dB/Hz.

AM4B • Combustion and Atmospheric Photonics—Continued

AM4B.3 • 16:45 Iterative holographic reconstruction based on the grating illumination with improved resolution by interpolation, Shaoqiong Feng1; 1Shanghai Jiao Tong Univ., China. We proposed an iterative reconstruction method with interpolation based on the grating illumination with improved resolution. UASF target as the sample in Numerical simulation and experiment were conducted to prove the feasibility of this method.

AM4B.4 • 17:00 Visiblity Enhancement of Hazy Images Using Polarimetric Dehazing Method Based on Stokes Parameters, Jian Liang1, Wenfen Zhang1, Liyong Ren1, Haijun Ju1, Zhaofeng Bai1, Enshi Gù1; 1Xi’an Inst Optics & Precision Mech., CAS, China. Polarimetric dehazing methods are proven very effective in enhancing the contrast and visibility of images captured in hazy weather. In this paper, we analyze the capability of visibility enhancement in experiments.

AM4B.5 • 17:15 Multimodal Multiplexing of Single-Virus Detection Using Multi-Mode Interference Waveguides, Damla Ozcelik1, Matthew A. Stott2, Joshua W. Parks1, Aadhar Jain1, Aaron Hawkins1, Holger Schmidt1; 1Duke Univ., USA; 2Univ. of Arizona, USA. We demonstrated on-chip Raman spectroscopy using microresonator soliton frequency combs by measuring the absorption spectrum of H2O in the near-infrared. The results show the potential for a chip-based, high precision spectroscopic system.

AM4C • Optofluidic Components and Systems—Continued

AM4C.3 • 16:45 Standing-wave Raman Tweezers for Optical Trapping and Sensitive Characterization of Nano-sized Structures, Mu-ying Wu1, Guan Yang1, Guihua Chen1, Yong-Qing Li1; 1Dongguan Univ. of Technology, China; 2Eastern Carolina Univ., USA. A standing-wave optical trap integrated with confocal Raman spectroscopy enables stable trapping and characterization of individual single-walled carbon nanotubes, graphene flakes, biological cells, SERS-active metal nanoparticles and other nanoparticles based on their increased Raman fingerprints.

AM4C.4 • 17:00 Single Gold Nanoparticle Trapping using an Optofluidic Chip, Mu-ying Wu1, Sha Xiong1, Lip Ke Qin1, Jin Shi1; 1Dongguan Univ. of Technology, China; 2East Carolina Univ., USA. We present an optofluidic chip for the trapping and separation of single gold nanoparticles (60-100 nm). Size and refractive index of a gold nanoparticle are determined by the trapping position using Drude and Mie theories.

AM4D • Nanophotonics, Waveguides, and Microresonators in Sensing—Continued

AM4D.3 • 16:45 Absorption Spectroscopy of Doped Conjugated Polymer Single-Particles with Toroidal Optical Microresonators, Erik H. Horak1, Kassandra A. Knapper1, Morgan Rea1, Fang Pan1, Kevin D. Heyman1, Randall H. Goldsmith1; 1Univ. of Wisconsin - Madison, USA. Applying toroidal optical microresonators as absorption spectrometers to examine the heterogeneous electronic structure of the doped conjugated polymer PEDOT:PSS from a single particle basis.

AM4D.4 • 17:00 Microresonator soliton dual-comb spectroscopy, Qian Yang1, Myoung-Gyun Suh1, Ki Y. Yang1, Xu Yi1, Kenny Vahala1; 1California Inst. of Technology, USA. Dual-comb spectroscopy is demonstrated using microresonator soliton frequency combs by measuring the absorption spectrum of H2O in the near-infrared. The results show the potential for a chip-based, high precision spectroscopic system.

AM4D.5 • 17:15 Near-Infrared Waveguide-Enhanced Raman Spectroscopy of Trace Gases, Todd H. Stievater1, Kee Koo1, Nathan Tyndall1, Dmitry Kozak1, Scott Holmstrom2, R. Andrew McGill1, Marcel W. Pruessner1, William Robinovich1, Jacob Khurgin1; 1US Naval Research Lab, USA; 2Univ. of Tulsa, USA; 3Johns Hopkins Univ., USA. Functionalized silicon nitride waveguides are used to detect Raman scattering from trace concentrations of toxic chemical species. Parts-per-billion detection limits are measured using single-mode rib and nanoslot waveguides pumped at 785 nm.

AM4D.6 • 17:30 Detection of Surface-enhanced Raman Signals from a Single Nanoplasmonic Antenna Integrated on a Single Mode Waveguide, Ali A. Raza1, Frederic Peyinskaya1, Pieter Wuytens1, Paul V. Doper1, Stéphane Clemmen1, Roel Baets1; 1IMEC, Gент Univ., Belgium; 2MIT, USA; 3IMEC, Belgium. We present the first demonstration of on-chip Raman spectroscopy using a single nanoplasmonic antenna integrated on a single mode nanophotonic waveguide. To achieve this goal, shot noise associated with waveguide background is investigated.
Andrea Cavanna1, Michael Taheri1, Cameron Sae Woo Nam1, Kim2, Chul Soo Kim1, Sophia E. Economou3, Gammon1; 

triplets is an interesting but not-yet-realized direct decay of pump photons into a two-dimensional black hole horizon and ergosphere in a nonlocal photon superfluid, such that the epsilon-near-zero regime coincides with the donor emission.

We experimentally demonstrate an integrated zero-index waveguides, Oral Reshef1, Philip Camayd-Muñoz2, Daryl Vulis2, Arnab Plasmons Using a Si Gable Tip, Eric Mazur2; 1Dept. of Physics, Harvard University, USA; 2School of Engineering and Applied Sciences, Harvard University, USA. We present small-footprint (=2x2-wide) silicon-based waveguides with an effective index of zero at a wavelength near &lambda; = 1630 nm. We characterize the refractive index using on-chip interferometry and measure the propagation loss to be 1.3 dB/μm.

Highly Efficient Excitation of Surface Plasmons Using a Si Gable Tip, Arnab Deynne1, Muhammad Alavi1, J. Stewart Atchison1, Mo. Mojahedi2, 1Univ. of Toronto, Canada; 2California Inst. of Technology, USA. We experimentally demonstrate an integrated silicon gabled tip to excite an SPP mode at 1550 nm wavelength at an Au/SiO₂ interface with 25.5% input to SPP output efficiency which can reach as high as 52%.

Magneto-optical Isolator for Nanoplasmic Waveguides, Vahid Foroughi Nezhad1, Georgios Veronis1, 1Princeton Univ., USA; 2The Univ. of New Mexico, USA. We introduce an extremely compact magneto-optical isolator consisting of a cavity placed in the proximity of a metal-dielectric-metal plasmonic waveguide. The transmission spectra of the structure depend on the direction of the incident waveguide mode.

We introduce an extremely compact magneto-optical isolator consisting of a cavity placed in the proximity of a metal-dielectric-metal plasmonic waveguide. The transmission spectra of the structure depend on the direction of the incident waveguide mode.

Monday, 16:00–18:00

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
SM4I.3 • 16:45
A Pulse-Phase-Based Phase-Locking Method for Multi-cavity Coherent Pulse Stacking, Yawei Yang1, John Byrd1, Jay Dawson1, Lawrence Doolittle1, Qiang Du1, Almantas Galvanauskas1, Gang Huang1, Wim Leeman2, John Ruppe1, Russell Wilcox1, Yilun Xu1, Lawrence Berkeley National Lab, USA; Lawrence Livermore National Lab, USA; Univ. of Michigan, USA. A novel phase-locking method, which locks cavity phase based on the pulse patterns detected from each cavity, has stabilized the output pulse intensity in a four-cavity Coherent Pulse Stacking experiment.

SM4I.4 • 17:00
Fractional Temporal Self-imaging for Mitigation of Nonlinear Propagation Impairments of Ultrashort Pulses, Seghalini Mohamed1, Reza Maram1, Jose Azana1, 2Énergie Matériaux Télécommunications, Institut National de la Recherche Scientifique, Canada. We propose a new approach to mitigate nonlinear propagation-impairments of pulses through pulse-division using fractional temporal self-imaging, overcoming limitations of previous methods for application at high repetition-rates. Successful demonstration on GHz-rate picosecond pulses is shown.

SM4I.5 • 17:15
High Repetition Rate Pulse Burst Generation using the Vernier effect, Tobias Pflöy1, Giedrius Andriukaitis1, Martynas Barkauskas1, Edgar Kakas1, Ignas Astrauskas1, Audrius Pupega1, Andrius Baltuska1, Romas Danielsen1, Almantas Galvanauskas1, Tadas Balcianas1, 1Technische Universität Wien, Austria; 2Light Conversion Ltd., Lithuania. In this work we show how a continuous wave, low threshold and well collimated terahertz laser vertical source can be obtained by coupling two sub-wavelength whispering galleries quantum cascade optical resonators with a metallic bridge.

SM4I.6 • 17:30
Generation of Programmable Envelope in High-Speed Optical Pulse Train by Fractional-Rate Intensity Modulation, Guo Xie1, Chester Shu1, 1Chinese Univ. of Hong Kong, China. We experimentally demonstrate periodic envelope programming of ~80 GHz optical pulse trains by using ~10 GHz multiplexed electronic patterns. The method synthesizes 78.08 GHz optical binary patterns and pulse trains with triangular and parabolic envelopes.

SM4J.3 • 16:45
Chip-scale Turing frequency comb for coherent high-power THz radiation, Jinghui Yang1, Shu-Wei Huang1, Shang-Hua Yang1, Mingyu Bi1, Dim-Lee Kwong1, Tanya Zelevinsky1, Mona Jarrah1, Chee Wei Wong1, 1Univ. of California, Los Angeles, USA; 2Inst. of Microelectronics, Singapore; 3Dep't of Physics, Columbia Univ., USA. We report chip-scale Turing frequency comb with narrow linewidth of 9 kHz and long term stability of 160 kHz on THz carriers. The Turing comb is transferred onto a plasmonic photomixer, achieving 600 mW terahertz radiation with high 1.1% optical-to-terahertz power conversion at room temperature.

SM4J.4 • 17:00
Terahertz quantum cascade dipole-antenna vertically emitting continuous wave laser, Luca Masini1, Alessandro Pitan1, Lorenzo Baldacchini1, Miriam S. Vitiello1, Riccardo Degl’innocenti1, Harvey E. Bennett2, Daniel A. Ritchie1, Alessandro Tredicucci1, 1NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Italy; 2Univ. of Life Sciences, Scuola Superiore Sant’Anna, Italy; 3 Cavendish Lab, Univ. of Cambridge, UK; 4NEST, CNR- Istituto Nanoscienze and Dipartimento di Fisica, Università degli studi di Pisa, Italy. In this work we show how a continuous wave, having potential for dual-comb spectroscopic applications.

SM4J.5 • 17:15
A Source-free Single-chip Terahertz Spectroscopy through Sub-wavelength Sensing of Antenna Near-fields, Xue Wu1, Kaushik Sengupta1, 1Princeton Univ., USA. In this work, near-field electromagnetic radiation is exploited to enable compact broadband THz spectroscopy in silicon-based integrated technology. Integrating passives with active devices in a silicon chip creates a new class of miniaturized THz systems.

SM4J.6 • 17:30
Imaging Polarization in GaN Surfaces by Laser Terahertz Emission Microscopy, Yuji Sakai1, Isao Kawayama1, Hideyoshi Nakahishi1, Masayoshi Tomouchi1, 1Osaka Univ., Japan; 2SCREEN Holdings, Japan. Polarisations in GaN surfaces are visualized using terahertz emission microscopy. A non-radiative-inversion domain that is hardly distinguishable with photoluminescence imaging was clearly observed with this method.

SM4K.3 • 16:45
Optical Properties of Ultrathin Plasmonic TiN Films, Desheh Shah1, Harsha Reddy1, Nathaniel Kinsey2, Vladimir M. Shalaev3, Alexandra Boltasseva1, 1Purdue Univ., USA; 2Virginia Commonwealth Univ., USA. Epi-taxial, ultrathin (<10 nm) plasmonic TiN films are characterized using spectroscopic ellipsometry and Hall measurements. Thin films with thickness down to 2 nm remain highly metallic with a carrier concentration on the order of 1022 cm−3.

SM4K.4 • 17:00
Light Management in Resonant Structures, Zongyu Yu1, 1Univ. of Wisconsin-Madison, USA. Light management based on resonant structures offer extraordinary optical confinement and novel functionalities for optoelectronic devices. We will discuss the limit of optical concentration and the non-Hermitian interactions that lead to optical-coupled electrical-isolated photodetectors for multi-modal light detection.

SM4K.5 • 17:15
Fast Wavelength-Switchable Figure-Nine Er Fiber Laser Using a Galvanometer-Driven Intracavity Filter, Toshio Fujita1, Yasuyuki Ozeki1, 1Electrical Engineering and Information Systems, The Univ. of Tokyo, Japan; 2Electrical and Electronic Engineering, The Univ. of Tokyo, Japan. We demonstrate fast wavelength switching of a polarization-maintaining Er fiber laser within <10 ms. Within the wavelength range of 30 nm, the pulse duration was ~1.1 ps and the time-bandwidth product was ~0.34.
Monday, 16:00–18:00

SM4M • Optical Parametric Oscillators—Continued

SM4N • Prevascular and Photonic Crystal Lasers—Continued

SM4O • Heterogeneously Integrated Si Photonics—Continued

SM4M.4 • 16:45
High-repetition-rate Picosecond Deep-infrared Optical Parametric Oscillator Based on CdSIP2, Ryan Hamerly1, Kirk Ingold3, Robert L. Byer1, Martin M. Fejer1; 1Stanford Univ., USA; 2ETH Zurich, Switzerland; 3USMA, USA. We report the first high-repetition-rate picosecond OPO based on CdSIP2, tunable across 6205-6695 nm in deep-IR, providing 105 mW at 6205 nm at 79.5 MHz, with 2.3% rms passive power stability over 12h in high-beam-quality.

SM4M.5 • 17:00
Optical Parametric Sources for Atmospheric Sensing, Antoine Godard1, Julie Armoignoum2, Erwan Cadio3, Guillaume Walter4, Jean-Baptiste Dherbecourt5, Guillaume Garju6; 1CNRS, France; 2ONERA - The French Aerospace Lab, France. We present our activities on the development of tunable optical parametric sources for gas sensing. In particular, we introduced the nested cavity OPO. We have also developed rapidly tunable OPOs based on aperiodic quasi-phase matching.

SM4N.3 • 16:45
Continuous-wave Optically Pumped Lasing of Hybrid Perovskite VCSEL at Green Wavelength, Mohammed A. Sharizal1, Zhixiong Liu1, Abdullah Al-Atawi1, Tien Khee Ng1,2, Boon S. Ooi1,2; KAUST, Saudi Arabia. We demonstrate the lasing of a perovskite vertical-cavity surface-emitting laser at green wavelengths, which operates under continuous-wave optical pumping at room-temperature by embedding hybrid perovskite between dielectric mirrors deposited at low-temperature.

SM4N.4 • 17:00
Narrowband Thermal Emitters Based on Photonic Crystals, Takashi Asano1, Takuya Inoue2, Susumu Noda1; 1Kyoto Univ., Japan. Single-peak narrowband thermal emitters with high energy utilization efficiencies are realized by controlling both photonic and electronic states. Ultrafast (~MHz) direct intensity modulation is also demonstrated.

SM4O.4 • 17:00
Polarization Diversity Quantum Dot Semiconductor Optical Amplifier Module for T-band Communication, Hiroyuki Tsuda1, Takaumi Chiba1, Tadashi Hajikano3, Katsumi Yoshizawa1, Yusumori Tomomatsu1, Hiroshi Takahashi1, Takayuki Kawashima1, ShojoziKawakami1, Yudai Okuno1, Koki Sugiyama1; 1Keio Univ., Japan; 2Photonic Lattice, Inc., Japan; 3OPTOQUEST CO., LTD., Japan; 4Pioneer Micro Technology Corp, Japan; 5Koshin Kogaku Co., Ltd., Japan; 6Sophia Univ., Japan. The polarization independent SOA module for T-band communication was fabricated using the quantum dot gain chip and the polarization diversity circuits with photonic crystal waveplates. The polarization dependent gain was successfully reduced to 0.5 dB.

SM4N.5 • 17:30
Simultan Formation in Mid-Infrared Femtosecond Optical Parametric Oscillators, Marc Jankowski1, Alixez Marandian2, Christopher R. Phillips3, Ryan Hamerly1, Kirk Ingold2, Robert L. Byer1, Martin M. Fejer1; 1Stanford Univ., USA; 2ETH Zurich, Switzerland; 3West Point Academy, USA. We report on observations of simultions, bright-dark soliton pairs, in femtosecond optical parametric oscillators. Simultan formation generates stable sub-50-fs half-harmonic pulses with sech^2 envelopes, slope efficiencies >400%, and conversion efficiencies >50%.

SM4N.6 • 17:30
Flat-top Frequency Comb Generation with Silicon Microring Modulator and Filter, Xinru Wu1, Hon Ki Tsang1,2; 1The Chinese Univ. of Hong Kong, Hong Kong. An optical frequency comb with five lines having <0.86 dB intensity deviation and 10 GHz spacing is experimentally obtained using a silicon microring modulator and a microring resonator filter with only 3.6 Vpp driving voltage.

SM4O.5 • 17:15
Self-Amplified Filter Fabricated in a SOI Photonics Foundry, Paulo F. Jarschel de Siqueira1, Mário C. Souza1, Rafael B. Merlo1, Newton C. Frateschi1; 1Gleb Wataghin Physics Inst., Univ. of Campinas, Brazil. We demonstrate a self-amplified filter based on Silicon Ring Resonators with Er-doped cladding. It is capable of filtering and routing resonant wavelengths, with simultaneous signal amplification. An equivalent internal gain of 4.7 dB/mm was observed.
AM4A.6 • 17:45
Toward fully monolithic 1550-nm lasers on silicon by direct hetero-epitaxy growth on patterned substrates, Ludovico Megalini1, Brian Cabinian1, Hongwei Zhao1, Douglas Oakley3, John Bowers1, Jonathan Klamkin1, 1UCSB, USA. We demonstrate diode rectifying behavior of 1550-nm laser structures on exact-oriented (001) Si substrates after coalescence of densely-packed, smooth, high crystalline quality, and millimeter-long InP nanowires grown by MOCVD using aspect-ratio-trapping and selective-area-growth technique.

SM4C.7 • 17:45
Enhancing the Response Time of Electrowetting Lenses Using Voltage Shaping, Omkar D. Supekar1, Mo Zohrabi2, Joseph Brown1, Juliet T. Gopinath3, Victor M. Bright5; 1Dept. of Mechanical Engineering, Univ. of Colorado Boulder, USA; 2Dept. of Electrical, Computer, and Energy Engineering, Univ. of Colorado Boulder, USA. We have demonstrated tunability of the response time of electrowetting lenses from underdamped to overdamped through input voltage shaping. This strategy shows great promise to further optimize the response time of electrowetting lenses.

SM4D.7 • 17:45
Chip-Based Tunable Direct Comb Spectroscopy, Mengjie Yu1,2, Yoshitomo Okawachi1, Austin G. Griffith2, Michal Lipson1, Alexander L. Gaeta1; 1Columbia Univ., USA; 2Cornell Univ., USA. We demonstrate mode-hop-free tuning of a modelocked frequency comb over 60 GHz in a silicon microresonator. A gas-phase spectroscopy of acetylene is performed with a high-spectral-resolution (< 80 MHz) over a bandwidth of 40 THz.
Joint

JM4E • Symposium on Sources of Nonclassical Light and their Scalability II—Continued

FM4F • Nonlinear Optics in Propagating Geometries II—Continued

FM4G • Controlling Emission, Absorption and Transfer of Energy with Metamaterials—Continued

FM4H • Chip-scale Plasmonic Devices—Continued

FM4F.8 • 17:45
Alkali Vapors in Mid-Infrared – Towards Gain, Yoel Sebbag1, Uriel Levy1; 1Dept. of Applied Physics, The Hebrew Univ. of Jerusalem, Israel. We measured direct influence of a mid-infrared laser at 5.23µm on the S\text{2+}→6P\text{1/2} transition of rubidium (85Rb) pumped by two photons at 780nm and 776nm. The hyperfine structure of the 6P\text{1/2} level is clearly identified.

FM4H.7 • 17:45
Ultra-compact and High-performance Silicon Photonic TE-pass Polarizer Based on a Si Stripe Waveguide Coated with Multilayer Hyperbolic Metamaterial Cladding, Lei Chen1, Yumin Liu1, Zhongyuan Yu1, Li Yu1; 1Beijing Univ of Posts & Telecom, China. A standard silicon stripe waveguide coated with 220nm-thick multilayer hyperbolic metamaterial cladding makes itself become an ultra-compact TE-pass polarizer, which is characterized by ultrahigh extinction ratio of 41dB and low insertion loss of 1.35dB.

17:30–18:30 Diversity & Inclusion in Optics and Photonics Reception, Market Room/Hilton

18:30–20:00 The National Academies Town Hall Meeting on the Future of Materials Research, Salon V & VI/Marriott

19:00–20:00 OSA Technical Group Poster Session, 230B

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
### SM4I • Ultrafast Pulse Combination and Manipulation—Continued

**SM4I.7 • 17:45**

**Frequency Domain Invisibility Enables Phase-Preserving Broadband Cloaking**, Luis Romero Cortes
d, Seshgliani Mohamed
d, Reza Maram
d, Jose. Azana
d; INRS-EMT, Canada. We propose and experimentally demonstrate the first invisibility cloaking principle capable of preserving both the amplitude and the phase of a broadband illumination wave. A multiple frequency resonance is successfully cloaked over a 500-GHz bandwidth.

### SM4J • THz QCLs and Imaging—Continued

**SM4J.7 • 17:45**

**GaN Terahertz Photodetectors for the Reststrahlen Gap of Intersubband Optoelectronics**, Habibeh Durmaz
d, Denis Nothn
d, Gordie Brummer
d, Theodore D. Moustakas
d, Roberto Paella
d; Boston Univ., USA; "Recep Tayyip Erdogan Univ., Turkey. Terahertz intersubband photodetectors are developed based on GaN/AlGaN quantum wells grown on a semi-polar GaN substrate, covering the frequency range that is fundamentally inaccessible to existing III-V semiconductor devices due to Reststrahlen absorption.

### SM4K • Resonant Optics—Continued

**SM4K.6 • 17:45**

**Engineered Pores of Hydrophilic Nanoporous Materials Using Wet-drying and Freeze-drying**, Dengxin Ji
d, Haomin Song
d, Borui Chen
d, Feng Yang
d, Alec R. Cherry
d, Feng Zhang
d, Nai Zhang
d, Xie Zeng
d, John D. Atkinson
d, Chi Zhou
d, Alexander N. Cartwright
d; "Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, USA; "Dept. of Industrial and Systems Engineering, The State Univ. of New York at Buffalo, USA; "Dept. of Civil, Structural and Environmental Engineering, The State Univ. of New York at Buffalo, USA. We manipulate the pore size of nanoporous polymeric photonic crystals using phase change between water and ice, demonstrating accurate post-manipulation of reflection resonances and thereby providing an approach to address grand challenges in nanomanufacturing and materials engineering.

### SM4L • Mode Locked Fiber Lasers II—Continued

**SM4L.8 • 17:45**

**Dispersion compensation of a compact NPE mode-locked Yb-doped all fiber laser oscillator by using tapered-fiber**, Peilong Yang
d, Zhongqi Hu
d, Hao Teng
d, Shaobo Fang
d, Zhiguo Lv
d, Zhiyi Wei
d; "School of Physics and Optoelectronic Engineering, Xidian Univ., China; "X’ian Inst. of Optics and Precision Mechanics, Chinese Academy of Sciences, China; "Inst. of Physics, Chinese Academy of Sciences, China. A mode-locked Yb-doped all fiber oscillator using tapered-fiber dispersion compensation was demonstrated. The spectrum was broadened to 20nm and compressed to 112 fs using diameter of 1 mm with length of 10 cm tapered fiber.

### Schedule

**17:30–18:30**  **Diversity & Inclusion in Optics and Photonics Reception, Market Room/Hilton**

**18:30–20:00**  **The National Academies Town Hall Meeting on the Future of Materials Research, Salon V & VI/Marriott**

**19:00–20:00**  **OSA Technical Group Poster Session, 230B**
| SM4M • Optical Parametric Oscillators—Continued |
| SM4N • Prevoskite and Photonic Crystal Lasers—Continued |
| SM4O • Heterogeneously Integrated Si Photonics—Continued |

SM4M.7 • 17:45 Electro-Optic Controlled, Highly Spectrum Narrowed Multiline Intracavity Optical Parametric Oscillators, Hung-Pin Chung1, Wei-Kun Chang1, Yen-You Chou1, Reinhard Geiss2, Shang-Da Yang3, Thomas Pertsch4, Yen-Hung Chen1; 1National Central Univ., Taiwan, 2Brain Research Center, National Tsinghua Univ., Taiwan, 3Inst. of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany, 4Inst. of Photonics Technologies, Dept. of Electrical Engineering, National Tsinghua Univ., Taiwan. An electro-optically spectrum narrowed, multiline optical parametric oscillator was built based on a novel aperiodically poled lithium niobate device. The power spectral density of the EO controlled system is enhanced by a factor of ~7.8.

SM4N.6 • 17:45 Photonic Crystal Surface-Emitting Lasers on Bulk Silicon Substrate, Shih-Chia Liu1, Deyin Zhao1, Hongjun Yang1, Carl Reuterskiöld-Hedlund1, Mattias Hammar1, Zhenqiang Ma3, Weidong Zhou1; 1Univ. of Texas at Arlington, USA; 2KTH-Royal Inst. of Technology, Sweden, 3Univ. of Wisconsin, USA. We report here heterogeneous photonic crystal (PC) bandedge surface emitting lasers on bulk silicon (Si) substrates. Thermal resistance was investigated to evaluate the heat dissipation and lasing characteristics afforded by this integration and potential for high efficiency application.

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17:30–18:30  Diversity & Inclusion in Optics and Photonics Reception, **Market Room/Hilton**

18:30–20:00  The National Academies Town Hall Meeting on the Future of Materials Research, **Salon V & VI/Marriott**

19:00–20:00  OSA Technical Group Poster Session, **230B**
ATu1A.1 • 08:00
Digital DNA Detection based on Compact Optofluidic Laser with Ultra-Low Sample Consumption, Wonsuk Lee1, Guishu Chen2, Xudong Fan3, Dongki Yoon1; 1KAIST, USA; 2Univ. of Michigan, USA. Optofluidic laser that has a single layer of DNA molecules on the ring resonator surface is proposed. A target DNA can be detected in truly digital manner only with a single pulse of laser excitation.

ATu1A.2 • 08:15
Integrated Sensor based on a-Si:H Photodiodes and Diffused Glass Waveguides for Biomedical Applications, Giampiero de Cesare1, Rita Asquini1, Alessio Buzzin1, Antonio d’Alessandro1, Augusto Nascetti1, Domenico Caputo1; 1DIET - Univ. of Rome “La Sapienza”, Italy. We present the design and fabrication of an evanescent waveguide sensor based on a-Si:H photodiodes for biomedical applications. The complete device presents a noise level lower than 2fA and a sensitivity of 300mA/W at 532nm.

ATu1A.3 • 08:30
3D Refractive Index Mapping of Single Cells, Patricia Y. Liu1,2, Chao-mao Hsieh1, L. K. Chin1, Yamin Wang1, Wee Ser1, Tarik Bourouina1, Jingbo Zhang1; 1Nanyang Technological Univ., Singapore; 2Université Paris-Est, France. We present the study of quantitative 3D refractive index mapping of single cells and intracellular lipid droplets with an Optical Diffractive Tomography system. Intracellular organelles, such as nucleus, mitochondria, lipid droplets are studied.

ATu1B.1 • 08:00
Unexpectedly Stalled: Two-Photon Microscopy Reveals White Blood Cell Adhesion in Capillaries Causes Reduced Brain Blood Flow in Alzheimer’s Disease, Chris B. Schaffer1; Biomedical Engineering, Cornell Univ., USA. About 2% of brain capillaries were occluded by leukocytes adhered to the vessel wall in mouse models of Alzheimer’s. When this adhesion was blocked, brain blood flow immediately increased by ~30% and spatial memory performance improved.

ATu1B.2 • 08:30
Transcortical three-photon fluorescence imaging of Drosophila brain at subcellular resolution with adaptive optics, Xiaodong Tao1, Hui-Hao Lin1, Tuwin Lam2, Ramiro Rodrigo3, Jing W. Wang1, Joel Kubby2; 1Univ. of California, San Diego, USA; 2Univ. of California, Santa Cruz, USA. We demonstrate non-invasive structural and functional imaging of neurons labeled with genetically encoded red fluorescent proteins in the living Drosophila brain at cellular and subcellular resolution using three-photon microscopy and wavefront correction.

ATu1C.1 • 08:00
Thin Disk Lasers for Research and Industrial Applications, Adolf Giesen; German Aerospace Center, Germany. The status of thin disk laser development will be discussed in detail as well as some important applications in research and industry.

ATu1D.1 • 08:30
Tutorial Chip-Based Optical Frequency Combs, Alexander L. Gaeta1; Columbia Univ., USA. Microresonator-based optical frequency combs could enable the realization of time and frequency metrology instruments in highly compact and robust platforms. I will provide an overview of the underlying principles and applications of such combs.
FTuE.1 • 08:00
Complete Coherent Control of Silicon-Vacancies in Diamond Nanopillars Containing Single Defect Centers, Jingyuan Linda Zhang1, Konstantinos Lagoudakis2, Yan-kai Tseng1, Constantinos Dory3, Marina Radulaski1, Yousif Kela1, Kevin Fischer2, Zhi-Xun Shen1, Nicholas Melosh1, Steven Chu1
We fabricate diamond nanopillar arrays containing single SiV centers with high yield and spectral stability, and perform ultrafast, all-optical complete coherent control over the state of individual SiV centers, as demonstrated by Rabi oscillation, Ramsey interference, and SU(2) control.

FTuE.2 • 08:15
Enhanced Quantum Sensing with Nitrogen-Vacancy Centers in Nanodiamonds Using All-Optical Charge Control, David Hopper1, Richard Grote1, Lee Bassett1; Nicholas Melosh1, Steven Chu1, Alexei Tyryshkin1, Sorawis Richard Grote1, Lee Bassett1; Nicholas Melosh1, Steven Chu1, Alexei Tyryshkin1, Sorawis Richard Grote.

FTuE.3 • 08:30
The neutral silicon split-vacancy defect in diamond, a promising color center for quantum communication, Brendon C. Rose1, Ding Huang1, Alexei Tyryshkin1, Sorawis Richard Grote1, Richard Grote1, Lee Bassett1; Nicholas Melosh1, Steven Chu1, Alexei Tyryshkin1, Sorawis Richard Grote1, Lee Bassett1; Nicholas Melosh1, Steven Chu1, Alexei Tyryshkin1, Sorawis Richard Grote1, Lee Bassett1; Nicholas Melosh1, Steven Chu1, Alexei Tyryshkin1, Sorawis Richard Grote1, Lee Bassett1.

FTuF.1 • 08:00
Frequency-Domain Boson Sampling, Chaitali Joshi1,2, Alessandro Farsi2, Alexander Gaeta1, Cornell Univ., USA; 3Applied Physics and Applied Mathematics, Columbia Univ., USA. We present a scheme to efficiently perform boson sampling using frequency modes which yields exponential reduction in losses and significantly reduced experimental complexity compared to conventional spatial-mode implementations.

FTuF.2 • 08:15
Gaussian Boson Sampling, Craig S. Hamilton1, Regina Kruse1, Linda Sanzoni1, Sonja Barkhofen1, Christine Silberhorn1, Igor Jex2,1Univ. of Paderborn, Germany; 2FNSPE, Inst. of Plasmaphysics, Slovak Academy of Sciences, Bratislava, Slovakia; 3UFMG, Disk, Belo Horizonte, Brazil. We demonstrate a new phenomenon occurs in the propagation of light through random media. Due to different mechanisms of interaction, recurrent scattering of on-shell propagating fields is impeded by strongly localized evanescent couplings.

FTuF.3 • 08:30
Multiparticle distinguishability: three photons are different in four ways, Adrian J. Menon1, Alex Jones1, Malte Trichter1, Benjamin Metcalfe1, Stefanie Barz2, Steven Kolthammer1, Ian A. Walmsley1; 1Univ. of Oxford, UK; 2Imperial College, UK; 3Univ. of Central Florida, CREOL, USA; 4CREOL, Univ. of Central Florida, USA. We demonstrate against current knowledge, that Anderson localization can occur for wavepackets outside the spectral extent of the disordered potential, mediated by second order transitions.

FTuG.1 • 08:00
Anderson Localization of Light in Spectrally-Tailored Disordered Potentials, Alex Dikopoltsev1, Hanan Herzig Sheinfux1, Mordechai Segev1; Technion, Israel. We demonstrate, against current knowledge, that Anderson localization can occur for wavepackets outside the spectral extent of the disordered potential, mediated by second order transitions.

FTuG.2 • 08:15
Phase transitions in the diffusion of light, Roxana Rezvani Naragh1, Aristide Dogariu2; 1Univ. of Central Florida, CREOL, USA; 2Physics, Univ. of Central Florida, USA; 3CREOL, Univ. of Central Florida, USA. We demonstrate a new phenomenon occurs in the propagation of light through random media. Due to different mechanisms of interaction, recurrent scattering of on-shell propagating fields is impeded by strongly localized evanescent couplings.

FTuG.3 • 08:30
Wavefront Shaping in Complex Media: From the Compensation to the Harnessing of Disorder, Sebastien Popoff1,2; 1Langevin Inst., ESPCI, France; 2CNRS, France. In the past ten years, many techniques were developed to control light propagation in complex media using spatial light modulators. The applications evolved from compensating for disorder to taking advantage of the randomness.

FTuH.1 • 08:00
Plasmon Drag in Nanostructured Metal and Effects of Spin Angular Momentum of Plasmons, Maxim Durach1, Natalie Noginova1, Georgia Southern Univ., USA; 2Norfolk State Univ., USA. Here we review recent advances in plasmon drag studies, and describe the plasmonovacuum effects associated with absorption of spin angular momentum (SAM) of plasmons.
08:00–10:00
STu1I • Ultrafast Applications
Presider: Fumihiko Kannari; Keio Univ., Japan

STu1I.1 • 08:00
Invited
Extreme Ultraviolet Vector Beams Driven by Multicycle Infrared Laser Pulses, Carlos Hernandez-Garcia1, Alex Turpin 2, Julio San Roman1, Antonio Picon3, Rokas Drevinskas3, Aura Cerkauskaite1; Peter Kazansky4, Charles Durfee4, Higgs J. Soia1; 1Universidad de Salamanca, Spain; 2Universitat Autonoma de Barcelona, Spain; 3Univ. of Southampton, UK; 4Colorado School of Mines, USA. We experimentally produce extreme-ultraviolet vector beams—from radially to azimuthally polarized—through high-order harmonic generation. Our simulations predict the generation of unique spatio-temporal structures in the form of attosecond vector beams.

STu1J • THz Materials Science
Presider: Rohit Prasankumar; Los Alamos National Lab, USA

STu1J.1 • 08:00
Off-resonant magnetization dynamics in Co, Fe and Ni thin films driven by an intense single-cycle THz field, Mostafa Shalaby1, C. Vicario1, Flavio Giorgianni1, Andreas Doppke1, Karel Carva2, Peter Oppeneer1, Ulrich Nowak2, Christoph P. Hauri1,5; 1Paul scherrer institut, Switzerland; 2Dept. of Physics, Univ. of Konstanz, Germany; 3Charles Univ., Czech Republic; 4Uppsala Univ., Sweden; 5Ecole Polytechnique Federale de Lausanne, Switzerland. We present time-resolved measurements exploring the THz-induced magnetization dynamics as function of the driving field strength in the ferromagnetic thin film samples Co, Fe and Ni. The experimental results are excellently reproduced by ab-initio calculations.

STu1K • Mid-IR Fiber Sensors
Presider: Khanh Kieu; Univ. of Arizona, USA

STu1K.1 • 08:00
Invited
Ultrafast Fiber Lasers in the Mid-IR Water Vapor Window, Darren D. Hudson1, Sergei Antipov1, Stuart D. Jackson1, Alexander Fuerbach1; 1Macquarie Univ., Australia. We demonstrate record performance in a mid-IR ultrafast fiber laser by using holmium instead of erbium as the active gain medium. The 2.9 μm laser emits 180 fs pulses with 37 kW peak power.

STu1I.2 • 08:30
Time-resolved Femtosecond Photoemission Spectroscopy using a 60-MHz Enhancement Cavity XUV Source, Arthur K. Mills1, Sergey Chabanovich1, Fabio Boschini1, MengKai Na1, Michael Schneider1, Pinder Dosanjh1, Doug Wong1, Giorgio Levy1, Andrea Damascelli1, David J. Jones1; 1Dept. of Physics and Stewart Blusson Quantum Matter Inst., Univ. of British Columbia, Canada. We perform time-resolved photoemission on the topological insulator Bi2Se3 at 60 MHz repetition rate, with a 25 eV probe and a 1.2 eV pump, with demonstrated time and energy resolution of <400 fs and <25 meV, respectively.

STu1J.2 • 08:15
Invited
Dynamics, Control, and Metastability in Correlated Oxides, Richard D. Averitt1; 1Univ. of California San Diego, USA. I will present results of photoinduced insulator-to-metal transition dynamics in La0.7Ca0.3MnO3 films that have been strain-engineered to quench the thermal IMT. Photoexcitation initiates a nonthermal transition to a “hidden” metallic phase that is metastable yet robust.

STu1K.2 • 08:30
Raman Generation in 2.9 – 3.5 μm Spectral Range in Revolver Hollow-Core Silica Fiber Filled by H2/D2 Mixture, Alexey Gladyshev1, Alexey P. Kosolapov1, Maxim M. Khudyakov1, Yury P. Yatsenko1, Andrey K. Senatorov1, Anton N. Kolyadin1, Alexander A. Krylov1, Victor G. Plotnichenko1, Mikhail E. Likhachev1, Igor A. Butykov1, Evgeny M. Dianov1; 1Fiber Optics Research Center of the Russian Academy of Sciences, Russia; 2Moscow Inst. of Physics and Technology (State Univ.), Russia. Mid-infrared Raman generation is demonstrated in gas-filled hollow-core silica fiber pumped by high-power 1.56 μm Er-doped fiber laser. Quantum conversion efficiency up to 8 % and peak output power up to 0.9 kW are achieved.
CLEO: Science & Innovations

Marriott Salon III

STu1M • Optical Interconnect Systems
Presider: Michael Vasilyev; Univ. of Texas at Arlington, USA

Silicon Photonic Systems-on-Chip, Michael Hochberg1; Elenion Technologies LLC, USA. We continue to see silicon photonics chip complexity doubling every 12-18 months, providing an excellent platform for developing photonic systems-on-chip (SoC). The complexity scaling is enabling more functionality for high-bandwidth applications and enabling new application domains, while bringing the overall system costs down.

STu1M.2 • 08:30
A 3x3 Switch Exploiting an Optical Vortex Beam Emitter based on a Silicon Three-Grating Microring, Mirco Scaffardi1, Muhammad N. Malik2, Emma Lazzeri1, Charalampos Kitsas1, Laura Meriggi2, Ning Zhang1, Marc Sorel1, Antonella Bogoni1,2; CNIT, Italy; 2Scuola Superiore Sant’Anna, Italy. A silicon three-grating microring is proposed and characterized as a device enabling 3x3 optical switching based on orbital angular momentum and wavelength. Bit error rate measurements show penalties <1dB for OOK traffic up to 20Gbaud.

Marriott Salon IV

STu1N • Photodetectors
Presider: Shiqiang Li; Univ. of Melbourne, Australia

Flexible waveguide-integrated photodetectors, Junyong Li1, Spencer Novak2, Kathleen Richardson1, Juejun Hu1; Materials Science and Engineering, MIT, USA; 2CREOL, Univ. of Central Florida, USA. We demonstrated a flexible waveguide-integrated metal-semiconductor-metal photodetector with 0.5 A/W responsivity near 1550 nm wavelength. The device can withstand a small bending radius of 0.7 mm without optical performance degradation.

STu1N.3 • 08:30
Subwavelength Angle Sensing Photodetector, Soongyu Yi1, Ming Zhou1, Zongfu Yu1, Pengyu Fan2, Dianmin Lin2, Shanhui Fan1, Mark Brongersma2; 1Univ. of Wisconsin - Madison, USA; 2Stanford Univ., USA. By mimicking internally coupled ears directional hearing capability of small animals, we demonstrate subwavelength angle sensing using coupled optical resonators in extremely small distance.

Marriott Salon V & VI

STu1O • Petawatt Laser Technology
Presider: Jake Bromage; Univ. of Rochester, USA

Invited
High Energy, High Repetition Rate Nd:Glass Laser Technology, Erhard W. Gaul1; 1Univ. of Texas at Austin, USA. Nd:Glass lasers enable high energy, ultra-high intensity pulses with 10PW peak power. Lasers technology with active cooling provides orders of magnitudes improved over previous shots rates will be discussed.

Temporal dual-pulse pumped Ti:Sapphire Amplifier, Zhebiao Gan1, Lianghong Yu1, Xiaolong Yuan1, Lu Xu1, Zhengheng Liu1, Shuai Li1, Yi Xu1, Jun Lu1, Haihe Lu1, Dinguojun Yin1, Xuewu Leng1, Ruxin Li1, Zhizhan Xu1; 1Shanghai Inst of Optics & Fine Mechanics, China. We report that 202.8 J output energy from a 150-mm-diameter Ti:sapphire amplifier was achieved with 320 J pump energy. A temporal dual-pulse pumped scheme was used to suppress the transverse parasitic lasing.
**ATu1A • Biosensing Technologies—Continued**

**ATu1A.4 • 08:45**
Thermal Expansion Feedback for Wavefront Shaping, Omer Tsang, Eyal Niv, Rafael Piestrup, University of Colorado at Boulder, USA. We present a technique for focusing inside scattering media that combines optical-coherence-tomography (OCT) and wave-front-shaping (WFS). We use OCT as a non-invasive feedback for WFS optimization of a separate penetrating laser, based on light-induced thermal-expansions.

**ATu1A.5 • 09:00**
Continuous characterization of viscoelasticity-modulated biopolymer hydrogels, Jose Guzman-Sepulveda, Jinan Deng, Jiuyu Fang, Aristide Dogariu, Department of Materials Science and Engineering, University of Central Florida, USA; CREOL, The College of Optics and Photonics, University of Central Florida, USA. We present a spatiotemporal coherence-gated dynamic light scattering technique that permits continuously assess non-equilibrium, long-term dynamical processes. We demonstrate experimentally by characterizing the evolution of mechanical properties in viscoelasticity-modulated biopolymer hydrogels.

**ATu1A.6 • 09:15**
Gallium Nitride Based Tactile Sensors, Jingyang Su, Pei-Cheng Ku, Department of Electrical Engineering, University of Michigan, USA. An optical tactile sensor is proposed using GaN LEDs and Si images. Performance comparable to human fingertips including high spatial resolution, fast response and multidirectional discrimination was shown.

**ATu1A.7 • 09:30**
Diagnostics of Femoral Head Status in Humans using High-Resolution Laser Spectroscopy - In Vitro Studies, Katarina Svanberg, Huying Lan, Wanaha Li, Hao Zhang, Peng Chen, Delong Chen, Wei He, Sune R. Svanberg; Lund Laser Centre, Sweden; Center for Optical and Electromagnetic Research, South China Normal University, China; Orthopedics Department, First Affiliated Hospital, China; First Clinical Medical School of Chinese Medicine, China. Bone decay processes, due to lacking blood supply, was studied by diode laser absorption spectroscopy detecting gas-filled pores in hip replacement operation specimen from 19 orthopaedical patients. Minimally invasive diagnostics seems feasible.

**ATu1B • A&T Topical Review on Neurophotonics I—Continued**

**ATu1B.3 • 09:00**
In Vivo Deep Tissue Visualization by Needle-Dependent Confocal Endomicroscopy, Jinhyo Ahn, Eunyul Kong, Ribadee Choe, Eunjoo Song, Yoonha Hwang, Ilwon Park, Pilhan Kim, Korea Advanced Institute of Science and Technology, Korea (the Republic of). In vivo longitudinal and repetitive cellular-level visualization of microvasculature and fluorescent cells in deep tissue such as skin dermis, solid tumor and brain of single mouse in minimally invasive manner was demonstrated by using a needle-type side-view confocal endomicroscopy.

**ATu1B.4 • 09:15**
End-Fire Silicon Optical Pulsed Arrays for Infrared Neural Stimulation Applications, Michael Kossey, Shannon Ahl, Charbel Raki, Amy Foster, Johns Hopkins University, USA. We propose infrared neural stimulation as an application for end-fire integrated optical beam steering devices. We show some initial results and discuss its implications for the future development of the technique.

**ATu1B.5 • 09:30**
Multifunctional Properties of High-speed Highly Uniform Femtosecond Laser Structuring—Continued

**ATu1B.6 • 09:30**
Wide-field Fast-scanning Photacoustic Microscopy of Brain Functions in Action, Junjie Yao, Jun Zou, Lihong Wang, John C. Wyant, Andrew Burns, Christian Heger, Stephan Buecheler, Lukas Crumb, Kyoungmin Ahn, Eunji Kong, Kibaek Ahn, Sensitronics Ltd, Switzerland; University of Bern, Switzerland; Korea Advanced Institute of Science and Technology, South Korea; Seoul National University, South Korea. We introduce a unique photoacoustic brain imaging system for non-invasive, high-speed, wide-field, high-spatial resolution imaging of deep brain structures. We present results from normal and pathological human brain samples using this system.

**ATu1B.7 • 09:30**
Multifunctional Properties of High-speed Highly Uniform Femtosecond Laser Patterning on Stainless Steel, Babak Ghadiri, Reza Norouzi, Mohammadreza Atabaki, Yonsei University, South Korea. We present a new mode-locked femtosecond laser system capable of delivering high-energy pulses with high repetition rate and high average power. The system is capable of patterning stainless steel with high spatial resolution and high depth of penetration. We present results from patterning stainless steel with various laser parameters such as pulse energy, repetition rate, and scan speed.

**ATu1B.8 • 09:30**
On-chip Comb Generation I—Continued

**ATu1C • Lasers for Additive Manufacturing and Surface Structuring—Continued**

**ATu1C.2 • 08:45**
Energy coupling efficiency and melt pool dynamics associated with the laser melting of metal powder layers, Maryababu J. Matthews, Johannes Trapp, Gabe Guss, Alexander Rubenchik, Lawrence Livermore National Lab, USA. Micro-calorimetry and high speed imaging are used to characterize energy coupling mechanisms in laser powder bed fusion additive manufacturing. Material developments to stabilize formation onset and melt pool dynamics are investigated as a function of laser parameters.

**ATu1C.3 • 09:00**
Laser beam ellipticity and microstructural control in metal additive manufacturing, Sheldon S. Wu, Tien T. Hoelging, John D. Roelting, Alexander Rubenchik, Lawrence Livermore National Lab, USA. We demonstrate an alternative approach to controlling the elliptical shape of the laser beam focused on a metal powder bed for additive manufacturing processes. This approach involves using a separate laser beam with an elliptical profile to modify the shape of the main laser beam before it is focused onto the powder bed. We present results from experiments performed on a variety of metal powder materials and discuss the implications for future laser additive manufacturing processes.

**ATu1C.4 • 09:15**
High throughput laser-scribing processes for industrial production of flexible CIGS thin-film solar modules, Andreas Burn, Christian Heger, Stephan Buecheler, Lukas Crumb, Kyoungmin Ahn, Eunji Kong, Kibaek Ahn, Sensitronics Ltd, Switzerland; University of Bern, Switzerland; Korea Advanced Institute of Science and Technology, South Korea; Seoul National University, South Korea. We present results from a high-throughput laser-scribing process for industrial production of flexible CIGS thin-film solar modules. The process involves using a laser to scribe patterns into the CIGS thin-film, followed by the deposition of conductive ink in the patterned areas to form electrical contacts. We present results from experiments performed on a variety of CIGS thin-film materials and discuss the implications for future industrial production of flexible CIGS thin-film solar modules.

**FTu1D • On-chip Comb Generation I—Continued**

**FTu1D.2 • 09:00**
Dynamics of soliton crystals in optical microresonators, Maxim Karpon, Hainrun Guo, Martin Pfeiffer, Erwan Lutz, Michael Geissemann, Miles Anderson, Tobias Koppenberg, Ecole Polytechnique Federale de Lausanne, Switzerland. We experimentally demonstrate and study the formation of and the interaction between soliton crystals in optical microresonators.

**FTu1D.3 • 09:15**
Low Threshold Frequency Comb Generation in AlGaAs-on-Insulator Microresonator in the Normal Dispersion Regime, Ayman N. Kamel, Minhao Fu, Kresten Yvind, Danmarks Tekniske Universitet, Denmark. We present milli-Watt threshold frequency comb generation in AlGaAs-on-insulator integrated microresonators exhibiting normal GVD by employing the effects of mode interaction.
### CLEO: QELS-Fundamental Science

<table>
<thead>
<tr>
<th>Session Code</th>
<th>Title</th>
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<tr>
<td>FTu1E.1 • 08:45</td>
<td>Photonics Problems in Diamond</td>
<td>Jörg Wrachtrup¹,²; Mete Atatüre², Marko Lon Burek¹, Mian Zhang ¹, Jose Pacheco ³, John Camille Stavrakas ², Alp Sipahigil¹, Michael Eric Bersin¹, Tim Schröder¹, Dirk Englund¹;</td>
<td>Sara L. Mordasini¹, Noël Wan¹, Michael Walsh¹, Eric Bersin¹, Tim Schröder¹, Dirk Englund¹; MIT, USA; Niels Bohr Inst., Denmark. We report a new fabrication process of planar photonic crystal nanocavities from bulk diamond. Experimental devices have quality factors Q=1x10⁷ with resonances matched to the negatively charged nitrogen vacancy zero phonon line, allowing for an enhanced spin-photon interface.</td>
</tr>
<tr>
<td>FTu1E.5 • 09:00</td>
<td>Efficient Dielectric Reflectors for Solid-state Emitters in Bulk Diamond</td>
<td>Ilja Gerhardt¹,², Mohammad Rezai², Matthias Gobbert³, Camille Stavratsis¹, Alp Sipahigil¹, Michael Burek¹, Jian Wan¹, Jose Pacheco ³, John Camille Stavrakas ², Alp Sipahigil¹, Michael Eric Bersin¹, Tim Schröder¹, Dirk Englund¹;</td>
<td>Sara L. Mordasini¹, Noël Wan¹, Michael Walsh¹, Eric Bersin¹, Tim Schröder¹, Dirk Englund¹; MIT, USA; Niels Bohr Inst., Denmark. We report on a dielectric reflector fabricated directly on the surface of bulk diamond. We measure saturated count rates of up to 2.9 million cps from a single nitrogen-vacancy center in diamond.</td>
</tr>
<tr>
<td>FTu1E.6 • 09:15</td>
<td>Protecting The Spin Coherence of Silicon Vacancy Color Centers from Thermal Noise</td>
<td>Donggyu Kim¹, Michael Walsh¹, Tim Schröder¹, Dirk Englund¹;</td>
<td>Using Diamond MEMS, we demonstrate the protection of the zero phonon line, allowing for an enhanced spin-photon interface.</td>
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<tr>
<td>FTu1F.4 • 09:00</td>
<td>Physical meaning of the radial index of Laguerre-Gauss beams</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<tr>
<td>FTu1F.5 • 09:15</td>
<td>Learning nitrogen-vacancy electron spin dynamics on a silicon quantum photonic simulator</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<td>FTu1G.5 • 09:15</td>
<td>Periodic Behavior in Aperiodic Multilayers</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<td>FTu1G.6 • 09:30</td>
<td>Smith-Purcell radiation in the presence of short-range disorder</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<td>FTu1H.3 • 08:45</td>
<td>Brewer Plasmonics – The Second Plasmonic Degree of Freedom</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<td>FTu1H.4 • 09:00</td>
<td>Beyond Toroidal Multipole</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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<tr>
<td>FTu1H.5 • 09:15</td>
<td>Quantum Optics Picture of Surface Enhanced Raman Scattering in Lossy Plasmonic Systems</td>
<td>Jianwei Wang¹, Stefano Paesani¹, Raffaele Santagati¹, Sebastien Knaur¹, Antonio A. Gentile¹, Nathan Wiebe¹, Maurizio Schiavon², Christian Buchleitner³, John Rarity¹, Jeremy L. O'Brien¹, Mark Thompson¹, Quantum Engineering Technology Labs, H. H. Wills Physics Lab, Univ. of Bristol, UK; Quantum Architectures and Computation Group, Microsoft Research, USA; Dept. of Applied Physics, Eindhoven Univ. of Technology, Netherlands. We present the experimental demonstration of quantum Hamiltonian learning. Using an integrated silicon-photonic quantum simulator with the classical machine learning technique, we successfully learn the Hamiltonian dynamics of a diamond nitrogen-vacancy center's electron ground-state spin.</td>
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</table>
STu1J • THz Materials Science—Continued

Terahertz Surface Plasmons in Grating-Coupled Graphene, \textsuperscript{1}Khawcham Tantianwarichapan, \textsuperscript{1}Xuanue Wang, \textsuperscript{1}Habibe Durmaz, \textsuperscript{2}Yuyu Li, \textsuperscript{2}Anna Swan, \textsuperscript{3}Roberto Paella, \textsuperscript{1}Bo’ston Univ., USA. Pronounced plasmonic absorption features at terahertz frequencies are measured in large-area graphene sheets coupled to periodic arrays of metallic nanoparticles, and limitations on their tunability caused by carrier density inhomogeneities are investigated.

Invited: Ultra-High Speed Microscopy of Complex (Amplitude and Phase) Samples Using a Single Camera Snapshot, \textsuperscript{1}Pavel Sidorenko, \textsuperscript{2}Oren Cohen, \textsuperscript{2}Oren Lahav, \textsuperscript{3}Technion Israel Inst. of Technology, Israel. We propose and demonstrate numerically a simple method for ultra-high speed microscopy of complex (amplitude and phase) samples. Our method exploits redundancy in (single-shot) photogrammetry for reconstruction of multiple frames from a single camera snapshot.

STu1K • Mid-IR Fiber Sensors—Continued

Mid-IR Spectrum Tailoring in Erbium-Doped Fluoride Fiber Amplifiers, Vincent Fortin, \textsuperscript{1}Simon Duval, \textsuperscript{1}Jean-Christophe Gaubier, \textsuperscript{1}Louis-Rafael Robichaud, \textsuperscript{1}Pascal Paradis, \textsuperscript{1}Michel Olivier, \textsuperscript{2}Michel Fichet, \textsuperscript{1}Martin Bernier, \textsuperscript{1}Réal Vallée, \textsuperscript{1}Université Laval, Canada, \textsuperscript{2}Cégep Garneau, Canada. We present an innovative laser system based on an erbium doped fluoride fiber amplifier for generating either high-power mid-IR supercontinuum or continuously tunable femtosecond pulses in the 3-4 \textmu m spectral band.

1 GS/s time-stretch imaging at 532 nm through fiber optics, \textsuperscript{1}Chiang Kong, \textsuperscript{1}Xiaoming Wei, \textsuperscript{1}Kevin Tsai, \textsuperscript{1}Kenneth Kin-Yip Wong, \textsuperscript{1}The Univ. of Hong Kong, Hong Kong. We demonstrate a 6-MHz green-light time-stretch imaging at a low data-stream of 1 GS/s. The highly-chirped pulse at 532 nm is generated through double-pass high-power frequency doubling, which provides a dispersion of ~7 ns/mm.

Short wavelength mode-locked thulium-doped fiber laser based on nonlinear polarization rotation, \textsuperscript{1}Can Li, \textsuperscript{1}Xiaoming Wei, \textsuperscript{1}Sai Tan, \textsuperscript{1}Nan Chen, \textsuperscript{1}Jiqiang Kang, \textsuperscript{1}Kenneth Kin-Yip Wong, \textsuperscript{1}The Univ. of Hong Kong, China. We demonstrate a short wavelength harmonically mode-locked thulium-doped fiber laser based on nonlinear polarization rotation. Stable soliton pulsing with record short wavelength of 1.787 nm and FWHM of 6.5 nm is achieved.

Multichannel multiphoton imaging of chondroid tissue with a CMOS camera, \textsuperscript{1}Tatiana Mihalache, \textsuperscript{2}Jia Li, \textsuperscript{2}Dong Chen, \textsuperscript{2}Sheng Zhang, \textsuperscript{2}Shuwei Shen, \textsuperscript{2}University of Toronto, Canada. We intraoperatively image chondroid tissue with a CMOS camera and multiphoton microscopy, demonstrating its ability to provide sub-cellular, real-time, multicolor imaging at high spatial resolution.

Best Paper: Broadband Single-Nanowire Photoconductive Terahertz Detectors Based on Undoped InP Nanowires, \textsuperscript{1}Sisi Tan, \textsuperscript{1}Nan Chen, \textsuperscript{1}Jiqiang Kang, \textsuperscript{1}Kenneth Kin-Yip Wong, \textsuperscript{1}The Univ. of Hong Kong, China. We demonstrate ultrahigh-speed broadband single-nanowire photoconductive terahertz detectors based on undoped InP nanowires, achieving a repetition rate of 92 MHz and 82 fs pulse duration.

Broadband Single-Nanowire Photoconductive Terahertz Detectors, \textsuperscript{1}Can Li, \textsuperscript{1}Xiaoming Wei, \textsuperscript{1}Sai Tan, \textsuperscript{1}Nan Chen, \textsuperscript{1}Jiqiang Kang, \textsuperscript{1}Kenneth Kin-Yip Wong, \textsuperscript{1}The Univ. of Hong Kong, China. We demonstrate broadband single-nanowire photoconductive terahertz detectors with a 92 MHz pulse repetition rate and 82 fs pulse duration.

Best Student Paper: Single-Camera Snapshot, (Amplitude and Phase) Samples Using a Multiphoton Imaging System, \textsuperscript{1}Bojan Resan, \textsuperscript{2}Andreas Rohrbacher, \textsuperscript{3}Vesna Villamaina, \textsuperscript{1}Marina Cuqquero, \textsuperscript{4}Jacob Licea-Rodriguez, \textsuperscript{5}Omar E. Olarte, \textsuperscript{6}Pablo Loza-Alvarez, \textsuperscript{6}Lumentum, Switzerland; \textsuperscript{7}School of Engineering, Univ. of Applied Sciences Northwestern Switzerland, Switzerland; \textsuperscript{8}ICFO-Institut de Ciencies Fotoniques, The Barcelona Inst. of Science and Technology, Spain. Multicolor two-photon fluorescence imaging is performed using blue-diode-pumped SESAM-modelocked Ti:Sapphire oscillator generating 5 nJ pulse energy, 82 fs pulse duration, at 780 nm central wavelength, with 92 MHz pulse repetition rate.

Ultrafast Photophysics of Single Crystal Metal Halide Perovskites Measured by Transient Multi-THz Spectroscopy, David G. Cooke, \textsuperscript{1}McGill Univ., Canada. Organometallic halide perovskites are a promising class of materials for optoelectronic devices, including photovoltaics. Recent multi-THz spectroscopy measurements of single crystal CH$_3$NH$_3$PbI$_3$ reveals free charge generation dynamics, intrinsic mobilities and exciton binding energies.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

**STu1M • Optical Interconnect Systems—Continued**

**STu1M.3 • 08:45**

*Phase Drift in Depletion-Mode Silicon Photonic Modulators, Jianchuan Lin*, Hassan Sepehrinia, Wei Shi, Leslie Rusch,* Université Laval, Canada. We experimentally examine a modulation-induced phase drift in depletion-mode silicon phase modulator and Mach-Zehnder modulator. The impact on BPSK signal is studied under varying modulator operating conditions.

**STu1M.4 • 09:00**

*Directly-modulated IM/DD OFDM Transmission over 100-km SSMF using SSB Filtering with Two Silicon Micro-ring Resonators, Mohamed Essghair Chaibi*, Karim Hassan, Laurent Bramerie, Christophe Peucherel,* FOTON Lab, Univ. of Rennes 1, ENSSAT, France; *Univ. Grenoble-Alpes, CEA, LETI, France. Optical single sideband signals generation using two silicon micro-ring resonators is demonstrated for 5.3-GHz wideband OFDM modulation. Transmission at 14.69Gb/s over 100-km SSMF is made possible thanks to the SSB filtering provided by the MRRs.

**STu1M.5 • 09:15**

*4-PAM Dispersion-Uncompensated Transmission with Micro-Ring Resonator Enhanced 1.55-μm DML, Francesco Da Ros*, Valentina Cristofori, Oskars Ozolins, Mohamed Chaibi, Xiaodan Pang, Gunnar Jacobsen, Sergei Popov, Michael Galili,* Technical Univ. of Denmark, Denmark; *NETLAB, Acero Sweden ICT, Sweden; **FOTON Lab, Univ. of Rennes, France; **School of ICT, Royal Inst. of Technology, Sweden. Real-time transmission of 14-GbD 4-PAM signal is demonstrated by combining a commercial 1.55-μm DML with a silicon MRR. BER below the HD-FEC threshold is measured after 26-km SSMF transmission without offline digital signal processing.

**STu1M.6 • 09:30**

*High-Speed IQ Modulator Based on Injection-Locked VCSL Array, Xian Xiao,1,2,* Nikolai K. Fontaine, Haoshuo Chen, Bin Huang, David T. Neilson, Kwangwoong Kim,1, Jeffrey H. Sinsky, Roland R. Ryf,* Bell Labs/NOVA, USA; *VERTILAS GmbH, Germany. We demonstrate an IQ modulator by employing two monolithic injection-locked VCSLs which are driven to produce pure amplitude modulation. QPSK signals are produced at 10 Gbaud with a peak-to-peak modulation voltage of 600 mV.

**STu1N • Photodetectors—Continued**

**STu1N.4 • 09:00**

*CMOS-compatible Mid-Infrared Silicon Detector, Romy Fan*, Steven Miller, Mengyu Yu, Austin G. Griffith, Jamie Cardenas, Michal Lipson,* Electrical and Computer Engineering, Cornell Univ., USA; *Electrical Engineering, Columbia Univ., USA; **Inst. of Optics, Univ. of Rochester, USA; *Applied Physics and Mathematics, Columbia Univ., USA. We demonstrate a CMOS-compatible mid-infrared detector at wavelengths ranging from 3.36 μm to 3.74 μm by exciting mid bandgap states in a sulfur-doped silicon waveguide with responsivities up to 2.2 mA/W.

**STu1N.5 • 09:15**

*Self-Aligned Local Electrolyte Gating of 2D Materials for Mid-Infrared Photodetection, Cheng Peng*, Dmitri K. Efetov,1, Sebastian Nanot,2, Ren-Jye Shiu,3, Gabriele Grosso,1, Yalang Yang1,2, Mark K. P.xe,1, Michael Galili,1, Jing Kong1, Frank Koppen1,2, Dirk Englund1,1, IMT, USA; ICFO – Institut de Ciencies Fotoniques, Spain; **ICREA-Institució Catalana de Recerca i Estudis Avançats, Spain. We present a new gating concept based on a self-aligned electrolyte technique that can enable spatially modulating charges with nanometer resolution. We use this technique to demonstrate a graphene mid-infrared thermopile photodetector with novel geometry.

**STu1N.6 • 09:30**

*Investigation of Si-based GeTe+Sn2 Photodetectors with 3.0 μm photoresponse, Thach Pham*, Yu Chen, Wu Du*, Joe Margraf1, Yiyn Zhou, Perry Grant1, Gregory Sun2, Richard Soref1, John Tolle1, Baohua Li2,3,4, Meizhi Sun1, Jun Kang1, Jian Zhou1, Xinglong Xie1, Jiacang Zhu2, Zunqu Lin1, Shanghai Inst. of Optics and Fine Mechanics, China. Broadband exceeding 30nm amplification has been realized experimentally based on 95% deuterated DKDP crystal with 532nm pump pulses, which meets numerical analysis well. The results indicate potential utilization for OPCPA systems of compressed 30fs pulses.

**STu1O • Petawatt Laser Technology—Continued**

**STu1O.3 • 08:45**

*Spectral shaping of an OPCPA preamplifier for a multi-PW laser at 20 fs, H. W. Lee*, Yeong Gyu Kim*, Ye Yoon Yoo, Jin Woo Yoon3, Jae Hee Sung1, Seoing Ku Lee1, Chang Won Lee1, Jung Moon Yang, Chang Hee Nam2,* Center for Relativistic Laser Science, Inst. for Basic Science, Korea (the Republic of); *Dept. of Physics and Photon Science, Gwangju Inst. Science and Technology, Korea (the Republic of); **Advanced Photonics Research Inst., Gwangju Inst. Science and Technology, Korea (the Republic of). We developed an OPCPA preamplifier for the 4-PW laser at CoBeLS. The output spectrum was shaped by controlling the pump laser temporal profile. Spectrally shaped laser pulse was generated with an energy of 240 mJ.

**STu1O.4 • 09:00**

*Experimental Demonstration for 808nm centered Ti:Sa amplifiers based on High Deuteration DKDP Crystals and the Potential Utilization in SGII-SPW System, Xiao Liang*, Meizhi Sun1, Jun Kang1, Jian Zhou1, Xinglong Xie1, Jiacang Zhu2, Zunqu Lin1, Shanghai Inst. of Optics and Fine Mechanics, China. We experimentally demonstrate a CMOS-compatible mid-infrared detector operating conditions.

**STu1O.5 • 09:15**

*High Repetition Rate Thin Disk Ti:Sa Amplifiers for Sub-PW class Laser Systems, Vladimir V. Chvykov*, Roland Nagymihaly, Huabao Cao, Mikhail Kalashnikov, Karoly Osvay,* ELI-HU Non-Profit Ltd., Hungary. Results of the proof-of-principal experiments with two types thin disc water cooled Ti:Sa amplifiers will be presented. Scaling simulations based on experimental results demonstrate feasibility of hundreds Hz sub-PW Ti:Sa laser systems.

**STu1O.6 • 09:30**

*Picosecond Contrast of Recompressed Ti:Sapphire Laser Pulses, Mikhail P. Kalashnikov*, Nikita Khodakovskiy1, Max Born Inst., Germany. The degradation of picosecond contrast in Ti:Sapphire lasers was investigated for different stretcher-compressor combinations. During amplification the coherent ragged post-pedestal, the feature of Ti:Sapphire medium, generates a coherent pre-pedestal limiting the temporal contrast.
ATu1A.8 • 09:45
Robust stiffness quantification using quantitative optical coherence elastography, Xuan Liu1, Farzana Zaki1, Yahui Wang1; 1New Jersey Inst. of Technology, USA. We demonstrated the capability of quantitative optical coherence elastography (qOCE) for robust measurement of material stiffness under different boundary conditions using the reaction force and displacement field established in the sample.

ATu1C.6 • 09:45
Tuning the Wettability of Steel by Femtosecond Laser Structuring, Daniel Puerto1, Camilo Florian Baron1, Evangelos Skoulas2, Emmanuel Stratakis1, Javier Solis1, Jan Siegel1; 1Instituto de Óptica, Spanish National Research Council, Spain; 2Inst. of Electronic Structure and Laser, Foundation for Research and Technology, Greece. We present a strategy to control the wetting properties of steel using high-repetition rate femtosecond laser-written parallel lines and grids with variable spacing. This approach also allows generating lateral anisotropy of the wetting angle.
Tuesday, 08:00–10:00
Executive Ballroom
210E
Executive Ballroom
210F
Executive Ballroom
210G
Executive Ballroom
210H

CLEO: QELS-Fundamental Science

FTu1E • Defects in Solids for Coherent Control and Single-Photon Generation—Continued
FTu1F • Quantum Optics and Quantum Information Processing—Continued
FTu1G • Light Manipulation with Disordered Media—Continued
FTu1H • Fundamental Plasmonic & Nanophotonic Effects—Continued

FTu1F.7 • 09:45
Experimental Implementation of Quantum-Coherent Mixtures of Causal Relations, Jean-Philippe MacLean1,2, Katja Ried2,3, Robert W. Spekkens4, Kevin Resch1, 1Dept. of Physics & Astronomy, Univ. of Waterloo, Canada; 2Perimeter Inst. for Theoretical Physics, Canada; 3Inst. for Quantum Computing, Univ. of Waterloo, Canada. We realize a nonclassical mixture of causal relations in a quantum optics experiment using a partial swap and derive a set of criteria for witnessing the coherence based on a quantum version of Berkson’s paradox.

FTu1G.7 • 09:45
Metasurfaces With Random Nanoantennas for Ultra-broadband Surface Enhanced Nonlinear Optics, Nan Zhang1,2, Zheng Ji1,2, Alex R. Cheney1, Haomin Song1, Dengxin Ji1, Xie Zeng1, Boni Chen1, Alexander N. Cartwright1, Kebin Shi1, Qiaoqiang Gan2, 1Dept. of Electrical Engineering, The State Univ. of New York at Buffalo, USA; 2Physics Dept., Peking Univ., China. We demonstrate a strong enhancement of second harmonic generation based on a three-layered super absorbing metasurface consisting of a dielectric spacer layer sandwiched by an array of random metallic nanoparticles and a metal ground plate.

FTu1H.7 • 09:45
Visible Frequency Plasmon Resonator exhibiting Quality Factors exceeding 750, Shawn Divitt1,2, Wenqi Zhu1,2, Jared Strait1, Henri J. Lezec1, Amit K. Agrawal1, 1Maryland NanoCenter, Univ. of Maryland, USA; 2Center for Nanoscale Science and Technology, National Inst. of Standards and Technology, USA. We propose a plasmon resonator consisting of a cylindrical hole in a metal film that supports whispering gallery type surface plasmon polariton modes exhibiting record-high quality factors (>750) in the visible frequency range.

10:00-10:30 Coffee Break, Concourse Level

10:30-11:30 JTu2A • Plenary Session I, Grand Ballroom

11:30-19:30 Exhibition Open, Exhibit Hall 1, 2 & 3

11:30-13:30 Unopposed Exhibit Only Time, Exhibit Hall 1, 2 & 3

12:00-13:30 OIDA VIP Industry Leaders Speed Meetings Lunch, Exhibit Hall (Advanced Registration Required)

12:00-15:00 SC352: Introduction to ultrafast pulse shaping—principles and applications
SC376: Plasmonics
SC410: Finite Element Modelling Methods for Photonics and Optics

12:00-16:00 SC270: High Power Fiber Lasers and Amplifiers
SC438: Photonic Metamaterials

12:30-13:30 Lunch Break (on your own)

12:00-13:30 Market Focus Session I: Precision Applications using Ultrafast Lasers, Exhibit Hall Theater

13:00-17:30 Alternative Careers Paths in Optics and Photonics, Willow Glenn/Marriott

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
STu1I • Ultrafast Applications—Continued

STu1I.7 • 09:45
Multiplexed detection for higher performance quantitative phase time-stretch microscopy, Bryan T. Bosworth¹, Mark A. Foster¹, Johns Hopkins Univ., USA. We present a simple fiber-based technique for multiplexing interferometric signals as a means to improve the SNR and electronic bandwidth of quantitative phase time-stretch microscopy, enabling better sampling rates and signal quality.

STu1J • THz Materials Science—Continued

STu1J.6 • 09:45
Selective Modulation of Terahertz Radiation using Photo-excited 2D Hybrid Lead Halide Perovskites, Ashish Charanana¹, Ajay Nahata¹, Univ. of Utah, USA. We demonstrate 100% modulation of selective Terahertz resonances using series of two-dimensional hybrid lead halide perovskites. The device operation in perovskite/silicon devices was achieved using a simple halogen lamp and a set of color filters.

STu1K • Mid-IR Fiber Sensors—Continued

STu1K.6 • 09:45
Mode-locking Regime Switching by Wavelength Tuning in a Tm-fiber Laser, Ruoyu Liao¹, Youjian Song¹, Lu Chai¹, Ming-lie Hu¹, Tianjin Univ., China. We demonstrate a passively mode-locked thulium-doped fiber laser which can switch among soliton, stretched pulse and dissipative soliton regimes by simply tuning central wavelength.

10:00–10:30 Coffee Break, Concourse Level

10:30–11:30 JTu2A • Plenary Session I, Grand Ballroom

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12:30–13:30 Lunch Break (on your own)

12:00–13:30 Market Focus Session I: Precision Applications using Ultrafast Lasers, Exhibit Hall Theater

13:00–17:30 Alternative Careers Paths in Optics and Photonics, Willow Glenn/Marriott
STu1M • Optical Interconnect Systems—Continued

STu1N • Photodetectors—Continued

STu1O • Petawatt Laser Technology—Continued

STu1N.7 • 09:45 Surface Micromachined MEMS-Tunable PIN-Photodiodes around 1550-nm, Julian Cesar1, Sujoy Paul1, Mohammad T. Haidar1, Brian Corbett1, Arkadi Chipouline1, Franco Küppers1; Technische Universität Darmstadt, Germany; Tyndall National Inst., Ireland. We report continuously widely tunable InP-based pin-photodiodes by integrating a surface micromachined MEMS-based Fabry-Perot filter with FWHM/FSR of 0.3 nm/189 nm. Detection of 36 nm is obtained for WDM- or sensing-applications around 1550 nm.

STu1O.7 • 09:45 Dependence of Compressed Pulse Contrast on Grating Surface Roughness, Yunxin Tang1, David Egan1, Chris Hooker1, Chris Gregory1, Oleg Chekhlov1, Cristina Hernandez-Gomez1, John Collier1, P.P. Rajeev1; Central Laser Facility, STFC Rutherford Appleton Lab, UK; The Orion Laser Facility, AWE, UK. We report a novel method to evaluate the impact of stretcher gratings on the compressed pulse contrast by quantitative characterization of the grating surface, demonstrating a correlation between the contrast pedestal and grating natural property.

10:00–10:30 Coffee Break, Concourse Level

10:30–11:30 JTu2A • Plenary Session I, Grand Ballroom

11:30–19:30 Exhibition Open, Exhibit Hall 1, 2 & 3

11:30–13:30 Unopposed Exhibit Only Time, Exhibit Hall 1, 2 & 3

12:00–13:30 OIDA VIP Industry Leaders Speed Meetings Lunch, Exhibit Hall (Advanced Registration Required)

12:00–15:00 SC352: Introduction to ultrashort pulse shaping—principles and applications
SC376: Plasmonics
SC410: Finite Element Modelling Methods for Photonics and Optics

12:00–16:00 SC270: High Power Fiber Lasers and Amplifiers
SC438: Photonic Metamaterials

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13:00–17:30 Alternative Careers Paths in Optics and Photonics, Willow Glenn/Marriott
The development of new anti-cancer therapy. lead to new physico-chemical approaches to elucidate early events in carcinogenesis, and can help decipher the gene expression code.

Invited

Emerging Photobiomodulation Therapeutics, Juanita Anders, USUHS, USA. The current status of photobiomodulation therapy will be presented. The importance of device parameters, wavelength selection related to the target tissue, photon dose related to cellular mechanisms, and opportunities for collaboration will be discussed.

13:30-15:30
Executive Ballroom 210A
ATu3A • Photobiomodulation Therapeutics
Presider: Ilko Ilev; U.S. Food and Drug Admin., USA

13:30-15:30
Executive Ballroom 210B
ATu3B • A&T Topical Review on Neurophotonics II
Presider: Chris Xu; Cornell Univ., USA

13:30-15:30
Executive Ballroom 210C
ATu3C • Industrial Optical Design & Sensing
Presider: Jan Kleinert; ESI, USA

ATu3A.1 • 13:30
Predicting Behavior from Cortical Activity Recorded through Widefield Transcranial Imaging, Li Zhu; Christian R. Lee1, David J. Margolis1, Leilah NajafiZadeh1, Rutgers Univ., USA. We present a method based on a visibility graph capable of predicting whisking activities with an accuracy of 93.57% from calcium signals of excitatory neurons that are recorded through widefield imaging in GCaMP6f reporter mice.

ATu3B.1 • 13:30
Assessment of Lexican for Blood Brain Barrier disruption to facilitate Fluorescence brain imaging, Rebecca W. Pak1, Hanh Le1, Heather Valentine1, Daniel Thorek1, Arman Rahimi2, Dean Wong1, Jin U. Kang1; Bio-medical Engineering, Johns Hopkins Univ., USA; Electrical and Computer Engineering, Johns Hopkins Univ., USA; Radiology and Radiological Sciences, Johns Hopkins Univ., USA. Mouse brain fluorescence was imaged after the tail vein injections of indocyanine green (ICG) dye and Lexican. The through-skull images showed dye in the vasculatures and permeating through the blood brain barrier into the tissue.

ATu3A.2 • 14:00
Convergence of Nanoimaging, Physics and Biology: Can Engineering Lead to a Cancer Cure?, Vadim Backman1,2; Northwestern Univ., USA; Cancer and Physical Sciences, Robert H. Lurie Comprehensive Cancer Center, USA. The development of new optical nanomaging technologies and the physics-based modeling of gene expression can help decipher the gene expression code, elucidate early events in carcinogenesis, and lead to new physico-chemical approaches to anti-cancer therapy.

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ATu3A • Photobiomodulation Therapeutics, Juanita Anders, USUHS, USA. The current status of photobiomodulation therapy will be presented. The importance of device parameters, wavelength selection related to the target tissue, photon dose related to cellular mechanisms, and opportunities for collaboration will be discussed.

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13:30-15:30
Executive Ballroom 210A
ATu3A • Photobiomodulation Therapeutics
Presider: Ilko Ilev; U.S. Food and Drug Admin., USA
### CLEO: QELS-Fundamental Science

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<td><strong>FTu3G • Toward Applications of Metasurfaces I</strong></td>
<td><strong>FTu3H • Active Plasmonics and Nanophotonics</strong></td>
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<td>President: James Franson; Univ. of Maryland Baltimore County, USA</td>
<td>President: Xiaobo Yin; Univ. of Colorado at Boulder, USA</td>
<td>President: Wei Zhou; Virginia Tech, USA</td>
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#### FTu3E • 13:30
On-demand source of entangled photon-pairs using the biexciton-exciton radiative cascade, Roni Winik1,2, Dan cogan1, Yaroslav Dan1, Ido schwartz1, Lior Gantz2, Emma Schmidig1, Nitam Louie1, Ronen Rappa1, Eyal Bux1, David Gershoni1; 1The Physics Dept. and the Solid State Inst., Technion - Israel Inst. of Technology, Israel; 2Andrew and Emi Ziberi Dept. of Electrical Engineering, Technion - Israel Inst. of Technology, Israel; 3Applied Physics Dept., The Ben Gurion School of computer sciences and engineering, The Hebrew Univ., Israel. We show that pairs of photons resulting from the radiative cascade of the confined biexciton are maximally entangled. The measured entanglement depends on the resolution by which the time between the pair emissions is determined.

#### FTu3F • 13:30
**Quantum Illumination: From Enhanced Target Detection to Gbps Quantum Key Distribution**, Jeffrey H. Shapiro1, IMT, USA. We review theory and experiments for quantum illumination—entanglement-based protocols for enhanced target detection and secure classical communication—and show that its unentangled descendant, floodlight quantum key distribution, affords Gbps secret-key rates over metropolitan-area distances.

#### FTu3G • 13:30
On-Chip Demonstration of a Transparent Perfect Mirror, Ali Kazemi Jahromi1, Soroush Shababang1, Hasan E. Kondakci1, Petri Melanen1, Seppo Orsila1, Ayman F. Abouraddy2, 1Univ. of Central Florida; 2CREOL, USA; 3Modulight, Inc., Finland. We experimentally demonstrate an active cavity exhibiting 100% spectrally flat reflection with no vestiges of structural resonances while still transmitting light across the gain bandwidth. This non-Hermitian structure is realized in an indium-phosphate platform.

#### FTu3H • 13:30
Massive Parallel Positioning of Nanodiamonds on Nanophotonic Structures, Justus C. Nduka1, Benjamin IsaacP1, Mikhail Y. Shaltenidze1, Simeon Bogdanov1, Agabai G. Nnanna1, Julie S. Biteen1, Mordechai Segev1, Vladimir M. Shalaev1, Alexandra Boltasseva1; 1Purdue Univ., USA; 2Univ. of Michigan, USA; 3Physics, Technion Israel Inst. of Technology, Israel. Precise and scalable positioning of nanoscale emitters, such as nanodiamonds with color centers, on solid substrates is essential for realizing integrated quantum devices and sensor arrays. We present a novel approach to meet this need.

#### FTu3E.2 • 13:45
**Engineering Spins in Quantum Dot Molecules for Scalable Quantum Photonics**, Xiangyu Ma1, Garnett Bryant1, Matthew Doty1; 1Univ. of Delaware, USA; 2National Inst. of Science and Technology, USA. We analyze the physics underlying emergent spin properties in self-assembled InAs Quantum Dot Molecules. We describe opportunities to engineer these structures for scalable and in situ tunable quantum photonic devices.

#### FTu3F.2 • 13:45
**Metasurface-Enabled On-Chip Quantum Entanglement**, Nir Shtrit1, Pankaj K. Jha1, Jeongmin Kim1, Xueqin Ren1, Yuan Wang1, Xiang Zhang2; 1Univ. of California Berkeley, USA; 2Lawrence Berkeley National Lab, USA. We report on on-chip quantum entanglement between two microscopically separated qubits by engineering their long-range interactions via a metasurface. The metasurface route to quantum state engineering opens a new paradigm for on-chip quantum technology.

#### FTu3G.2 • 13:45
**Broadband transparent all-dielectric metasurfaces**, Sergey S. Kruk1, Lei Wang1, Hanzhi Wang1, Tao Li1, Ivan Kravchenko3, Dragomir Neshev1, Yuri Kivshar1; 1Univ. of Central Florida, USA; 2Mathematics, Massachusetts Inst. of Technology, USA. We introduce a multi-frequency finite-difference frequency-domain algorithm for active nanophotonic devices simulations from first principles. This algorithm overcomes large time-scale differences between optical and modulation frequencies and efficiently simulates performances of modulated devices.

#### FTu3H.1 • 13:30
**Quantum Enhancement of Single Photon Detection Efficiency of Sources Based on Both Cavity Trade-off Between Indistinguishability and Entanglement**, Afshin Nazari1, Roy Terhune2, Michael Hendry3, Andrew Babak4, David Gershoni5, Giancarlo Ruocco5; 1Purdue Univ., USA; 2Lawrence Berkeley National Lab, USA; 3Physics, Technion Israel Inst. of Technology, Israel. Precise and scalable positioning of nanoscale emitters, such as nanodiamonds with color centers, on solid substrates is essential for realizing integrated quantum devices and sensor arrays. We present a novel approach to meet this need.

#### FTu3H.2 • 13:45
**Modeling Nonlinear Resonators Comprising Graphene: A Coupled Mode Theory Approach**, Thomas A. Christopoulos1, Odysseas Tsilipakos1, Nikolaos Grivas1, Georgios Sinatkas1, Emmanuel K. Kriezis1, 1Dep. of Electrical and Computer Engineering, Aristotle Univ. of Thessaloniki, Greece; 2Institute of Electronic Structure and Laser, Foundation of Research and Technology - Hellas, Greece. We develop a perturbation theory framework for modeling nonlinear resonators comprising dispersive sheet materials. It is applied to model optical bistability with graphene based nonlinear resonant structures in the THz and near-infrared regimes.

#### FTu3E.3 • 14:00
**Phonon Limit to Simultaneous Near-Unity Efficiency and Indistinguishability in Semiconducotor Single Photon Sources**, Jake Iles-Smith1, Ahsan Nazari2, Lara McCutcheon3, Jesper Mark1; 1DTU, Denmark; 2The Univ. of Manchester, UK; 3Univ. of Bristol, UK. We investigate the role of phonons on the emission properties of solid-state single photon sources. We demonstrate a fundamental trade-off between indistinguishability and efficiency of sources based on both cavity and waveguide architectures.

#### FTu3F.3 • 14:00
**Transverse Localization of Light for Single-mode and Secure Information Transport**, Marco Leonetti1,2, Salman Karbasi1, Arash Mafi1, Behnam Abaie1, Eugenio DelRe1, Giancarlo Ruocco1, Andrea Chicchi1, Italian Inst. of Technology, Italy; 2Depart. of Electrical and Computer Engineering, Univ. of California, USA; 3Dept. of Physics and Astronomy and Center for High Technology Materials, Univ. of New Mexico, USA. We demonstrate how reconfigurable localized optical patterns allow to encode up to 6 bits of secure information in disorder-induced high transmission channels loaded with single photons.

#### FTu3G.3 • 14:00
**Broadband transparent all-dielectric metasurfaces**, Sergey S. Kruk1, Lei Wang1, Hanzhi Wang1, Tao Li1, Ivan Kravchenko3, Dragomir Neshev1, Yuri Kivshar1; 1Univ. of Central Florida, USA; 2Mathematics, Massachusetts Inst. of Technology, USA. We employ the generalized Huygens principle to design and fabricate highly transparent dielectric metasurfaces for complex wavefront manipulation with 99% polarization conversion and 99% diffraction efficiencies and broadband operation at telecom wavelengths.

### Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
13:30–15:30
STu3I • Ultrafast Metrology I
Presider: Christophe Dorrer; Univ. of Rochester, USA

STu3J • High-field THz Generation
Presider: Matthias Hoffmann; SLAC National Accelerator Lab, USA

STu3K • Structured and Gas-filled Fibers
Presider: Benjamin Pulford; Air Force Research Lab., USA

13:30–15:30
JTu3L • Symposium on Ultrafast Laser Technology for X-ray Free Electron Lasers I
Presider: Ingmar Hartl; DESY, Germany

STu3I.1 • 13:30
Tutorial Beyond the Fringe: Interferometry for Ultrafast Optics, Ian A. Walmsley; Univ. of Oxford, UK. Interferometry has proven to be a spectacularly successful technique in ultrafast optics, enabling the complete characterization of light pulses from atto- to nano-seconds. I will describe the principles of spectral interferometry in this application.

Ian Walmsley is the Hooke Professor of Experimental Physics and the Pro-Vice-Chancellor for Research and Innovation at the University of Oxford, UK. His research in optical science and technology ranges from ultrafast optics to quantum information science. Currently he is the Director of the Networked Quantum Information Technology Hub, the largest collaboration in the UK National Quantum Technologies Programme.

STu3J.1 • 13:30
Broadband terahertz generation with a stair-step echelon, Koustuban Ravi1,2, Benjamin Ofon-Oka1, Prasahnh Tharavajj1, Wenqian Huang1, Franz Kaertner3, Keith Nelson1; 1MIT, USA; 2Ultrafast Optics and X Rays, Center for free electron lasers, Germany. A method to overcome limitations of conventional broadband terahertz generation techniques is presented. A stair-step echelon allows for the creation of superior tilted-pulse-fronts to yield larger frequencies and bandwidths, energy conversion efficiencies exceeding 5%.

STu3J.2 • 13:45
Towards high power and low noise mid-infrared DFG ultrafast source, Qian Cao1,2, Franz Kaertner1,2, Guoqing Chang1; 1DESY, Germany; 2Physics, Univ. of Hamburg, Germany. We theoretically demonstrate that high power low noise mid-IR pulses can be obtained by using SPM-enabled pulses as the signal. Compared with Raman soliton pulse, SPM-enabled pulse exhibits high energy and low timing jitter.

STu3J.3 • 14:00
Aperiodically poled structures for high efficiency broadband terahertz generation, Koustuban Ravi1,2, Alireza Yahaghi2, Arya Falahi1, Franz Kaertner3,1; 1MIT, USA; 2Ultrafast Optics and X Rays, Center for free electron lasers, Germany. We introduce a combination of aperiodically poled structures and chirped mirrors for broadband terahertz generation. Unprecedented spectral and temporal shaping possibilities with energy conversion efficiencies >5% and terahertz output energies of ~10 mJ are predicted.

STu3K.1 • 13:30
Tutorial Nanowire-based Hybrid Optical Fibers: A Platform for Nonlinear Light Generation, Nanoscale Plasmonics and Single Nanoobject Detection, Markus Schmidt1,2; 1Leibniz Inst. of Photonic Technology, Germany; 2Otto Schott Inst. of Material Research, Germany. Nanowires inside hybrid optical fibers provide new functionalities for various fields such as plasmonics, nonlinear optics and biophotonics. Here I review our results on plasmonic nanotips, nanoparticle tracking and coherent mid-IR light generation.

Markus A. Schmidt is professor at the University of Jena and leads a Research Group at the Leibniz Institute of Photonic Technology. He was team leader at the Max Planck Institute for the Science of Light and spent a research stay Imperial College London. He obtained his PhD in Hamburg.

STu3K.2 • 13:45
Ultrafast Laser-Enabled Science at XFELs, Wilfried Wurth1,2; 1Dept. Physik and Center for Free-Electron Laser Science, Universität Hamburg, Germany; 2DESY Photon Science, Germany. Ultrafast science with x-ray free-electron lasers requires in many cases ultrashort laser pulses ranging from THz to UV. Science examples ranging from physics and chemistry to life science will be given.

JTu3L • Invited High Rep-Rate Pump-Probe-Lasers for XFELs, Tino Lang1; 1Deutsches Elektronen-Synchrotron DESY, Germany. Abstract not available.
STu3M.1 • 13:30
Modulation Format Independent and Low Complexity CPE Algorithm for Elastic Optical Networks, Yang Tao, Xue Chen, Huan Chen, State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We propose a modulation format independent blind carrier phase estimation (MFI-CPE) algorithm for arbitrary mQAM coherent systems. Comprehensive numerical simulations and experimental results demonstrate its effectiveness and comparable performance to traditional BPS.

STu3M.2 • 13:45
A High-sensitivity Coherent Receiver without Frequency Recovery Enabled by Doubly Differential QPSK, Christian Sanchez, Stylianos Sygletos, Lida Huan Chen; hybrid FMF/SMF span for CO-OFDM transmission. The sensitivity for the 134-Gb/s coherent system transmission over 80-km SMF was below -27.5 dBm.

STu3M.3 • 14:00
Quasi-Single-Mode Raman amplification in hybrid FMF/SMF span for CO-OFDM transmission, Liang Xu, Jingchi Cheng, Ming Tang, Zhenhua Feng, Qiong Wu, Huibin Zhou, Xi Chen, Ruoxu Wang, Songnan Fu, Deming Liu; harvested in acquisition programs of record $50 million. The competitively awarded programs are chosen to advance the current state of the art in HEL technology, stimulate the industrial base and fill technology gaps, thus providing a broad capability that can be harvested in acquisition programs of record by the military services.

STu3N.1 • 13:30
Micrometer Scale Lithium Niobate Electro-optic Modulators, Mian Zhang, Cheng Wang, Brian Stern, Michal Lipson, Marko Loncar, Cornell Univ., USA; John A. Paulson School of Engineering and Applied Sciences, Harvard Univ., USA; Electrical Engineering, Columbia Univ., USA. We demonstrate electro-optic modulation on a monolithic lithium niobate nanophotonic platform up to 40 Gba/s. We show electro-optic efficiency as high as 7 pm/V in microresonators and half-wave voltage length product as low as 2 Vcm in micro-Mach-Zehnder interferometers.

STu3N.2 • 13:45
Record-High In-Device Electro-Optic Coefficient of 359 pm/V in a Silicon-Organic Hybrid (SOH) Modulator, Clemens Kinninger, Yasar Kutuvantavida, Heiner Zwickel, Stefan Weil, Matthias Lauermann, Delwin Elder, Larry Dalton, Wolfgang Freude, Sebastian Randel, Christian Koes, Inst. of Photonics and Quantum Electronics, Karlsruhe Inst. of Technology, Germany; Inst. of Microstructure Technology, Karlsruhe Inst. of Technology, Germany; Infinera Corporation, USA; Dept. of Chemistry, Univ. of Washington, USA. We demonstrate a record-high electro-optic coefficient of $\beta_{33} = 359$ pm/V in a silicon-organic hybrid (SOH) modulator using the electro-optic chromophore JJD1. The voltage-length product amounts to $V_{ul} = 320 \text{ V\mu m}$, enabling error-free 25 Gbit/s signaling at drive voltages of 180 mVpp.

STu3N.3 • 14:00
Inter-modal Brillouin Scattering in an Integrated Waveguide, Eric Kittlaus, Iain McKinnie; Integrated Waveguide, Eric Kittlaus, Iain McKinnie; Invited

JTu3O.1 • 13:30
High Energy Laser Joint Technology Office - A Mission Overview, Larry Grimes; HEL-JTO, USA. The High Energy Laser Joint Technology Office (HEL-JTO) was established in 2000 for the purpose of developing and executing a comprehensive investment strategy for HEL science and technology that would underpin weapons development. The JTO is currently sponsoring 70 programs across industry, academia, and government agencies with a budget of approximately $50 million. The competitively awarded programs are chosen to advance the current state of the art in HEL technology, stimulate the industrial base and fill technology gaps, thus providing a broad capability that can be harvested in acquisition programs of record by the military services.

JTu3O.2 • 14:00
Title to be Determined, Iain McKinnie; Lockheed Martin, USA. Abstract not available
ATu3A.3 • 14:30
Label-Free Sensing of Intrinsic Biomarkers Related to Medical Device Performance
Employing a Noninvasive Fingerprint Infrared Spectroscopy Method, Moinuddin Hassan1, Ilko K. Ilevi, U S Food and Drug Administration, USA. An advanced sensing methodology based on a noninvasive label-free fingerprint infrared spectroscopy approach for detecting and identifying intrinsic biomarkers related to the safety and efficacy of optical diagnostics and therapeutics technologies and devices is presented.

ATu3A.4 • 14:45
Eliciting Host Immunity Selectively against Cancer Cells Treated with Silica-Phthalo cyanine-Based Near Infrared Photostimulated Immunotherapy, Hisatoaka Kobayashi1,2, National Inst. of Health, USA. Near infrared photostimulated immunotherapy (NIR-PIT) is a new type of molecularly-targeted cancer phototherapy based on antibody-photosensitizer conjugates. By crashing cancer or immunosuppressor cells, NIR-PIT efficiently activates host immunity against NIR-PIT treated cancer cells growing in patients.

ATu3C.3 • 14:30
Laser-induced Fluorescence for Detection of Alloying Elements During Laser Welding of Austenitic Stainless Steel, Brian Simonds1, Jeffrey W. Sowards1, Paul A. Williams1; 1National Inst. of Standards and Tech, USA. We demonstrate a sensitivity increase of 10^4 over optical emission spectroscopy by applying laser-induced fluorescence to detect evaporating alloying elements during laser welding. As proof-of-principle, we target silicon in stainless steel in the near-UV.

ATu3C.4 • 14:45
An Optical Remote Sensor for Fingerprint Identification using Speckle Pattern, Ariel Schwarz1, Amir Shemer1, Nisan Ozana1, Ran Califa1, Javier Garcia2, Zev Zalevsky3; 1Faculty of Engineering, Bar Ilan Univ., Israel; 2Dep. of Optics, University Valencia, Spain; 3Continuo Biometrics, Israel. The implementation of a simple, inexpensive optical device for remote fingerprint identification is presented. The sensor is based on temporal tracking of back-reflected secondary speckle patterns generated while illuminating a finger with a laser.

ATu3C.5 • 14:45
Large Effective \( \chi^{(2)} \) Nonlinearity via Coherent Photon Conversion on a SiN Chip, Alessandro Farsi1,2,3, Sven Ramelow2, Stéphane Clemmen1, Xingchen Ji4,5, Michal Lipson5, Alexander L. Gaeta1; 1APAM, Columbia Univ., USA; 2Inst. for Physics, Humboldt Univ., Germany; 3Inst. of Physics, Humboldt Univ., Germany; 4EE, Columbia Univ., USA. We generate large effective \( \chi^{(2)} \) nonlinearities in a purely \( \chi^{(3)} \)-nonlinear SiN microresonator using the coherent photon conversion scheme and measure a normalized effective second harmonic generation efficiency above 77%/mW.
FTu3E.6 • 14:45
Robust Multicolor Single Photon Emission from Point Defects in Hexagonal Boron Nitride, Toan T. Tran1, Christoph Elbadawi1, Daniel Totonjian1, Charlene J. Levy1, Gabrielle Gross1, Ertugrul Cubukcu1, Hai Zhu2,3, Qinghai Song2,1, Fei Yi3, Mingliang Ren2,3, Yan Li1,2,4, Ivan A. Burenkov1, Sergey V. Polyakov2, Christopher R. Considine1, Helmut Fedder2, Jong Whatchart2, Mozifur Ali3, Marcus W. Doherty1, Vinod M. Menon1, Carlos A. Meneses1, Physics, CUNY-City College of New York, USA; 23rd Physics Inst., Univ. of Stuttgart, Germany; 3Center for Physical and the near-infrared ranges. Excitation of single photon emitters via a two-photon process can be employed for high resolution imaging and has applications in quantum optics. Here, we present one- and two-photon excitation of single defects in hexagonal boron.

FTu3F.3 • 14:30
Optimum Mixed-State Discrimination for Noisy Entanglement-Enhanced Sensing, Quntao Zhuang1, Zheshen Zhang1, Jeffrey H. Shapiro1, Marcus I. Aharonovich2, Shigeki Takeuchi1; 1Univ., Japan; 2Univ. of Technology Sydney, Australia. We propose a structured receiver for optimum mixed-state discrimination in quantum illumination target detection, paving the way for entanglement-enhanced minimum-error-probability sensing in an entanglement-breaking environment.

FTu3G.5 • 14:30
All-Dielectric Metasurface for Polarization-Insensitive Color Printing, Shang Sun1,2, Zhenxing Zhou2,1, Zonghui Duan2,1, Shumin Xiao1,2,3, Qian T. Zhang1,2,3, Qi Gu2,3, Zongmin Wang1,2,3, Ling Liao1,2,3, Junfeng He1,2,3, Quntao Zhuang1,2,3, Zheshen Zhang1,2,3; 1Kyoto Inst., NIST and UMD, USA; 2Na-}

FTu3F.4 • 14:45
M-state frequency shift keying discrimination below the standard quantum limit, Ivan A. Burenkov1, Sergey V. Polyakov2, Joint Quantum Inst., NIST and UMD, USA; 3National Inst. of Standards and Technology, USA. We introduce a new quantum receiver based on frequency-shift keying encoding. We show that with the appropriate discrimination strategy the accuracy of this method significantly exceeds that of phase-shift keying-based quantum receivers.

FTu3G.6 • 14:45
All-Silica Multifunctional Beam Information Detector without Destroying Original Wavefronts, Guangyuan Li1,2, Qiong Li1,2, Pengliang Dong1,2, Qihuang Gong1,2, Bo Wang1,2, Weiguo Chu1,2, Mark Brongersma1, Yan Li2,3, Stanford Univ., USA; 4Shanxi Univ., China. The device can be used as a voltage reconfigurable single or dual wavelength light source.

FTu3H.5 • 14:30
Higher-Order Surface Plasmon Contributions to Plasmonic Interferometry, Dong-fang Li1, Jing Feng1, Domenica Pacifico1, Brown Univ., USA. We experimentally unveiled up to the sixth-order surface plasmon contributions to hole-groove plasmonic interferometry using discrete Fourier transform. This method is further extended to double-slit plasmonic structures to deconvolve competing interference effects from asymmetric interfaces.
STu3J • High-field THz Generation—Continued

STu3J.4 • 14:15
Generation of Narrowband, High-intensity, Carrier-envelope Phase-stable Pulses Tunable Between 4 and 18 THz, Biaolong Liu1; Hubertus Bromberger1; Andrea Cartella1; Thomas Gebert1; Michael Forst1; Andrea Cavalleri1; MPI for Structure and Dynamics of Matter, Germany; 2Oxford Univ., UK. We demonstrate the generation of narrowband (<1 THz) high-energy (~2 µJ) carrier-envelope phase-stable pulses, tunable between 4 and 18 THz as achieved by difference-frequency mixing between chirped near-infrared pulses in organic DSTMS.

STu3J.5 • 14:30
Coherent Field Transients below 15 THz from Phase-Matched Difference Frequency Generation in 4H-SiC, Marco Patrick Fischer1; Johannes Bühler1; Takayuki Kunitaka1; Gabriel Fitzky1; Alfred Leitenstorfer1; Daniele Brida1; Dept. of Physics and Center for Applied Photonics, Univ. of Konstanz, Germany. We experimentally demonstrate tunable, phase-matched difference frequency generation fully covering the spectral regime below 15 THz using 4H-SiC as nonlinear crystal. The material is also exploited as a broadband detector for electro-optic sampling.

STu3J.6 • 14:45
Broadband and narrowband terahertz source at extreme field strength, C. Vicario1; Mostafa Shalaby1; Flavio Giorgianni1; Andrea Ovchinnikov1; Olég Chefonov1; Christoph P. Hauri1; 1MPI for Structure and Dynamics of Matter, Germany; 2Oxford Univ., UK. We present recent progress in THz pulse generation, shaping technology and THz diagnostics in the low-frequency range (0.1-10 THz) for strong-field experiments at the Free Electron Laser: Intense Laser-based THz Sources for XFEL Experiments, Christoph P. Hauri1; 1SwissFEL, Paul Scherrer Inst., Switzerland. We present recent progress in THz pulse generation, shaping technology and THz diagnostics in the low-frequency range (0.1-10 THz) for strong-field experiments at the Free Electron Laser.

STu3K.2 • 14:30
Liquid-Core Nodeless Anti-Resonant Fiber for Biochemical Sensing, Xiaolu Liu1; Yingying Wang2; Wei Ding2; Shouwei Gao3; Ling Cao3; Xian Feng2; Pu Wang2; Beijing Univ. of Technology, China; 3Inst. of Physics, Chinese Academy of Sciences, China. A low refractive index liquid-core fiber is formed under anti-resonant guidance mechanism with broad transmission band and single modeness. A Raman spectroscopy experiment shows the versatility of this fiber platform for biochemical sensing.

STu3K.3 • 14:45
Efficient fiber gas Raman amplifier based on hydrogen-filled hollow-core fiber, Zefeng Wang1; Bo Gu2; Yubin Chen2; Xiaoming Xi1; Jianjun Cao1; Jinbao Chen2; 1National Univ of Defense Technology, China. A highly efficiency 1908 nm gas Raman amplifier based on hydrogen-filled hollow-core fiber is reported for the first time. Seeded by a tunable laser, the maximum power conversion efficiency of 41% is obtained.

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STu3M • Coherent Transmission Systems—Continued

STu3M.4 • 14:15
Long-haul Transmission of 4x100 Gb/s DP-QPSK Signals over 2800 km with Span Lengths Greater than 250 km, Chao Li1, Jian Zhao1, Lin Zhang1, Qi Mo2, Zhiqun Yang1, Wei Wang1, Guifang Li1; 1Tianjin Univ., China; 2Univ. of Central Florida, USA; 3Fiberhome & Fujikura Optics Co., Ltd., China. We experimentally demonstrate 4x100-Gb/s PM-QPSK transmission with a 50-GHz channel spacing and a span length greater than 250 km over a record reach of 2800 km. The transmission system uses a low-loss large-effective-area fiber and EDFA/DRA amplification.

STu3M.5 • 14:30
Invited
Progress of Digital Coherent Optical Communication Systems, Maurice O’Sullivan1; 1Ciena incorporated, Canada. We describe the progress of single mode digital optical coherent transmission towards increasing practical network capacity.

STu3N • Electro-Optic & Acousto-Optic Devices—Continued

STu3N.4 • 14:15
Integrated Two-Dimensional Free-Space Acousto-Optics on Suspended Membranes, Huan Li1, Qiyu Liu1, Mo Li1; 1Dept. of Electrical and Computer Engineering, Univ. of Minnesota, USA. We propose and have experimentally demonstrated integrated two-dimensional free-space acousto-optics on suspended membranes. Both the Stokes and anti-Stokes sidebands due to Brillouin frequency shift have been observed in a prototype aluminum nitride device.

STu3N.5 • 14:30
Invited
Integrated Graphene Electro-Optic Phase Modulator, Ipsrita Datta1, Christopher Phare1, Avik Dutta2, Aseema Mohanty1, Michael Lipson1; 1Columbia Univ., USA; 2Electrical and Computer Engineering, Cornell Univ., USA. We report the first experimental demonstration of a graphene electro-refractive modulator with $V_{\pi}$ of 0.14 Vcm, and minimal absorption modulation based on graphene capacitor integrated on Si3N4 with embedded high-K and high breakdown dielectric.

STu3N.6 • 14:45
High-speed Active Devices Integrated in Hybrid Silicon on Silicon Nitride Platform, Amir H. Hosseinnia1, Majid Sodagar2, Hesam Moradinejad2, Tianren Fan1, Ali A. Eftekhar2, Ali Adibi1; 1Georgia Inst. of Technology, USA; 2Skorpios Technologies, USA. We present a hybrid resonant linear frequency comb generator and a modulator for pulse formation and fast electro-optic modulation. Integrated in a hybrid silicon-on-silicon nitride platform, such devices utilize the high-speed plasma dispersion in Si and high-Q resonance in SiN.

JTu3O • Symposium on Military Applications of High Powered Lasers I—Continued

JTu3O.3 • 14:30
Invited
Advances in High Power Laser Systems for Directed Energy, Guy Renard1; 1Northrop Grumman Corp, USA. Laser Weapon (Directed Energy) Systems are experiencing increased interest and nearing deployment. The latest technology research to address these applications is reviewed. Progress with ongoing research activities and remaining challenges will be discussed.
ATu3A • Photobiomodulation Therapeutics—Continued

ATu3A.5 • 15:00
Wound Healing Study and Ablation Rate Measurements with the Novel Picosecond Infrared Laser (PIRL), Stephanie Maier1, Nils-Owe Hansen1, Sebastian Kruber1, Tobias Gosau2, Dennis Eggert1, Alexandre Gliese1, Hannes Petersen2, Hartmut Schlüter1, R. J. Dwayne Miller1, *Anatomy and Experimental Morphology, Univ. Medical Center Hamburg-Eppendorf, Germany; 1Atomicly Resolved Dynamics, Max Planck Inst. for the Structure and Dynamics of Matter, Germany; 2Otoralngology, Head and Neck Surgery and Oncology, Univ. Medical Center Hamburg-Eppendorf, Germany. We present the first wound healing study in rat skin, showing minimal scar formation with the Picosecond-Infrared-Laser (PIRL) compared to a conventional scalpel and electrosurgical device. In addition, we show first ablation rate measurements.

ATu3A.6 • 15:15
Multi-dimensional Imaging in the Terahertz Regime for Theranostic Applications, Holger Breitenborn1, Rafik Naccache1, Anna Mazhorova1, Matteo Clerici2, Daniele Modotto3, Ottavia Mazzei4, Anna Mazharovav5, Francois Vidal1, Roberto Morandotti1, 1Energy, Materials, Telecommunications, INRS, Canada; 2School of Engineering, Univ. of Insubria and CNISM UdR Como, Italy; 3Dipartimento di Scienza e Alta Tecnologia, Univ. of Pavia, Italy; 4Dipartimento di Ingegneria dell’Informazione, Università di Brescia, Italy; 5Univ. of Manitoba, Canada. We demonstrate a novel terahertz radiation-based joint thermal-hyperspectral imaging method for theranostic applications. Hyperspectral imaging of a drug formulation was realized in the stratum granulosum of skin, in the presence of plasmonically heated gold nanoparticles.

ATu3B • Industrial Optical Design & Sensing—Continued

ATu3C.6 • 15:00
Photo-Acoustic Sensor for Detection of Oil Contamination in Compressed Air Systems, Mikael Lassen1, David Baslev-Harder1, Anders Brusch1, Dita Heikens2, Stefan Persijn2, Jan C. Petersen1, *Danish Fundamental Metrology, Denmark; 2VSL - The Dutch Metrology Inst., Thijnseweg 11, Netherlands. We demonstrate an in-situ sensor to detect oil contamination in compressed air complying with the ISO-8573 standard. The sensor is based on the photo-acoustic effect and will be beneficial for a large category of industries.

ATu3B • On-chip Comb Generation II—Continued

ATu3C.7 • 15:15
Design and Fabrication Toward a Shorter, Lightweight Night Vision Goggle Objective Assembly with a Nanolayered Polymer Gradient Refractive Index Lens, Howard Fern1, Michael Panting2, *Peak Nano Optics, USA. A night vision goggle objective is described leveraging a spherical gradient refractive index lens fabricated from polymeric nanolayered materials. The objective achieves a reduction in optical elements to reduce system length 15% and weight 28%.

FTu3A • Design & Sensing—Continued

FTu3A.5 • 15:00
Efficient Broadband Optical Parametric Amplification in Non-Uniform Bulk Crystals, Andrey Markov1, Anna Mazhorova1, Holger Breitenborn1, Andrew Bruhacs1, Matteo Clerici2, Daniele Modotto3, Paolo Di Trapani4, Arkady Mayor5, Francois Vidal1, Roberto Morandotti1, 1Energy, Materials, Telecommunications, INRS, Canada; 2School of Engineering, Univ. of Insubria and CNISM UdR Como, Italy; 3Univ. of Manitoba, Canada. We demonstrate ~50% efficient adiabatic optical parametric amplification in bulk crystals by introducing temperature-gradient phase-matching. We provide details on the choice of temperature profile that maximizes conversion efficiency and increases bandwidth to over 300 nm.

FTu3A.6 • 15:15
30 GHz Frequency Comb Spanning 160 THz in the Near-Infrared, Andrew J. Metcalfe1, Connor Fredrick2, Ryan Terrien1, Scott Papp1, Scott Diddams1, 1Time and Frequency Division, National Inst. of Standards and Technology, USA, 2Physics, Univ. of Colorado - Boulder, USA. We generate a 30 GHz electro-optic frequency comb at 1064 nm and extend its spectral bandwidth to 160 THz through nonlinear spectral broadening. Further, we frequency double the broadened spectrum producing a visible comb which spans over 100 THz.
**FTu3E • Quantum Optics of Single Emitters—Continued**

**FTu3E.7 • 15:00**
High Fidelity Source of a Single Atom in its 2D Quantum Ground State, Pimonpan Sompet1, Yin H. Fang1, Eyal Schwartz1, Matthew D. Hunter1, Jindaratamee Phrompa1, Mikkel F. Andersen1; 1The Dodd-Walls Centre for Photonic and Quantum Technologies, Dept. of Physics, Univ. of Otago, New Zealand. We combine the near-deterministic preparation of a single atom in optical tweezers with magnetically-insensitive Raman sideband cooling, to prepare an atom in its motional ground state with 2D fidelity of ~0.7 for the entire procedure.

**FTu3F • Quantum-Enhanced Measurements—Continued**

**FTu3F.6 • 15:00**
A nonlinear interferometer with intrinsic stability, Joseph M. Lukens1, Nicholas A. Peters2, Raphael C. Pooser3, 1Quantum Information Science Group, Oak Ridge National Lab, USA; 2The Bredesen Center for Interdisciplinary Research and Graduate Education, The Univ of Tennessee, USA; 3Dept. of Physics, The Univ. of Tennessee, USA. We realize a passively stable nonlinear interferometer based on a single parametric amplifier, attaining 99.9% visibility by combining RF modulation and spatial filtering. Our configuration offers new capabilities for robust interferometric sensors.

**FTu3G • Toward Applications of Metasurfaces I—Continued**

**FTu3G.7 • 15:00**
Lasing and Anti-Lasing in a Single Cavity, Xiang Zhang1; 1Univ. of California Berkeley, USA. Using parity-time symmetry, we experimentally realize lasing and anti-lasing at the same equency in a single cavity. Because of the time-reversal property, the demonstrated lasing and anti-lasing resonances share common resonant features such as identical frequency dependence, coherent in-phase response and line spectral resolution. Lasing and anti-lasing in a single device offers a new route for light modulation with high contrast approaching the ultimate limit.

**FTu3H • Active Plasmonics and Nanophotonics—Continued**

**FTu3H.7 • 15:15**
Coupled Metallic Nanolaser Arrays, William Hayenga1, Midya Parto1, Hossein Hodaee1, Patrick LiKamWa1, Demetrios Christodoulides1, Mercedeh Khajavikhan1; 1Univ. of Central Florida, CREOL, USA. Heptamer arrays of coupled metallic nanolasers are demonstrated. The lasers operate in a single transverse and longitudinal mode, have low thresholds, and are capable of generating high output powers.

**FTu3E.8 • 15:15**
Deterministic single-atom array preparation using dynamic holographic optical tweezers, Hyosub Kim1, Woojun Lee1, Jaewook Ahn1, KAIST, Korea (the Republic of). We report a new method to load N=20 single-atoms near-deterministically (90% for 3-by-3 square and 80% for N=19 ring lattice) in 2D lattices, using dynamic holographic optical tweezers implemented with a 2D liquid-crystal spatial-light modulator.

**FTu3F.7 • 15:15**
Single-photon fiber bundle cameras (SFI-CAMs) for quantum enhanced superresolution microscopy, Yonatan Israel1, Ron Tenne1, Dan Onori1, Yaron Silberberg1, Weizmann Inst. of Science, Israel. We present a method that utilizes quantum correlation measurements for multi-emitter sub-diffraction localization in a time-dependent scene. This is demonstrated using a newly developed imaging configuration based on fiber bundle coupled single-photon avalanche detectors.

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**15:30–16:00** Coffee Break and Unopposed Exhibit Only Time, Exhibit Hall 1, 2 & 3

**15:30–16:15** Market Focus Session II: Update on Optics and Photonics Markets and Opportunities, Exhibit Hall Theater

**16:30–17:00** Market Focus Session III: Science Olympiad, Exhibit Hall Theater
Deep UV pulse shaping at 207nm via Frequency domain Nonlinear Optics (FNO), Bruno E. Schmidt1,2, Philipp Lasme1, Bruno E. Schmidt1,2, Christian Bressler1,3, Franz Kaertner1,2; 1The Hamburg Centre for Ultrafast Imaging CUI, Univ. of Hamburg, Germany; 2Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Germany; 3European XFEL GmbH, Germany.

We have observed optical birefringence in neat water induced by single-cycle intense terahertz pulses. The refractive index changes are explained by the electronic space-charge modulation driven by the strong terahertz electric field.

Experimental generation of deep-ultraviolet second-harmonics in an air-silica photonic crystal fiber, Jinhui Yuan1, Zhe Kang2, Feng Li1, Xianting Zhang1, Xinzhu Sang1, 2Beijing Univ. of Technology, China; 3China National Space Agency.

We demonstrate first time pulse characterization with a transient grating FROG at 207nm.
Tuesday, 13:30–15:30

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

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Noninvasive Glucose Measurements in Skin using Mid-IR Quantum Cascade Laser Spectroscopy, Alexandra Weth1, Grant Schultheis1, Anqi Dong1,2, Sabbir Laikat1, Claire Gmach1,3, Princeton Univ., USA; 2Google Inc., USA; 3Princeton Identity, USA. A mobile sensor using a quantum cascade laser and integrating sphere has been implemented to detect glucose noninvasively in human skin. Principal component analysis of the backscattered spectra closely matched the known glucose absorption spectrum.

In vivo Raman Spectroscopic Sensing of Biophysical Changes in Skin Cancer, Xu Feng1, Austin May1, Hieu Nguyen1, Jason Zhang1, Matthew Fox2, Jason Reichenberg2, Mia Markey1, James Tunnell1,2, Department of Biomedical Engineering, Univ. of Texas at Austin, USA; 3Department of Medicine, Dell Medical School, Univ. of Texas at Austin, USA. We developed a biophysical Raman model of human skin and validated it using in vivo clinical screening data. Key biophysical changes were used for fast and accurate diagnosis of melanoma and nonmelanoma skin cancer.

Precision Multiple-access RF Dissemination by Hybrid Frequency Modulation Technique, Yajie Cui1, Tianwei Jiang1, Song Yu1, Chenxia Liu1, Ruohan Wu1, Wanyi Gu1, Bin Luo1, Guohua Wu1,2, Beijing Univ. of Posts and Telecommunications, China. A precise multiple-access radio frequency dissemination scheme with anti-dispersion function by hybrid frequency modulation technique is proposed. The residual phase jitter at arbitrary node is less than 0.034-rad over 50.2-km fiber link.

Comparison of nano particle implantation with picosecond lasers by concerning different wavelengths from Aluminum and Copper on Silicon wafer substrate, Mohammad Hossein Ashadat1, Martin Kasatza1, Hans Joachim Eichler1, Klaus Lang1, Veronika Glaw1,5, PacTech & TU-Berlin, Germany; 5PacTech GmbH, Germany; 6Technical Univ. of Berlin, Germany. Germany Copper and Aluminum have similar reactions in infra-red lasers for nano particle printing and different behavior in frequency doubled lasers. Absorption of two different metals shows various roughness of thin film on silicon wafer substrates.

Full-photonic-assisted ultra-wideband arbitrary waveform generation with extended time aperture for multipath channel sounding and compensation, Bohao Liu1, Praginesh Reddy1, Andrew Werner1, 2Electrical and Computer Engineering, Purdue Univ., USA. Photonic-assisted radio-frequency arbitrary waveform generation via pulse shaping and frequency-to-time mapping is demonstrated with a time-bandwidth product of 250 (34 ns x 7.3 GHz). It is applied to multipath wireless channel sounding and subsequent precompensation.

Comparison of nano particle implantation with picosecond lasers by concerning different wavelengths from Aluminum and Copper on Silicon wafer substrate, Mohammad Hossein Ashadat1, Martin Kasatza1, Hans Joachim Eichler1, Klaus Lang1, Veronika Glaw1,5, PacTech & TU-Berlin, Germany; 5PacTech GmbH, Germany; 6Technical Univ. of Berlin, Germany. Germany Copper and Aluminum have similar reactions in infra-red lasers for nano particle printing and different behavior in frequency doubled lasers. Absorption of two different metals shows various roughness of thin film on silicon wafer substrates.

Invited Relevance of Modeling Laser-Material Interactions in the Industrial Context, Wolfgang Schulz1,2, 3Fraunhofer IIL Aachen, Germany; 4RWTH Aachen Univ., Germany. Implementing a virtual production system is challenging due to machine specific interactions, uncertainties and unknowns. The theory of design oriented thinking adapted for manufacturing favours fast iteration in digitized design cycles instead of optimizing the model quality in one step. A virtual production system is seen to become a set of “digital shadows” emulating relevant properties of the underlying techno-physical systems. Different model reduction techniques are demonstrated resulting in “digital shadows” able to generate dense data by millions of runs within acceptable calculation time.

Sum-Frequency Generation and Photon Pair Creation in AlGaAs Nano-Scale Resonators, Giuseppe Marino1,2, Alexander S. Soltsev1, Lei Xu1, Valerio Gili1, Luca Carletti1, Alexander N. Poddubny1,2, Dania Srimova1, Httao Chen1, Guoquan Zhang1, Anatoly Zayats1, Costantino Angelis5, Giuseppe Leo1, Yur Kivshar2, Andrey Sukhorukov1, Dragomir N. Neshev1,2, Department of Physics, King’s College London, UK; 3Nonlinear Physics Centre, Research School Of Physics and Engineering, Australian National University, Australia; 4Université Paris Diderot – Paris 7, France; 5Dipartimento di Ingegneria dell’Informazione, Univ. of Brescia, Italy; 6Nankai Univ., China. We demonstrate experimentally sum-frequency generation in AlGaAs nano-resonators, establishing a quantum-classical correspondence with spontaneous parametric down-conversion. We predict that AlGaAs nano-resonators can be used as high-rate sources of photon pairs with non-classical correlations.

Label-free Mid-Infrared Photothermal Spectroscopy and Imaging of Neurological Tissue, Atcha Totachawattana1,2, Michael S. Regan1, Nathalie Y. Agar1, Shyamsunder Erramilli1,2, Michelle Y. Sanders1,6, Electrical and Computer Engineering, Boston Univ., USA; 2Photonics Center, Boston Univ., USA; 3Department of Physics, Boston Univ., USA; 4Neuroscience, Brigham and Women’s Hospital, USA; 5Surgery and Radiology, Harvard Medical School, USA; 6Division of Materials Science and Engineering, Boston Univ., USA. We present mid-infrared photothermal spectroscopy for label-free characterization of various healthy and diseased brain tissue types in a mouse model. The photothermal spectroscopy and imaging results allow to quantitatively distinguish between different tissue types.
Tuning the Photon Statistics of a Strongly Coupled Nanophotonic System, Constantin Dory, Kevin Fischer, Kai Müller, Konstantinos Lagoudakis, Tomas Sarmento, Armand Rundquist, Linda J. Zhang, Yousif Kelaita.

We demonstrate the generation of single- and two-photons at a time from a quantum dot-photon crystal resonator system. Controlling the detuning between emitter and cavity allows us to drive a non-linear ladder of hybridized light-matter states.

Towards an Implementation of Superdense Teleportation in Space, Joseph C. Chapman, Trent Graham, Francesco Marsili, Matthew Shaw, Christopher Zeilinger, Paul G. Kwiat.

In our effort to implement superdense teleportation (SDT) from space to earth, we have incorporated Doppler compensation methods and we installed 4 superconducting nanowire detectors so our system can operate efficiently with high loss, showing that we retain the ability to efficiently perform SDT.

Towards Applications of Metasurfaces II, Presider: Alexey Yamitov, Missouri Univ of Science & Technology, USA.


We experimentally demonstrate an ultrafast tunable metasurface consisting of subwavelength gallium arsenide nanoparticles supporting Mie-type resonances, which are all-optically tuned by 30 nm in spectral domain under pump fluences as low as <400 μJ/cm².

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STu4L.1 • 16:00
Single-Shot Optical Recording with Sub-Picosecond Resolution Implementing a Differentiated Semiconductor Nonlinearity, Ryan D. Muri, John E. Heebner, Lawrence Livermore National Lab, USA. We demonstrate a novel optical recording method implementing carrier-based nonlinear optical phase response in semiconductors. The integrating carrier response is mitigated with an all-optical derivative technique. A 50 ps record with sub-ps resolution was demonstrated.

STu4L.2 • 16:15
A Simple, Picojoule Sensitive Ultraviolet Autocorrelator Based on Two-Photon Conductivity in Sapphire, Kenneth Leedle, Karel Urbanek, Robert L. Byer, Stanford Univ., USA. We present a simple autocorrelator for picojoule 220-278 nm pulses from femtosecond-picojoule laser oscillators based on two-photon conductivity in sapphire. The sub-20 W peak power sensitivity is over 10X better than previous UV autocorrelators.

STu4L.3 • 16:30
Noiseless Spectral Amplification of Optical Frequency Combs, Luis Romero Cortes, Reza Maram, Hugues Guillet de Chatel-lus, Jose Azana, INRS-EMT, Canada. We propose a technique capable of increasing the power of the lines of a frequency comb without introducing noise, and demonstrate it by resolving the lines of a comb, originally buried below the background noise.

STu4J • 16:00
A Carrier-offset-stabilized Dual Kerr Microresonator Frequency Comb, Scott Papp; 1NIST, USA. We present a photonic-chip Kerr microresonator frequency comb with carrier-envelope-offset frequency stabilization. The system leverages a dual reduction strategy from optical to microwave frequencies using 1 THz and 22 GHz repetition rate Kerr microcombs.

STu4J.1 • 16:00
16:00–18:00
STu4J • Microcomb Nonlinear Optical Technology
Presider: Yoshitomo Okawachi; Columbia Univ., USA

STu4J.2 • 16:30
Accessing octave-spanning soliton microcomb states in a thermally stable waveguide, Qing Li, Travis C. Briles, Daron Westly, Tara Drake, Jordan R. Stone, Bogdan Ilc, Scott Diddams, Scott Papp, Kartik Srinivasan; 1CNST, NIST, USA; 2Maryland NanoCenter, Univ. of Maryland, USA; 3Time and Frequency Division, NIST, USA. We report the demonstration of octave-spanning soliton microcomb states in high-$Q$ Si$_3$N$_4$ microresonators. These states are shown to be thermally stable and can therefore be accessed with slow frequency tuning of the pump laser.

STu4J.3 • 16:30
Generation of Higher-Order Orbital Angular Momentum in Polarization-Maintaining Fiber, Brendan M. Heffernan, Robert Niederrieter, Mark Siemens, Juliet T. Gopinath; 1SLAC National Accelerator Lab, USA.

STu4K • 16:00
16:00–17:45
STu4K • OAM & Higher-Order Mode Fibers
Presider: Peter Dragic; Univ of Illinois at Urbana-Champaign, USA

STu4K.1 • 16:00
Polarization-maintaining fiber for guiding light in large-effective-area higher-order modes, Raja Ahmad, Jeffrey W. Nicholson, Kaz S. Abedini, Paul W. Westbrook, Clifford Headley, Patrick W. Kild, Eric M. Monberg, Man F. Yan, David J. DiGiovanni; OFS Labs, USA. We present a polarization-maintaining (PM) fiber for higher-order optical modes (HOMs) with effective area 1200–2800 $\mu$m$^2$. The LP$_{01}$(LP$_{01}$) mode exhibits a birefringence of 1.8×10$^{-4}$ (2.4×10$^{-4}$), and propagates with 13(23) dB polarization-extinction ratio over 1(3) m.

STu4K.2 • 16:15
200 nm tunable acousto-optic fiber grating for OAM mode generation in the visible spectral range, Du-Ri Song, Tao He, Lu Yan; Siddharth Ramachandran; 1Boston Univ., USA, 2Beijing Inst. of Technology, China. We demonstrate low loss (0.7 dB) efficient (90%) tunable generation of OAM modes over a range of 200 nm in the visible spectral range using acousto-optic fiber gratings, of utility in numerous applications requiring spectrally diverse OAM light.

STu4K.3 • 16:30
Timing & Synchronization of Lasers at XFELs, Ryan Coffee; 1SLAC, USA. I will show preliminary results for an interference enabled cross-correlation that promises both improved signal levels and high-speed onboard processing that is expected for few-fs synchronization at high repetition rate x-ray free-electron lasers.
**Tuesday, 16:00–18:00**

**Marriott Salon III**

**STu4M • Nonlinear Impairments in Optical Communications**

**Presider:** Takashi Sugihara; Mitsubishi Electric Corporation, Japan

**16:00**

**STu4M.1 • 16:00**

**Invited**

Nonlinear Propagation in Fibers for Space Division Multiplexing, Cristian Antonelli1, Antonio Mecozzi1, Ori Golani2, Mark Shalit1, 1Università degli Studi dell’Aquila, Italy; 2Tel Aviv Univ., Israel. We review the modeling of nonlinear propagation in fibers for Space Division Multiplexing (SDM), and discuss the impact of mode coupling and modal dispersion on the nonlinear interference between the WDM channels of an SDM system.

**16:15**

**STu4M.2 • 16:30**

Impacts of Signal Nonlinearity on 106 & 112 Gb/s PAM4 Transmission, Jinwoo Cho1, Rohit Mittal1, Deepthi Chakilam1, Mahan Movassaghi2, Hai-Feng Liu1, Intel Corporation, USA. We experimentally demonstrate 106 and 112 Gbps PAM4 transmission and quantify the link penalty induced by a nonlinear MZM (Mach-Zehnder Modulator). Less than 0.5 dB penalty requires higher than 90% linearity.

**16:30**

**STu4M.3 • 16:30**

Optomechanics in Bulk Crystalline Phonon Resonators, William H. Renninger1, Prashanta Kharel1, Ryan Behunin1, Peter T. Rakich1, Yale Univ., USA. Shaping photophonon coupling in bulk crystalline solids, we demonstrate a new paradigm for coherent optomechanical interaction with access to high frequency (>10 GHz) ultra-high quality factor (40×10^6) phonon modes. Both experiment and theory are presented.

**STu4M.4 • 18:00**

Optical Vortex with Comb-like Laser Spectra in Yb:YAG/YVO4 Microchip Raman Laser, Jun Dong1, Xiaolei Wang1, Xiaojie Wang1; 1Xiamen Univ., China. Various stable optical vortices with comb-like laser spectra have been generated in Yb:YAG/YVO4 microchip Raman laser. Wide span comb-like laser spectra of 1.98 THz with 30 laser lines around 1.07 μm has been obtained.

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**Marriott Salon IV**

**STu4N • Optomechanics**

**Presider:** Paul Barclay; Univ. of Calgary, Canada

**16:00**

**STu4N.1 • 16:00**

**Invited**

Optomechanical Crystals at Millikelvin Temperatures, Oskar J. Painter1; 1California Inst. of Technology, USA. We will present pulsed optical measurements of silicon optomechanical crystals at millikelvin temperatures. These measurements highlight the exciting new opportunities for application of microwave phononic devices in the quantum realm, but also some of the challenges.

**16:15**

**STu4N.2 • 16:15**

High-Accuracy, Model-Based Near-Field Beam Shaping, Christophe Dorrer1, Jeremy Hassett1; 1Univ. of Rochester, USA. We present the use of a digital micro-mirror device to generate and rapidly switch between vector beams with spatially controllable intensity, phase and polarization. We demonstrate this functionality by creating radially polarized, azimuthally polarized and Poincaré beams at a frame rate of 4kHz.

**16:30**

**STu4N.3 • 16:30**

High-speed Polarisation Shaping of Arbitrary Vector Beams Using a Digital Micro-mirror Device, Kevin J. Mitchell3, Sergey Turtaev2, Miles J. Padgett1, Tomas Czmar1, David B. Phillips1; 1School of Science and Engineering, Univ. of Dundee, UK; 2School of Life Sciences, Univ. of Dundee, UK; 3School of Physics and Astronomy, Univ. of Glasgow, UK. We present the use of a digital micro-mirror device to generate and rapidly switch vector beams with spatially controllable intensity, phase and polarization. We demonstrate this functionality by creating radially polarised, azimuthally polarised and Poincaré beams at a frame rate of 4kHz.

**STu4N.4 • 18:00**

Optical Vortex with Comb-like Laser Spectra in Yb:YAG/YVO4 Microchip Raman Laser, Jun Dong1, Xiaolei Wang1, Xiaojie Wang1; 1Xiamen Univ., China. Various stable optical vortices with comb-like laser spectra have been generated in Yb:YAG/YVO4 microchip Raman laser. Wide span comb-like laser spectra of 1.98 THz with 30 laser lines around 1.07 μm has been obtained.

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**Marriott Salon V & VI**

**CLEO: Science & Innovations**

**16:00**

**STu4O • Spatial and Temporal Beam Control**

**Presider:** Jay Doster; Northrop Grumman, USA

**16:00**

**STu4O.1 • 16:00**

High-Accuracy, Model-Based Near-Field Beam Shaping, Christophe Dorrer1, Jeremy Hassett1; 1Univ. of Rochester, USA. We present the use of a digital micro-mirror device to generate and rapidly switch between vector beams with spatially controllable intensity, phase and polarization. We demonstrate this functionality by creating radially polarized, azimuthally polarized and Poincaré beams at a frame rate of 4kHz.

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**STu4O.2 • 16:15**

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**STu4O.3 • 16:30**

Optical Vortex with Comb-like Laser Spectra in Yb:YAG/YVO4 Microchip Raman Laser, Jun Dong1, Xiaolei Wang1, Xiaojie Wang1; 1Xiamen Univ., China. Various stable optical vortices with comb-like laser spectra have been generated in Yb:YAG/YVO4 microchip Raman laser. Wide span comb-like laser spectra of 1.98 THz with 30 laser lines around 1.07 μm has been obtained.
ATu4A • Spectroscopic Sensing—Continued

ATu4A.4 • 16:45
Localized Surface Plasmon Resonance Platform for Multi-point and Real-time Biosensing, Hana T. Lin1, Chi-Chen Lin1, Nien-Tsu Huang2; 1Graduate Inst. of Biomedical Electronics and Bioinformatics, National Taiwan Univ., Taiwan; 2Dept. of Electrical Engineering, National Taiwan Univ., Taiwan.

We develop a LSPR platform composed of a nanoplasmonic sensor, a spectrometer, and a motorized stage to achieve multi-point and real-time biosensing. The assay can be done in 1 hour with 60 μL sample requirement.

ATu4A.5 • 17:00
Mobile Microscope for Quantitative Fluorescence Sensing Through Highly Autofluorescent and Scattering Media, Zoltan Goric1, Yair Rivenson1,2, Hatice Ceylan Koydemir1,2, Derek Tseng1, Tamara Tray1, Vasiliy Demas1, Aydogan Ozcan1,2; 1Ecole Polytechnique, 2Inst. for Quantum Technology, 3MIT, USA.

We present a mobile fluorescence microscope weighing <40 grams and demonstrated a computational sensing method for quantitative measurement of fluorescent dyes through highly autofluorescent, scattering and absorbing tissue phantom.

ATu4A.6 • 17:15
CMOS-based Fluorescence Biosensor with Integrated Nanoplasmonic Filters, Lingyu Huang1, Kaushik Sengupta2; 1Princeton Univ., 2Ecole Polytechnique.

In this work, we present the first integrated biosensor chip, fabricated in standard CMOS technology with integrated copper-based nanoplasmonic filters that allows elimination of all external optical instruments and encompasses the sensing platform, sensors, scanner in a mm-sized CMOS chip.
Efficient deterministic giant photon phase shift from a single charged quantum dot, Petros Androvitsianus1, Andrew Young1, Joseph Lennon1, Christian Schneider2, Sebastian Maier1, Janna Hinchliff1, George Akinson1, Edmund Harbord1, Martin Kamp1, Sven Hoelfling1, John Rarity1, Ruth Oulton1, 1Univ. of Bristol, UK; 2Universität Würzburg, Germany; 3Univ. of St Andrews, UK. We demonstrate a deterministic shift in phase of an input single photon by a negatively charged quantum dot in a low Q-factor, high output efficiency micropillar cavity, with values up to 2/π.

Bright and Coherent On-Chip Single Photons from a Very High Purcell Factor Photonic Crystal Cavity, Alistair Brash1, Feng Liu1, John O’Hara1, Luis Martins1, Rikki J. Coles1, Catherine L. Phillips1, Ben Royall1, Christopher Benthaim2, Igor E. I. Tsuknev1, Luke Wilson1, Maurice S. Skolnick1, Mark Fox1, 1Dept. of Physics and Astronomy, Univ. of Sheffield, UK; 2School of Engineering and Computer Science, Univ. of Hull, UK. Using a novel two-pulse resonance fluorescence technique we demonstrate a Purcell factor of ~35 in a cavity quantum dot system. Highly coherent single photons are efficiently emitted into a waveguide, forming a near-ideal source for integrated quantum circuits.

Photoluminescence imaging based nanopositioning of single quantum dots for near-optimal single-photon emission. Jin Liu1,3, Yu-ming He2, Luca Sapienza4, Mohammad Memarian1, John Reno3, Tat-suo Itoh1, Benjamin Williams1,2, Mohammad Memarian1, John Reno1, Tat-suo Itoh1, Benjamin Williams1,2, 1Dept. of Electrical Engineering, Univ. of California, Los Angeles, USA; 2California NanoSystems Inst., Univ. of California, Los Angeles, USA; 3Sandia National Labs, Center of Integrated Nanotechnologies, USA. We report a terahertz metasurface terahertz laser with electronically-controlled polarization, Degun Chen1, Luyao Xu1, Christopher Curwen1, Mohammad Memarian1, John Reno1, Tat-suo Itoh1, Benjamin Williams1,2; 1Dept. of Electrical Engineering, Univ. of California, Los Angeles, USA; 2California NanoSystems Inst., Univ. of California, Los Angeles, USA; 3Sandia National Labs, Center of Integrated Nanotechnologies, USA. We report a terahertz metasurface terahertz laser without moving parts that can electronically switch between two orthogonal linearly polarized outputs. It exhibits excellent beam pattern, single-mode operation, and power up to 93 mW at 77 K.

Random Perfect Absorption in 2D Atomic Layers on All-Dielectric Substrates Mediated by Anderson Localization, Judson Ryckman1, 1Holcombe Dept. of Electrical and Computer Engineering, Clemson Univ, USA. We present an approach for achieving perfect absorption in 2D atomic layers utilizing randomized dielectric layers. The emergence of high Q optical modes featuring >99.9% absorption in single-layer graphene is shown.
How Short should your Nonlinear Crystal be for Pulse Diagnostic?, Ning Hua1, Jean-Claude M. Diels1, Univ. of New Mexico, USA. Ultrashort pulse diagnostic require a nonlinear crystal satisfying the conflicting requirements of fidelity in reconstruction and efficiency. It is shown that correct autocorrelations can be obtained with longer crystals than generally assumed.

Single-Shot Measurement of Temporally-Dependent Polarization State of Femtosecond Pulses by Angle-Multiplexed Spectral-Spatial Interferometry, Ming-wei Lin1, Igor Jovanovic1, Inst of Nuclear Engineering and Science, National Tsing Hua Univ., Taiwan; 2Dept. of Nuclear Engineering and Radiological Sciences, Univ. of Michigan, USA. Various temporally-dependent polarization states of ultrashort laser pulses have been reconstructed in a single shot measurement by angle-multiplexed spatial-spectral interferometry.

High Resolution Single-shot Time Stretch Spectroscopy with Wavelength Demultiplexer at One Billion Frames per Second, Takeshi Makino1, Hideaki Furukawa1, Mohammad Asghar1, Paul Trinh1, Bahram Jalali1, Xiaomin Wang1, Tetsuya Kobayashi4, Wai Rees McNally5, Alessandro Farsi2, Alexander Klenner2, Michal Lipson3, Alexander L. Gaeta1, Applied and Engineering Physics, Cornell Univ., USA; 2Aston Inst. of Photonic Technologies, Aston Univ., UK; 3Electrical Engineering, Columbia Univ., USA; 4School of Electrical and Computer Engineering, Cornell Univ., Namibia; 5Dept of Physics, Columbia Univ., USA. We introduce a wavelength demultiplexing solution or capturable pulse-repetition-rate, ultrafast interferometry. Three shot spectrum measurement based on time scanning enables exploration of Kerr-comb and mode-structure imperfection effects.

The talk describes the status, recent progress and near future plans in the Free-Electron Laser Science, Germany; 2Cycle GmbH, Germany; 3The Hamburg Center for Ultrafast Imaging, Hamburg Univ., Germany. We report the generation of radially polarized laser pulse from a gain-switched diode-seeded Yb-doped fiber MOPA system delivering 100ps pulses at a repetition rate of 1.367MHz with up to 25.8μJ pulse energy.

Large-Scale Turnkey Timing Distribution System for Attosecond Photon Science Facilities, Kemal Shafak1,2, Haynes Pak1,2, Johann Denkri1,2,1, Kai H. Park1,2, Erwin Cano1, Anan Dai1, Dariusz Fodor2,1, Aram Kalaydzhyan1, Joachim Meier1,2, Wahid Nasimzadah1, Matthias Neuhaus1, Philipp Schiepel1, Eduard Seibel1, Thomas Tilp1, Franz Kaertner1,2, Center for Free-Electron Laser Science, Germany; 2Cycle GmbH, Germany; 3The Hamburg Center for Ultrafast Imaging, Hamburg Univ., Germany. We have demonstrated an all-fiber erbium fiber laser using few-mode fiber long-period grating and carbon nanotube for cylindrical vector beam generation. We have demonstrated an all-fiber erbium laser incorporating a few-mode fiber long-period grating passively Q-switched by carbon nanotube for cylindrical vector beam generation. The laser can output both radially and azimuthally polarized beams.

High energy, radially polarized picosecond laser pulses from a Yb-doped fiber MOPA, Di Lin1, Neda Baktash1, Shaf-ul Alam1, David Richardson1, Univ. of Southampton, UK. We demonstrate the generation of radially polarized laser pulse from a gain-switched diode-seeded Yb-doped fiber MOPA system delivering 100ps pulses at a repetition rate of 1.367MHz with up to 25.8μJ pulse energy.

Laser-based Soft X-ray FEL Seeding: Recent Advances and Outlook at FERMI, Mitcho B. Danailov1, Paolo Cinquegrana1, Alexander Demidovich1, Gabor Kural2, Iaylo Nikolov2, Paolo Siglottii3, Elettra-Sincrotrone Trieste S.C.P.A., Italy. The talk describes the status, recent progress and near future plans in the Free-Electron Laser seeding by ultrashort UV pulses implemented at FERMI as a root to generate XUV pulses with very exciting properties.
**STu4M • Nonlinear Impairments in Optical Communications—Continued**

**STu4M.3 • 16:45**
Nonlinear Fourier Based Spectral Filtering, Morteza Kamalian Kopae1, Jaroslaw E. Prilepsky1, Stanislaw A. Derevyanko2, Son T. Le3, Sergei Tunitsyn1; 1Aston Inst. of Photonic Technologies, Aston Univ., UK; 2Electrical and Computer Engineering, Ben-Gurion Univ. of the Negev, Israel; 3Nokia Bell Labs, Germany. The new concept of filtering the nonlinear spectrum of signal in order to reduce the noise-induced signal degradation is introduced and, as the result, the performance improvement at high powers is demonstrated.

**STu4M.4 • 17:00**
Nonlinearity-tolerant modulation formats at 3.5 bits/symbol, Keesuke Kojima1, Tsuyoshi Yoshida1, Toshiaki Kaike-Akino1, David S. Millar1, Keesuke Matsuda2, Kieran Parsons1; 1Mitsubishi Electric Research Labs, USA; 2Information Technology R&D Center, Mitsubishi Electric Corp., Japan. We propose two nonlinearity-tolerant high dimensional modulation formats at 3.5 bits/symbol, which can also be an alternative for PS-QPSK (3 bits/symbol) or DP-QPSK (4 bits/symbol).

**STu4N • Optomechanics—Continued**

**STu4N.3 • 16:45**
Optimal Coupling in Cavity Optomechanical Systems, Marcel W. Pruessner1, Todd H. Stievater1, Doewon Park1, Christopher L. Panuski1, William S. Rabinovich3; 1US Naval Research Lab, USA; 2U.S. Naval Academy, USA. We analyze a cavity optomechanical system suitable for foundry-level fabrication. Contrary to many structures, in which only the cavity design is optimized, we find an optimal coupling strength resulting in maximized optomechanical interaction and readout.

**STu4N.4 • 17:00**
Optomechanics with hybrid carbon nanotube resonators, Alexandros Tavernarakis1, Alexandros Stavrinidis1, Alex Nowak1, Ioannis Tsoulos1, Adrian Bachold1, Pierre Verlet1,2; 1ICFO, Spain; 2Institut Lumiere Matiere, France. In this paper we report our first experimental results towards the establishment of a novel optomechanical platform consisting of a hybrid, carbon nanotube-based mechanical resonator.

**STu4O • Spatial and Temporal Beam Control—Continued**

**STu4O.3 • 16:45**
Selective Spatial Mode Excitation and Amplification in Ho:YAG Single Crystal Fiber, Yuan Li1, Wenzhe Li2, Keith Miller1, Eric Johnson2, Craig Nie3, James A. Harrington2; 1Clemson Univ., USA; 2Rutgers Univ., USA. Different spatial modes, LP01, LP11, and LP12, were successfully excited and amplified in a 0.5% Ho:YAG single crystal fiber (SCF) amplifier fabricated by the laser heated pedestal growth (LHPG) method at 2 μm.

**STu4O.4 • 17:00**
An Apodized-Imaged Hartmann Mask for Quantitative Wavefront Measurements in Laser Systems, Christophe Dorrer1, Adam Kalb1, Kyle Gibney1, Archana Sharma1, Seung-Whan Bahk1; 1Univ. of Rochester, USA. A Hartmann mask with apodized holes is demonstrated for in-situ wavefront characterization in laser systems with existing near-field imaging diagnostics. Spatially dithered binary pixelated apertures alleviate diffraction effects and improve the measurement accuracy.

**STu4O.5 • 17:15**
An Invited Talk Nonlinearity-tolerant modulation for 3.5 bits/symbol, Keesuke Kojima1, Tsuyoshi Yoshida1, Toshiaki Kaike-Akino1, David S. Millar1, Keesuke Matsuda2, Kieran Parsons1; 1Mitsubishi Electric Research Labs, USA; 2Information Technology R&D Center, Mitsubishi Electric Corp., Japan. We propose two nonlinearity-tolerant high dimensional modulation formats at 3.5 bits/symbol, which can also be an alternative for PS-QPSK (3 bits/symbol) or DP-QPSK (4 bits/symbol).

**STu4O.6 • 17:15**
Gain-dependent Self-phasing in a Coherently Combined Fiber Laser with Imbalanced Losses, Mint Kunkel1, James R. Leger1; 1Univ. of Minnesota, USA. The individual beams in a coherently combined two-core fiber laser are influenced by mismatched loss and phase. Interplay between the gain dependent (Kramers-Kronig) phase and gain saturation determines the complex fields. Experiment and theory are compared.
SiO2 Platform, Integrated Photonic Waveguides on Al2O3/SiO2 platform are proposed to cover the 220-320nm wavelength-range, which is of paramount significance in protein and nucleic acid quantification. The proposed system requires 500x less volume of solutions compared with NanoDrop™.

A small aperture terahertz chip for ultra-trace blood glucose level measurement, Kazunori Senita1, Kosuke Okada1, Iwao Kawayama1, Hironaru Murakami1, Masayoshi Tonouchi1; 1Osaka Univ., Japan. A small aperture terahertz chip was demonstrated for ultra-trace human blood measurement. The obtained refractive index decreases with an increase of blood glucose level and shows our chip can be worked as a terahertz glucometer.

Electrically tunable whispering gallery mode resonator based on nematic-liquid-crystal-infiltrated silica capillary, Chengkun Yang1, Bo Liu1, Hao Zhang1, Haifeng Liu1; 1Inst. of Modern Optics, Nankai Univ., China. A tunable whispering gallery mode (WGM) resonator based on nematic-liquid-crystal-infiltrated silica capillary is presented in this paper. WGM wavelength shift is achieved by exploiting the birefringence effect of liquid crystal triggered by applied electric field.

The Coloring and Color Enhancement of Noble Metals via Multi-Burst Picosecond Pulses, Jean-Michel Guay1, Antonio Cala-Lesina2, Joshua Baxter1, Peter Gordon2, Sean Barry2, Lora Ramunno1, Pierre Berini1, Cala’Lesina1, Joshua Baxter1, Peter Gordon2, Sean Barry2, Lora Ramunno1, Pierre Berini1; 1Univ. of Ottawa, Canada; 2JILA, Univ. of Colorado & NIST, USA. We report on the fast angle-independent coloring of noble metals. We show the passivation and color tuning of the colored surfaces via the deposition of thin layers of aluminum oxide by atomic layer deposition (ALD).

A thermal and a two-temperature model (TTM) describing femtosecond laser-material interactions are compared. Both models accurately describe thermal response of silicon to multi-pulse irradiations, while the TTM distinguishes between thermal and nonthermal regimes. Four-wave-mixing spectroscopy based on optical frequency combs. We use a co-linear excitation geometry and demonstrate separation of the linear and four-wave-mixing signals using heterodyne detection with a local oscillator comb.

Comparison of Two-Temperature and Thermal Models for Prediction of the Optimal Femtosecond Laser-Material Processing of Silicon, Ryan E. Scott1, Lauren L. Taylor1, Jie Qiao1; 1Rochester Inst. of Technology, USA. A thermal and a two-temperature model (TTM) describing femtosecond laser-material interactions are compared. Both models accurately describe thermal response of silicon to multi-pulse irradiations, while the TTM distinguishes between thermal and nonthermal regimes.

The coloring and color enhancement of noble metals via multi-burst picosecond pulses, Jean-Michel Guay1, Antonio Cala-Lesina2, Joshua Baxter1, Peter Gordon2, Sean Barry2, Lora Ramunno1, Pierre Berini1, Cala’Lesina1, Joshua Baxter1, Peter Gordon2, Sean Barry2, Lora Ramunno1, Pierre Berini1; 1Univ. of Ottawa, Canada; 2JILA, Univ. of Colorado & NIST, USA. We report on the fast angle-independent coloring of noble metals. We show the passivation and color tuning of the colored surfaces via the deposition of thin layers of aluminum oxide by atomic layer deposition (ALD).

Demonstration of Local Teleportation Using Classical Entanglement, Diego Guzman-Silva1, Robert Brunning1, Felix Zimmermann1, Christian Vetter1, Markus Gräfe1, Matthias Heinrich1, Stefan Nolte1, Michael Duparré1, Andrea Aviello1, Marco Ormigotti1, Alexander Szameit2; 1Friedrich–Schiller-Universität Jena, Germany; 2Max Plank Inst. for the Science of Light, Germany; 3Univ. of Rostock, Germany. We report on an optical implementation of the teleportation protocol in the classical realm, solely based on entanglement between spatial and modal degrees of freedom of a purely classical light field.

FTu4D.8 • 17:45
Four-Wave-Mixing Comb Spectroscopy, Bachana Lomsadze1,2, Steven T. Cundiff1,2; 1Univ. of Michigan, USA; 2JILA, Univ. of Colorado & NIST, USA. We experimentally demonstrate four-wave-mixing spectroscopy based on optical frequency combs. We use a co-linear excitation geometry and demonstrate separation of the linear and four-wave-mixing signals using heterodyne detection with a local oscillator comb.

FTu4D.7 • 17:30
Demonstration of Local Teleportation Using Classical Entanglement, Diego Guzman-Silva1, Robert Brunning1, Felix Zimmermann1, Christian Vetter1, Markus Gräfe1, Matthias Heinrich1, Stefan Nolte1, Michael Duparré1, Andrea Aviello1, Marco Ormigotti1, Alexander Szameit2; 1Friedrich–Schiller-Universität Jena, Germany; 2Max Plank Inst. for the Science of Light, Germany; 3Univ. of Rostock, Germany. We report on an optical implementation of the teleportation protocol in the classical realm, solely based on entanglement between spatial and modal degrees of freedom of a purely classical light field.
Mode switching in bimodal microcavities and its connection to Bose condensation, Heinrich A. Leymann2, Daniel Vorberg1, Thomas Lettau1, Caspar Hofmann1, Christian Schneider1, Martin Kamp1, Sven Höfling1, Roland Ketzmerick2, Jan Wiersig2, Stefan Reitzeinstein1, Andre Eckardt1, 1Max Planck Inst. for the Physics of Complex Systems, Germany; 2Inst. for theoretical physics, Otto-von-Guericke Univ. Magdeburg, Germany. We introduce an analytical theory for mode switching in a microcavity, which shows excellent agreement with experiment and numerics. This switching process is triggered by the intermode kinetics and resembles the physics of Bose condensation.

Stabilization of Long, Deployed Optical Fiber Links for Quantum Networks, Matthew E. Grein1, Mark L. Stevens1, Nicholas D. Hardy1, P. B. Dixon1, 1Massachusetts Inst. of Tech Lincoln Lab, USA. We implemented an active feedback loop to compensate path-length drift on a deployed ~84-km-long optical fiber link between Lincoln Lab and MIT to enable quantum networking measurements and applications.

Effect of Strong Coupling on Photodegradation of the p3HT Semiconducting Polymer, Vanessa N. Peters1, M. O. Faruk1, Rohan Alexander1, D’Angelo A. Peters1, Mikhail Noginov2, 1Norfolk State Univ, USA, 2School of Engineering, Univ. of Michigan, USA. We have studied photodegradation of the semiconducting polymer p3HT in the resonant cavity and the control samples. The nearly three-fold reduction of the reaction rate is attributed to the strong polymer-cavity coupling.

Directly Intensity-Modulated Quantum Key Distribution, George L. Roberts1, Marco Lucamarini2, James F. Dynes1, Seb J. Savory1, Zhihong Yuan1, Andrew J. Shields2, 1Engineering Dept., Cambridge Univ, UK, 2Toshiba Research Europe Limited, UK. The coherent one-way (COW) protocol is implemented using direct laser modulation, with security enabled by optical injection locking. This method generates secure keys at rates above 1 Mbit/s with interference visibilities over 98 %.

Active Metamaterials Based on Monolayer Titanium Carbide MXene for Random Lasing, Zhuxian Wang1, Xiangeng Meng1, Krishnakai Chaudhuri1, Mohamed Alhabeb1, Shaibam I. Azzam1, 1Purdue Univ., USA; 2Dept. of Materials Science and Engineering, and Birck Nanotechnology Center, Purdue Univ., USA. We present an approach employing a random metamaterial constructed by dispersing monolayer Ti3C2 nanoflakes into the gain medium for achieving random lasing. The optical feedback is suggested to be provided by Ti3C2 nanoflakes through saturable absorption.

Broadband hot electron generation for solar energy conversion with plasmonic titanium nitride, Alberto Naldoni1,2, Uncan Guler1, Zhuoxian Wang3, Marcello Marelli1, Francesco Malara1, Xiangeng Meng1, Lucas V. Besteiro1, Alexander O. Govorov3, Alexander V. Kildishev1, Vladimir M. Shalaev1, 1CNR-Istituto di Scienze e Tecnologie Molecolari, Italy; 2School of Electrical & Computer Engineering and Birck Nanotechnology Center, Purdue Univ., USA; 3Dept. of Physics and Astronomy, Ohio Univ., USA. Plasmonic TiN decorated TiO2 nanowires support 4 times larger generation of over-barrier hot electrons than the Au/TiO2 system resulting in an enhanced photovoltaic splitting activity due to TiN broader plasmonic resonance and improved interface properties.
STu4I • Ultrafast Metrology II—Continued

STu4J • Microcomb Nonlinear Optical Technology—Continued

STu4K • OAM & Higher-Order Mode Fibers—Continued

JTu4L • Symposium on Ultrafast Laser Technology for X-ray Free Electron Lasers II—Continued

17:00–18:30 Meet the OSA Editors’ Reception, Market Terrace
### Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

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| **STu4N.6** • 17:30  
Non-reciprocal Optomechanical Modulator, Donggyu B. Sohn1, Junhwan Kim1, Gaurav Bahl1; 1Univ. of Illinois, USA. We experimentally demonstrate non-reciprocal optical modulation using piezoelectric optomechanics. Non-reciprocity is achieved by breaking time-reversal symmetry for the light propagation in an optical resonator by unidirectionally traveling acoustic wave. |
| **STu4N.7** • 17:45  
Direct Stabilization of Optomechanical Oscillators, Ke Huang1, Mani Hossein-Zadeh1; 1Univ. of New Mexico, USA. We demonstrate a simple and effective technique for stabilization of optomechanical oscillators. We show that using oscillation amplitude and laser detuning as the feedback and control parameters provide long term stability and reduce system complexity. |
| **STu4O.7** • 17:30  
Multi-Joule, Sub-200ps Laser Pulse Generation via SBS Sub-Phonon Lifetime Pulse Compression, Chengyong Feng1, Xiaozhen Xu1, Jean-Claude Diels1; 1Univ. of New Mexico, USA. Multi-Joule level SBS sub-phonon lifetime pulse compression is demonstrated with a energy-scalable generator-amplifier setup to obtain 1.3J, 170ps (close to half of the phonon lifetime) laser pulses at 532nm. |
| **STu4O.8** • 17:45  
Coherent Enhancement of 10 µs Burst-Mode Ultraviolet Pulses at Megawatt Peak Power, Abdurahim Rashman1, Yun Liu1; 1Oak Ridge National Lab, USA; 2Univ. of Tennessee, USA. A doubly-resonant optical cavity and its locking technique have been developed to achieve coherent enhancement of 402.5-MHz, 50-ps, megawatt peak power ultraviolet (355 nm) laser pulses operating at a 10-µs/10-Hz burst mode. |

**17:00–18:30 Meet the OSA Editors’ Reception, Market Terrace**
**JTu5A.1** An Ultra-High Sensitive Biosensor using Dual Resonance Long Period Grating in a Metal Clad Ridge Waveguide, Nabanir Saha1, Arun Kumar1; 1Indian Inst. of Technology, Delhi, India. We propose and analyze an ultrahigh sensitive bio-sensor using long period grating near dispersion turning point in a metal clad ridge waveguide showing a refractive index sensitivity of 12µm/RIU for watery solutions at telecommunication wavelength.

**JTu5A.2** Coherent Raman spectroscopy with a graphene-synchronized all-fiber laser, Daniel Popa1, Daniele Viola2, Giancarlo Soavi1, Bo Fu1, Luca Lombardi1, Stephen Hodge1, Dario Polli1, Tullio Scopigno1, Giulio Cerullo1, Andrea Ferrari1; 1Engineering, Univ. of Cambridge, UK; 2Physics, Politecnico di Milano, Italy; 3Physics, Univ. Sapientia, Italy. We demonstrate a wavelength-tunable all-fiber, graphene-synchronized all-fiber laser with Yb and Er cavities spanning 1040-1080 and 1535-1560 nm, corresponding to ~2750 - 3200 cm⁻¹ frequency detuning. We apply the laser to coherent anti-Stokes Raman spectroscopy.

**JTu5A.3** Ex vivo study of diffusion of indocyanine green (ICG) in cow retinal layers using optical coherence tomography, Changhto Lee1, Soohyun Lee2, J. Jeremy Chae1, Gyeongwoo Cheon1, Berk Gonenc3, Peter L. Gehlbach1, Ana2, Carolina Benetti2, Luciano Bachmann3, Patricia A. Liao1,2, Derly A. Sanchez1, Martini Kossatz1, Hans Joachim Eichler1, Xiaoming Yang1, Jarno N. van der Kolk1, Antonino Cala1; 1IPEN - CNEN-SP , Brazil; 2Universidade de Sao Paulo, Brazil; 3Faculdade de Filosofia, Ciencias e Engenharia, Universidade Federal do ABC, Brazil. ICG fluorescence imaging of an eye is developed and tested.

**JTu5A.4** Biochemical Evaluation of Bone Submitted to Ionizing Radiation by ATR-FTIR Spectroscopy, Pedro A. Castro1,2; 1Hebrew Univ. of Jerusalem, Israel; 2Technion-Israel Inst. of Technology, Haifa, Israel. The fast transiting atoms, the roll-off frequency of possible applications is considered.

**JTu5A.5** Structural Characterization of Dentin Irradiated with Er,Cr:YSGG Laser and Fluoride for Caries Prevention, Patricia A. Ana1, Carolina Benetti1, Luciano Bachmann1, Denise M. Zelle1; 1Center for Lasers and Applications, IPEN-CNEN-SF, Brazil; 2Center for Engineering, Modelling and Applied Social Sciences, Universidade Federal do ABC, Brazil; 3Faculdade de Filosofia, Ciencias e Letras de Ribeirao Preto, Universidade de Sao Paulo, Brazil. Er,Cr:YSGG laser induces the formation of bioactive calcium phosphate, as well as decreases the content of protein and water on dentin tissue, even when associated with a fluoride gel and at low energy densities.

**JTu5A.6** Effects of Reflective Index Mismatch on Stimulated Raman Scattering and Coherent Anti-Stokes Raman Scattering Microscopy, Jiyang Chen1,2, Antonio Cala1, Lora Ramunno1; 1Univ. of Ottawa, Canada; 2SRS and CARS microscopy images are distorted by near-field enhancements and microscoping depending on object shape, producing microm shifts in image position and up to an order of magnitude signal enhancement.
existing sources cease to function above

Realization of Quantum information and

Yang Li1, Phillip Camayd-Munoz 1, Cleaven

Mike J. Ford 1, Igor Aharonovich 1, Milos

Weiping Zhang2;

or spin-selective atom mirror for the incident

We propose a scheme to realize spin-

C. Pooser1, Nick Black2, Miller Eaton3, Benja-

Raphael

Diamond Metamaterials,

JTu5A.26

tum emitters efficiently and can transport

We report progress of the self-

Mehran Kianinia 1, Sherif

Robust Solid State Quantum System Op -

adiabatic passage through a dark state with

is used for the implementation of shortcut to

progress of the self-

1Univ. of technology Sydney, Australia.

1Quantum Information Science

1East China Normal Univ.,

1Univ. of Oregon, USA.

1Northwestern Univ., USA.

1Univ. of technology Sydney, Australia.

1Univ. of Oregon, USA.

1Harvard Univ.,

133

1MIT, USA.

1Univ. of Tsukuba, Japan.

1The Univ. of Tokyo, Japan;

1Univ. of Tsukuba, Japan. Weyl points existing below the line light are numerically demon-

strated in semiconductor-based simple chiral

structures intended for near-infrared optical applications. Corresponding topologically-

protected edge states are well-certified even at the vacuum interface.

JTu5A.43

effect of Nonlocal Metal-Dielectric Envi -

roment on Concentration Quenching of HITC Dye, Srujana Prayarakos, Carl E.

Bonner, Mikhail A. Noginov; ’Norfolk State Univ., USA. We have experimentally demonstrated the inhibition of luminescence

self-quenching in heavily doped HITC-PDMA polymeric films in vicinity of lamellar metal-

dielectric metasurfaces with hyperbolic dispersion and metallic surfaces.

JTu5A.44

Quantum Features of Optical Metatronics, Yakov Lumer, Ingo Liberbra; Nader Enge -
	a; 1Univ. of Pennsylvania, USA. We present a quantum circuit model for the description of charges and fields around a nanosphere in the context of optical metatronics. We calculate quantum charge fluctuations and note an excellent agreement with full-wave model.

JTu5A.45

Nonlinear Metamaterials: Breaking the Dipole Approximation, Omri Wolf, Yuanna Yang, ’Igal Brener; ’sandia national labs, USA. Second order nonlinearity vanishes for centrosymmetric materials in the dipole approximation. For metamaterials this second-harmonic generation is negligible in highly symmetric meta-atoms. We show a new type of meta-atom in which the dipolar approximation breaks down.
JTuA.46 Statistical Measures of Spatial and Spectral Contrast in Binary Aperiodic Nanostuctures, Yu-Chun Hsueh 1, Kevin J. Webb 2, 1Purdue Univ., USA. We describe the influence of the large number of degrees of freedom from a binary nanostucture using a multivariable statistical method. This analysis provides design guidelines to achieve spatial and spectral field control for applications.

JTuA.47 Plasmon ultraviolet laser using patterned hyperbolic metamaterials, Kun-Ching Shen 1, Din-Ping Tsai 1, Yuh-Jen Cheng 1, 1Academia Sinica, Taiwan. An ultraviolet plasmonic nanolaser was demonstrated using a patterned hyperbolic metamaterials (HMM) on AlGaN MQWs. The excited strong SPP resonance in the HMM structure provides a resonant feedback to the MQWs to reach lasing action.

JTuA.48 Fiber-Metasurface for Wavefront Shaping, Zeba Naqvi 1, Christopher Rosenbury 1, Michael Fiddy 1, Ting-Hua Her 1, 1Univ. of North Carolina at Charlotte, USA. An array of embedded subwavelength fibers is proposed as a flexible, large-scale and mass-productive metasurface for wavefront shaping. As a proof of concept, we numerically demonstrate beam deflector, focusing optics, high reflector and sinusoidal wavefront shaping.

JTuA.49 Longitudinal Shaping of Subwavelength Infrared Beams using Plasmonic Bulk-eye Structure with Concentric Slits, Ahmed Dorrah 1,2, Arthur Q. Montazemi 1, Hoi-Ying Holman 1, Mo Majahedi 1, 1Univ. of Toronto, Canada; 2Berkeley Synchrotron Infrared Structural Biology (BSIB) Program, Lawrence Berkeley National Lab, USA. We report on a bulk-eye gold nanostructure which focuses infrared beams into subwavelength scale with the ability to shape the longitudinal intensity profile and the focal length, thus addressing many challenges in label-free imaging, nanolithography, and biomedical applications.

JTuA.50 Tailored Supercontinua via Spatial Beam Shaping, Alexandra Zhdanova 1, Yujie Shen 1, Jonathan Thompson 1, Marlan Scully 1, Vladimir Yakovlev 1, Alexander Sokolov 1, Texas A&M Univ., USA. We show that programable phase-only spatial optimization of the pump beam leads to significant broadening and flexible tunability of the supercontinuum spectrum without loss of input energy.

JTuA.51 Observation of a Parity-Time-Symmetry Phase Transition in a Fiber Cavity, Ali Kazemi Jahromi 1, Abdus U. Hassan 1, Demetrios Christodoulides 2, Ayman F. Abouraddy 1, 1Univ. of Central Florida, CREOL, USA. We predict and experimentally demonstrate that the lasing threshold can be lowered by virtue of PT-symmetry, and for the first time observe PT-symmetry-breaking in a long fiber cavity despite the presence of random phase fluctuations.

JTuA.52 Observation of Coherent Perfect Absorption in a Short-Length Weakly Absorbing Fiber, Ali Kazemi Jahromi 1, Ayman F. Abouraddy 1, 1Univ. of Central Florida, CREOL, USA. We predict and experimentally confirm that a moderately-doped few-centimeter-long fiber can completely absorb an incoming beam, if the fiber is placed in a properly-designed cavity that satisfies the requirements for coherent perfect absorption.

JTuA.53 Ferromagnetic-like Mode-locking Transition with Replica Symmetry Breaking in Nd:YAG Laser,Andre de Lima Moura 1, Pablo Pinheiro 1, Ernesto Raposso 1, Anderson Gomes 1, Cid de Araujo 1, Campus Araripina, Universidade Federal de Alagoas, Brazil; 1Departamento de Fisica, Universidade Federal de Pernambuco, Brazil; 2Laboratorio de Fisica Teorica e Computacional, Universidad Federal de Pernambuco, Brazi. We demonstrate the replica symmetry breaking (RSB) in the ferromagnetic-like mode-locking regime of multimode Nd YAG lasers. This photonic phase, distinct of the RSB in random lasers, illustrates the universal character of the phenomenon in lasers.

JTuA.54 Disorder driven spectral features of lasing in an Anderson localizing optical fiber, Belham Alabe 1, Esmail Mobini 1, Salman karbasi 1, Thomas Hawkins 1, John Ballato 2, 1Univ. of New Mexico, USA; 2Air Force Research Lab, USA; 3UES,Inc., USA. We report examples of an image produced by difference frequency generation on one and the same side of a metasurface independently of the source location. Directionally-selective extinguishing of nonlinearly-generated multipolar modes is also shown numerically.

JTuA.55 Relative Performance of One-Dimensional Nonlinear Plasmonic Structures, C. Martin de Stefano 1, Guangyan Li 1, Stefano Palomba 1, 1Univ. of Sydney, Australia. Plasmonic structures are promising for nonlinear optics because they strongly confine light. Many group velocity models have been proposed but their relative merits remain under-explored. We compare different one-dimensional plasmonic structures and contrast with dielectric ones.

JTuA.56 Nonperturbative Orbital Angular Momentum Buildup of Extreme-Ultraviolet Vortex Beams, Laura rega 1, Julio San Román 1, Antonio Picon 1, Luis Plaza 1, Carlos Hernandez-Garcia 1, Universidad de Salamanca, Spain. Extreme-ultraviolet vortices are produced from the nonlinear conversion of infrared twisted beams through high-harmonic generation (HHG). The nonperturbative nature of HHG engenders an unexpectedly rich scenario for the orbital angular momentum buildup in extreme-ultraviolet vortices.

JTuA.57 Localized Photonic Modes at Synthetic Light Interfaces, Anttoni Pankov 1, Ilya Vatnik 1, Dmitriy V. Churkin 1, Andrey Sukhorukov 1, 1Novosibirsk State Univ., Russia; 2Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National Univ., Australia. We predict novel localized modes supported by surface magnetic currents at interfaces between lattices with different synthetic gauge fields of identical photonic band-gaps, and formulate their implementation in fiber loop mesh lattices with phase modulators.

JTuA.58 Parity-Time-Symmetric Fiber Ring Laser, Sergey Smirnov 1, Maxim Makarenko 1, Sergey Suchkov 1, Ilya Vatnik 1, Dmitriy V. Churkin 1, Andrey Sukhorukov 1, 1Novosibirsk State Univ., Russia; 2Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National Univ., Australia. We propose a fiber laser composed of coupled ring cavities with gain and loss, featuring parity-time transition between symmetrized broken single-mode and bistable symmetric regimes, controllable by static phase shifters without active modulation.

JTuA.59 One-way Nonlinear Mirror and Cancellation of Nonlinear Response via Multipolar Interference From Metasurfaces, Ekaterina Poutova 1,2, Augustin Urbas 3, 1Air Force Research Lab, USA; 2UES, Inc., USA. We report examples of an image produced by difference frequency generation on one and the same side of a metasurface independently of the source location. Directionally-selective extinguishing of nonlinearly-generated multipolar modes is also shown numerically.

JTuA.60 Modal Phase Matching in Nanostructured Zincblende Semiconductors for Second-Order Harmonic Generation, Eleonor De Luca 1, Reza Sanatina 1, Mounir Mensi 1, Sriivasan Anand 1, Marcon Svoloch 1, 1KTH Royal Inst. of Technology, Sweden. Gallium phosphide nanowaveguide arrays, designed to fulfill the phase matching conditions and field-overlap, are characterized by second-harmonic generation. The bandwidth of 30m with maximum conversion efficiency of 10^2 is measured for 1500 nm optical pulses.

JTuA.61 Experimental Comparisons of P-T Symmetric Magneto-Electric Interactions in Molecular Liquids, Elizabeth F. Dreyer 1, Alexander A. Fisher 1, Stephen C. Rand 1, 1University of Cen-tral Florida, USA. We generate diffraction-free non-accelerating pulsed Air beams having a highly correlated spatio-temporal spectrum. Acceleration is controllably restored by introducing uncertainty in the spectral correlation.

JTuA.62 Tunable Raman Solitons from 2.05 μm to 2.25 μm with High Conversion Efficiency, Hongxing Shi 1, Xian Feng 1, Fengfang Tian 1, Peng Wang 1, Shuang Shi 1, Jia Xu 1, Pu Wang 1, 1Beijing Univ. of Technology, China. We report high conversion efficiency Raman solitons which possess 80% of the pulse energy and have wavelength tunable range from 2.05 μm to 2.25 μm. 166-fs soliton pulses are obtained at wavelength of 2.25 μm with an average power of 970 mW, corresponding to a peak power of 140 kW.

JTuA.63 Realizing Ultra-Low Reflection and Reduced Dispersion of Slow Light, Frank Bellio 1,2, Freddie Page 1, Andreas Pusch 1, Joachim Hamm 1, John Donegan 1,2, Ortwin Hess 1, 1Trinity College Dublin, Ireland; 2Advanced Materials and Bioengineering Research, Ireland; 1Imperial College London, UK. We investigate hyperbolic, multilayered thin films which demonstrate epilons-near-zero behavior and contain stopped light energy bands. Together these two phenomena are able to radiatively excite slow light with reduced group velocity dispersion and perfect antireflection.

JTuA.64 Simulation and Experimental Design of Saturated Excitation (SAX) Multiphoton Microscopy (MPM), Genevieve Vigil 1, Yide Zhang 1, Amin Khan 1, Scott S. Howard 1, 1Univ. of Notre Dame, USA. SAX is modeled and found to generate irregular PSF containing spatial frequency content beyond the diffraction limit. No special chemistry and minimal modification of MPM is needed toward super-resolved fluorescence imaging in scattering media.

JTuA.65 Nonlinear Raman-Nath Second Harmonic Generation with Structured Fundamental Wave, Haigang Liu 1, Jun Li 1, Xiaohui Zhao 1, Yuanzheng Xie 1, Xiandong Chen 1, 1Shanghai Jiao Tong Univ., China; 2College of Science and technology, Jiangxi Normal Univ., China. We proposed and experimentally demonstrated that nonlinear Raman-Nath second harmonic can be achieved when a fundamental wave with the phase periodically modulated, termed as structured fundamental wave, incident in a homogeneous nonlinear medium.

JTuA.66 Demonstration of Non-accelerating Space-Time Airy Beams, Hasan F. Kondakci 1, Ayman F. Abouraddy 1, 1CREOL, Univ. of Central Florida, USA. We generate diffraction-free non-accelerating pulsed Airy beams having a highly correlated spatio-temporal spectrum. Acceleration is controllably restored by introducing uncertainty in the spectral correlation.

JTuA.67 Nonlinear Raman-Sanathan Second Harmonic Generation with Structured Fundamental Wave, Joachim Hamm 1, John Donegan 2, Ortwin Hess 1, 1Trinity College Dublin, Ireland; 2Advanced Materials and Bioengineering Research, Ireland; 1Imperial College London, UK. We investigate hyperbolic, multilayered thin films which demonstrate epsilon-near-zero behavior and contain stopped light energy bands. Together these two phenomena are able to radiatively excite slow light with reduced group velocity dispersion and perfect antireflection.
JTu5A.68 Intracavity Phase Interferometry Enhanced with Resonant Linear Dispersion, James Hendrie1, Matthias Lenzer2, Ladan Arasian1, Jean-Claude M. Diels1; 1Univ. of New Mexico, USA; 2Lenzer Research, USA. Intracavity phase interferometry measures a beat frequency between two counter circulating pulses within a mode-locked cavity. A modification of sensitivity through insertion of resonant linear dispersion is experimentally demonstrated, while the pulse velocity remains unchanged.

JTu5A.69 On-chip Ultrafast Pulse Generator Based on Integrated Near-field Anapole Lasers, Juan Sebastian Tetoan Gongora1, Andrea Miroshnichenko1, Yuri Kivshar1, Andrea Fratalocchi1; PRIMALIGHT, King Abdullah University of Science and Technology, Saudi Arabia; 2Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Australia. We developed an all-dielectric integrated source of ultrafast pulses by exploiting the mutual interference and synchronisation of near-field nanolasers emitting at the anapole frequency.

JTu5A.70 Amorphous-Crystalline Micro- and Nanostructures in Silicon Fabricated Using Amorphous Light Pulses, Yasser Fuentes Edul1, Mario García Lechuga1, Daniel Puerto1, Camilo Florian Baron1, Adriana Garcia-Lisa1, Santiago Sánchez Cortés1, Javier Solís1, Jan Siegel1; Instituto de Óptica, Spanish National Research Council, Spain; 2Instituto de Estructura de la Materia, Spanish National Research Council, Spain. We demonstrate an innovative way to fabricate different types of amorphous-crystalline surface structures in silicon using ultrashort laser pulses. Fluence-dependent solidification dynamics and interference of incident and scattered laser light are identified as underlying mechanisms.

JTu5A.71 A Full-wave Model for Laser-Induced Plasma emission from Metal Micro-Particles on a Glass Surface, Omer Malhi1, Alexander Rubenchik1, Manyaloobi Mattews1, Lawrence Livermore National Lab, USA. A model based on full-wave simulations is used to evaluate laser-induced plasma emission from metal micro-particles on silica glass surface. The predicted deposited plasma energy distribution resulting from the light interference explains experimental observations.

JTu5A.72 Three-dimensional waveguide coupler/beam splitter in lithium niobate crystals by femtosecond laser writing, Jinman Lv1, Xingzhao Hao1, Feng Chen1; 1Xiamen Univ., China. We report on the fabrication of three-dimensional waveguide coupler in LiNbO3 crystal by using femtosecond laser writing. This coupler is used to implement 1x4 beam splitting. The numerical simulations are in agreement with experimental results.

JTu5A.73 Chiral nearfield generation from chiral surface relief fabricated by optical interference of beams, Kenji Horada1, Katsuhiko Miyamoto1, Takashige Omatu1,2; Chiba Univ., Japan; 1Molecular Chemistry Research Center, Chiba Univ., Japan; 2Kitsum Inst. of Technology, Japan. We demonstrated the plasmon-enhanced nearfield induced chiral mass transport, in which the superimposed azo-polymer thin film is twisted, around the chiral surface relief formed by optical vortex illumination in combination with nano-imprinting technology.

JTu5A.74 Nonlinear above-threshold photoemission in single-wall carbon nanotube induced by fs-pulsed laser, Mark Green1, Jamie Swartz1, John Robert Headrick1, Augustine Urbas1, Junichiro Kono2, Matteo Pasquali1, Tsing-Hua Her1; 1Univ. of North Carolina at Charlotte, USA; 2Air Force Research Lab, USA. We study nonlinear above-threshold photoemission (ATPE) in single-wall carbon nanotubes at two wavelengths. NIR photoemission demonstrates 5-photon ATPE, while UV ATPE is dominantly a 2nd process. Two-pulse correlation exhibits enhanced photoemission with a very short lifetime less than 200 fs.

JTu5A.75 Vacuum-field Rabi Splitting at SWIR in Photocurrent of Quantum Cascade infrared Photodetectors Coupled to Metamaterial Nano-antennas, Matias Katz1, Ofer Soria1, Ben Dor1, Nicolas Grandjean1, Meir Orenstein1, Gad Bahl1; 1Dept. of Electrical Engineering, Technion-Israel Inst. of Technology, Israel; 2Inst. of Condensed Matter Physics, Ecole Polytechnique Federale de Lausanne, Switzerland. We present the design, realization, and characterization of room temperature optical and electrical strong light–matter coupling between interband transitions, at wavelength of 1.8 microns, in quantum cascade detector and planar metamaterials nano-antenna cavity.

JTu5A.76 Tunable Redox Property of Silver Deposited TiO2 Nanocomposite Synthesized by Pulsed Laser Ablation, Rui Zhou1, Shengdong Lin1; 1Xiamen Univ., China. Silver deposited TiO2 nanocomposites with tunable redox property were fabricated by laser ablation of silver and titanium targets in de-ionized water. This approach opens a route for one-step synthesized redox system for potential applications in photocatalyst.

JTu5A.77 Infrared Absorption Spectroscopy of Monolayers with Thin Film Interference Coatings, sencer ayas1,2, Gokhan Bakan1,3, Gokhan Bayraktar1; 1Dep. of Communications Engineering, Bahcesehir University, Turkey; 2Dept. of Radiology, Stanford Univ., USA; 3Electrical and Electronic Engineering, Atılım Univ., Turkey. We report high performance Infrared spectroscopy platforms based on interference coatings on metal using CaF2 dielectric films and Ge,Sb2Te5 (GST) phase-change films. Irr radiation bands of proteins and organic monolayers are also detected.

JTu5A.78 Phonon Chirality and Indirect Cooling in an Optomechanical System, Seung-an Kim1, Xunrong Xu1, Jacob Taylor2,3; 1Mechanical Science and Engineering, Univ. of Illinois at Urbana-Champaign, USA; 2Joint Quantum Inst., Univ. of Maryland, USA; 3Joint Center for Quantum Information and Computer Science, National Inst. of Standards and Technology. We demonstrate dynamical induction of chiral phonon transport in optomechanical resonators by means of travelling-wave acousto-optical interaction. The phenomenon results in unidirectional defect tolerant transport and chiral cooling of high-Q phonon modes in the system.

JTu5A.79 Controllable Coupling of an Ultra-High-Q Microtoroid Cavity with Monolayer Graphene, Xun Zhang1, Huibo Fan2, Xiaoshun Jiang1, Min Xiao1,2; 1College of Engineering Sciences, Nanyang Univ. of Tech., China; 2College of Physics Science and Technology, Yangzhou Univ., China; 3Dept. of Physics, Univ. of Arkansas, USA. We have demonstrated the coupling between an ultra-high-Q microcavity and monolayer graphene with tunability of the Q-factor from 1.5 x 10^10 to 1.2 x 10^10. The Q-factor has been finely tuned by adjusting the gap between them.

JTu5A.80 A hybrid system with highly enhanced graphene SERS for rapid and tag-free tumor cell detection, Yi Ningbo1, Zonghui Duan1, Qiangshi Song1, Shumin Xiao1,2; Harbin Institute of Technology Shenzhen, China. Herein we demonstrate a facile device based on GSERS in a sandwich-structure of reduced graphene oxide between Ag and Au, of which the coupling of localized surface plasmons demonstrated to realize huge enhanced G-SERS, the potential for detection and identification for tag-free tumor cells.

JTu5A.81 Accurate Calculation of Modal Refractive Indices in SlightlyElliptical Optical Fibers, Aku J. Antikainen1,2,1 Rene-Jean Essiambre1,2,1; 1Univ. of North Carolina at Chapel Hill, USA; 2Nokia Bell Labs, USA; 3Lab for Laser and Optical Energetics, USA. We present a novel perturbation approach to accurately calculate the effective indices of mode propagation constants in step-index fibers. The method enables simple computation of the mode profiles and their effective indices.

JTu5A.82 All Reflective Multiphoton Microscope for use with Compact Multi-colored Broad-band Femtosecond Fiber Lasers, Benjamin Cromwell1, Robert Baker1, Babak Amirsolaimian1, Soroush Mehravan1, Khan Q. Kie1; 1Univ. of Arizona, USA. We present and discuss a design for a multiphoton microscope that uses all reflective elements for beam shaping and expansion, which removes the effects of dispersion on femtosecond pulses as well as chromatic aberrations.

JTu5A.83 Gain Asymmetry in Saturated Raman-Assisted Parametric Amplification, Bofang Zheng1, Xingzhao Hao1, Feng Chen1; 1The Chinese Univ. of Hong Kong, Hong Kong. The spectral asymmetry in saturated Raman-assisted parametric amplification is investigated experimentally and numerically using a five-wave model. We identify that the interplay between dispersive waves and high-order four-wave mixing processes breaks the gain symmetry.

JTu5A.84 Pulse Generation from Laser Light using Temporal Talbot Array Illuminators, Carlos R. Fernandez-Pousa1,2, Reza Maram1, Jose Azana3; 1Dep. of Communications Engineering, Universidad Miguel Hernandez de Elche, Spain; 2Inst. National de la Recherche Scientifique, Centre Énergétique, Matériaux, Télécommunications (INRS-EMT), Canada. Pulse generation from cw laser light with >70% collection efficiency, 60-200 ps pulse widths and repetition rates 1-1.25 GHz is demonstrated using multilevel phase modulator based 1/2, 1/6 and 1/10 fractional Talbot dispersive propagation.

JTu5A.85 Detrital Effects in Brillouin Distributed Sensors Caused By EDFA Transient, Cheng Feng1, Harit Irizba1, Jan Marielara1, Thomasm Schneider1, Alayn Loayssa2; 1Institut de Nanotechnik, Technische Universität Braunschweig, Germany; 2Departamento de Ingeniería Electrónica y Electrónica, Universidad Pública de Navarra, Spain. We investigate the deleterious effect and the error in Brillouin optical time-domain analyzers induced by the combination of a low extinction ratio pulse generation with the transient behavior of erbium-doped fiber amplifiers.

JTu5A.86 Light-controlled Optical Fiber Comb Filter Based Enabled by Colloidal Quantum Dots, Geo Feng1, Yang Wang1, Ming Tang1, Huang Liu1; 1Wuhan National Lab for Optoelectronics (WNL0) & School of Optics and Electronic Information, Huazhong Univ. of Science and Technology (HUST), China. Utilizing the quantum confinement effect of colloidal quantum dots (CQD) embedded with exposed-core glass fiber interferometers, a light-absorption controlled tunable optical fiber comb filter is achieved by simply applying –mW level pump power.

JTu5A.87 Optimizing Output Power Through Temporal Pulse Shaping, Graham R. Allan1, Mark A. Stephen2, Anthony W. Yu1, James B. Abshire1, Stewart T. Wu1, Jeffery Chen1, Kenji Numata1; 1Wuhan National Lab for Optoelectronics (WNL0) & School of Optics and Electronic Information, Huazhong Univ. of Science and Technology, China. We have doubled the output pulse energy to 550uJ from a Raman Pumped VUMA EDFA by pulse shaping the input while operating below SBS damage threshold with a 7.5KHz rep-rate, 1uJ pulses at 1521nm.
JTuSA.88 High power average all-Fiber Superluminescent Pulse Amplifier with Tunable Repetition Rates and Pulse Widths, Hattao Zhang, He Hao, Xingli Shen, Linu He, Mali Gong, Tsinghua Univ., China. We reported a high average power of 570 W laser generated by an all-fiber superluminescent pulse amplifier (SPA) structure, operating at variable repetition rates from 0.5 MHz to 2 MHz and pulse widths from 100 ns to 220 ns.

JTuSA.89 Compact and robust high-order random Raman fiber laser, Han Wu, Zinan Wang, Qiheng He, Wei Sun, Yunjiang Rao, UESTC, China. We report a compact and robust cavity design for generating high-order random Raman fiber lasing. A pump combiner and broadband reflector are used to form forward pumping, providing a promising way to increase the output power significantly.

JTuSA.90 Tunable Multimode Fiber Laser Based on Nematic Liquid Crystal Fiber Device and Tunable Electric Field Sensor, Hyun J. Lee, Sung-Jo Kim 2, Myeong Ock Ko 1, Jong-Hyun Mali Gong 1; Sungkyunkwan National Univ., South Korea; 2Center for Soft and Living Tissue Research, Sungkyunkwan Univ., South Korea. We demonstrate a generation of high-order random Raman fiber lasing. A pump robust cavity design for generating high-order mode-locked fiber laser employing clock extraction from the second-harmonic of a 904 nm laser. The second-harmonic frequency is tuned by applying electric field to the sensing layer, which, in turn, enhances the sensitivity of the fiber sensor.

JTuSA.91 Image Transport Through Silica-Air Random Core Optical Fiber, Jian ZHAO 1, Jose E. Antonio Lopez 1, Rodrigo A. Correa 1, Arash Mashfii 2, Marie Windtkeck 1, Axel Schulzgen 1, CREOL, College of Optics and Photonics, Univ. of Central Florida, USA; Dept. of Physics and Astronomy, Univ. of New Mexico, USA. Optical image transport through low-loss silica-air based disordered fiber is reported for the first time. Transverse Anderson localization is confirmed by propagating a 97nm laser beam through a 4.6 cm-long segment of random fiber.

JTuSA.92 Investigation of double-clad Yb 3+-doped phosphate fiber for 976 nm single-frequency laser amplification, Jingwei Wu 1, Xiushan Wang 1, Jingwei Wu 1, Xiushan Wang 1, Yaping Chen 1, Sheng-Lung. Huang 3, Wood-Hi Wang 1, Ting-Sou Rou 1, Nan-Kuang Cheng 1; 1UESTC, China. We report a compact and robust cavity design for generating high-order mode-locked fiber laser employing clock extraction from the second-harmonic of a 904 nm laser. The second-harmonic frequency is tuned by applying electric field to the sensing layer, which, in turn, enhances the sensitivity of the fiber sensor.

JTuSA.93 Stable Operation of Regeneratively and Harmonically Mode-Locked Fiber Ring Laser Employing Clock Extraction from the Second Harmonic, Koji Maeda 1, Kai Sakuma 1, Tokyo Univ. of Science, Japan. We demonstrate a generation of regeneratively and harmonically mode-locked fiber laser employing clock extraction from the second-harmonic of the repetition frequency. The proposed laser showed much better stability than did a laser employing conventional clock extraction.

JTuSA.94 Higher Gain of Single-Mode Cr-Doped Crystalline Core Fibers by Online Control of Molten Zone, Iu-Chun Nien 1, Tsung Hau Wang 1, Ting-Sou Rou 1, Nan-Kuang Chen 1, Sheng-Lung Huang 1, Wood-Hi Cheng 1; 1Graduate Inst. of Optoelectronic Engineering, National Chung Hsing Univ., Taiwan; 2Dept. of Electro-Optics Engineering, National United Univ., Taiwan; 3Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan. A single-mode Cr-doped crystalline core fiber with longer fiber length by online controlling molten zone is demonstrated a gross gain of 4.2 dB. This gross gain is the highest yet reported for the SMDCCF.

JTuSA.95 Squeezed Hollow Core Photonic Bragg Fiber for Surface Sensing Applications, Jingwei Wu 1, Xiushan Wang 1, Jingwei Wu 1, Xiushan Wang 1, Yaping Chen 1, Sheng-Lung. Huang 3, Wood-Hi Wang 1, Ting-Sou Rou 1, Nan-Kuang Cheng 1; 1UESTC, China. We theoretically and experimentally confirm that squeezing a section of the Bragg fiber core increases overlap between the optical fields of the core-guided modes and the modes bound to the sensing layer, which, in turn, enhances sensitivity of the fiber sensor.

JTuSA.96 Steering Lasing Beam in Topological Light Sources, Babak Bahrani 1, Junhee Park 1, Marcil Peraza 1, Ionel Mihalic 1, Akira Nomura 1, University of Washington, USA. We demonstrated the bound state in the continuum Surface Emitting Laser that can steer the beam with angles depending on the topology. This novel type of the topological light source operates at room temperature.

JTuSA.97 Carrier Dynamics of Ultrafast Semiconduc tors Disk Lasers, Cesare Alfieri 1, Dominik Waldburger 1, Sandra M. Link 1, Matthias Golling 1, Ursula Keller 1, ETH Zurich, Switzerland. We theoretically and experimentally investigate gain dynamics of modelocked semiconduc tor disk lasers in the sub-200 fs regime. Spectral holes are burned in and short carrier lifetime in the conduction band is limiting output power and optical-to-optical pump efficiency.

JTuSA.98 A novel dual-loop feedback scheme to reduce spurious tones in self-mode-locked two-section quantum Dash laser emitting at 1.55 μm, Haroon Asghar 1,2, Ehsan Sooudi 1, Pramod Kumar 1, Alfonso Gonzalez 1, John Mcarney 1, 2; 1Univ. College Cork, Ireland; 2Tyndall National Inst., Ireland. We demonstrate a novel dual-loop scheme to suppress external cavity side-bands and modal overlaps induced in spectrum of self-mode-locked laser resulting from conventional single loop feedback and dual loop feedback configurations.

JTuSA.99 1.9 THz Difference-Frequency Generation in Mid-Infrared Quantum Cascade Lasers with Grating Outcouplers, Jae Hyun Kim 1, Seungyong Jung 1, Yifan Jiang 1, Kazuee Fujita 1, Masahito Hikata 1, Akio Ito 1, Tadakata Masahiro 1, Mikhail A. Belkin 1, Univ. of Texas at Austin, USA; 2Hamamatsu Photonics, Japan. We report terahertz quantum cascade lasers based on intra-cavity difference-frequency generation. Devices are designed using a double-metal waveguide with surface-grating outcouplers. Over 40 mW of power output at 1.9 THz is produced at room temperature.

JTuSA.100 High-Power 1.65-μm Slab-Coupled Optical Waveguide Amplifiers, Jason Plant 1, Dominic F. Sianyi 1, Toby Garrod 1, Antonio Napoleonio 1, Sara Mouser 1, Paul Jouwdaak 1, Lincoln Lab, MIT, USA; 2II-VI Epixworks, USA. 1.65-μm slab-coupled optical waveguide amplifiers (SCOWAs) that produce >300 mW output power at 20 dB gain are demonstrated. Such high-power devices could enable compact, large standoff-distance methane sensors.

JTuSA.101 Stable and Narrow Linewidth Semiconduct or Laser Assembly with Coherent Optical Negative Feedback, Konosuke Aoyama 1, Shuhei Kobayashi 1, Masashi Wada 1, N. Kutz 2, Steven T. Cundiff 1, Herbert G. Waldburger 1, Sandro M. Link 1, Matthias Hau Wang 1, Ting-Sou Rou 1, Nan-Kuang Cheng 1; 1Dept. Engineering Physics, Ecole polytechnique federale de Lausanne, Switzerland; 2Univ. of Washington, USA. We theoretically and experimentally confirm that a saturable absorber length and experimentally demonstrate a stable and narrow linewidth laser based on an assembles coherent optical negative feedback system. The linewidth reduction from 13.5 MHz to 3.0 kHz is kept for more than an hour.

JTuSA.102 Model for Frequency Comb Generation in Single-Section Quantum Well Diode Lasers, Mark Dong 1, Niall Mangjan 1, J. N. Kutz 2, Steven T. Cundiff 1, Herbert G. Winful 1; 1Univ of Michigan, USA; 2Applied Mathematics, Univ. of Washington, USA. We present a new, traveling-wave model for single-section quantum well diode lasers. We find that strong four wave mixing based upon the gain grating, coupled with longitudinal spatial hole burning, allows for frequency comb generation.

JTuSA.103 CDD-based thermoreflectance measurements of a multi-section slotted laser, David McClooskey 1, Rudi O'Reily Meehan 1, Michael Wallace 2, Ryan Enright 1, John Donegan 3, 1School of Physics, Trinity College Dublin, Ireland; 2Future Networks and Communications (CONNECT), Ireland; 3Efficient Energy Transfer Dept. (EET), Bell Labs, Nokia, Ireland. We investigate the use of multi-section slotted lasers to obtain high resolution images of surface temperature variations in a three section slotted single mode laser. These measurements indicate temperature gradients across the laser grating section, which can be used to better infer wavelength tuning models.

JTuSA.104 Voltage-Controlled Oscillators Based on Optically Injected Semiconductor Lasers, Nicholas G. Ushack 1, Joseph S. Suelzer 1, Joseph W. Haefner 1; 1US Air Force Research Lab, USA. We theoretically and experimentally demonstrate a novel type of the chaotic oscillator laser using a self-phase-modulated-segmented laser, which, in turn, increases complexity and is advanced. By changing the feedback, the probability density distribution of its output intensity is close to symmetry.

JTuSA.105 Time delay signature suppression and complexity enhancement of chaos in laser with self-phase-modulated optical feedback, Chengpeng Xue 1, Ning Jiang 1, Guilian Li 1, Chao Wang 1, Shuqin Lin 1, Kunlin Li 1, Kun Gu 1; 1Univ of Electronic Science & Tech China, China. Chaos generated by a semiconductor laser subject to self-phase-modulated optical feedback is proposed, where the time-delay-signature is concealed and complexity is enhanced. Fascinating, the probability density distribution of its output intensity is close to symmetry.

JTuSA.106 Withdrawn.

JTuSA.107 High Frequency and High Power Monolithic Mode-Locked Laser, Pengchao Zhao 1, Anirj Li 1, Wanhua Zheng 2; 1State Key Lab on Integrated Optoelectronics, Inst. of Semiconductors, CAS, China; 2Labor of State Optoelectronics Information Technol. Inst. of Semiconductors, CAS, China. We theoretically analyze the impact of a saturable absorber length and experimentally demonstrate a mode-locked laser with a pulse width of 1.75 ps, peak power of 188 mW, and pulse energy of 0.33 pJ.

JTuSA.108 1.5 μm Laser Diode on InP/InSb substrate using Epitaxial Growth using Direct Bonding Method, Periyangaayam Gandhi Kallaran 1, Tetsuo Nishiyama 1, Naoki Kamada 1, Yuu Onuki 1, Kazuhiko Shimomura 1, Soujiro Un 1, Japan. We have demonstrated for the first time 1.5μm GaInAsP laser diode on silicon substrate using direct wafer bonding and MOVPE growth. Our unique approach prior to the growth is that we do the adhesion of InP substrate and Si substrate using hydrophilic wafer bonding technique.
Audo2, Cyril Paranthoen1, Christophe Levallois2, Weiwei Hu2, Jerome Faist1, Zhixin Wang2, Xuefan Yin2, Chao Peng2, James O’Gorman2,3, Chuan Seng Tan1,2, Yiding Lin1,2, Han-Youl Ryu3, Mee-Yi Ryu4, National Univ., South Korea; 5Air Force Inst. Technology, China.

France; 2Institut de Physique de Rennes, UMR CNRS 6251, Université de Rennes 1, France; 3Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Sud, France. InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP is demonstrated. Up to 163 mW and 7 mW have been obtained in multi-mode and single-mode operation, respectively. Class-A behavior is demonstrated on such device.

Single-Defect Hexapole Mode GeSn Photonic Crystal Laser: Fabrication and Simulation, Shuyu Bao1,2, Haodong Qiu1, Yeji Kim3,2, Shalom Shabtai1, Weiwei Hu1,2, Zhaocheng Xue1,2, Hervé Folliot1, Mehdi Alouini2,3,2 Nanosil Photonics GmbH, Germany; Nokia, Finland; 2Foton, UMR CNRS 6251, Université de Rennes 1, France; 3Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Sud, France. InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP is demonstrated. Up to 163 mW and 7 mW have been obtained in multi-mode and single-mode operation, respectively. Class-A behavior is demonstrated on such device.

Single-Defect Hexapole Mode GeSn Photonic Crystal Laser: Fabrication and Simulation, Shuyu Bao1,2, Haodong Qiu1, Yeji Kim3,2, Shalom Shabtai1, Weiwei Hu1,2, Zhaocheng Xue1,2, Hervé Folliot1, Mehdi Alouini2,3,2 Nanosil Photonics GmbH, Germany; Nokia, Finland; 2Foton, UMR CNRS 6251, Université de Rennes 1, France; 3Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Sud, France. InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP is demonstrated. Up to 163 mW and 7 mW have been obtained in multi-mode and single-mode operation, respectively. Class-A behavior is demonstrated on such device.

Class-A Operation of InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser, Salvatore Pesi1,2, Kevin Audou1, Cyril Paranthoen1, Christophe Levallois2, Nicolas Chevalier1, Gouich Loa1, Steve Bouhet1, Cyril Hamel1, Carmen Gomez1,2, Jean-Christophe Harmand1, Sophie Bouchoule1, Hervé Folliot1, Mehdi Alouini2,3, Foton, UMR CNRS 6251, INSA de Rennes, France; 2Institut de Physique de Rennes, UMR UR1-CNRS 6251, Université de Rennes 1, France; 3Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Sud, France. InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP is demonstrated. Up to 163 mW and 7 mW have been obtained in multi-mode and single-mode operation, respectively. Class-A behavior is demonstrated on such device.
JTu5A.129
Spectral Hole Narrowing in Er\(^{3+}\)-4f Transitions by Isotope Separation, Takehiko Tawara\(^{1,2}\), Giacomo Manardi\(^{1}\), Kaoru Shimizu\(^{1}\), Hiroo Omi\(^{1,2}\), Satoru Adachi\(^{1}\), Hideki Gotoh\(^{1}\), NTT Basic Research Labs, Japan; \(^{2}\)NTT Nanophotonics Center, Japan; \(^{3}\)Hokkaido Univ., Japan. We report effect of isotope separation on the homogeneous linewidth in Er\(^{3+}\)-doped Y\(_2\)SiO\(_5\), measured by using spectral hole burning. Isotope \(^{167}\)Er\(^{3+}\) provides a drastic reduction of the spectral hole width by strongly suppressing instantaneous spectral diffusion.

JTu5A.130
Continuously-chirped grating formation by low-cost laser interference lithography for achieving tunable guided mode resonance filter, Tzu-Chieh Kao\(^{1}\), Jia-Jin Lin\(^{1}\), Chia-Wei Huang\(^{1}\), Chia-Wei Huang\(^{1}\), National Sun Yat-sen Univ., Taiwan. A guided-mode-resonance filter based on continuously-chirped gratings is realized by a modified Lloyd's mirror interferometer to provide a sharp transmission dip at the resonant wavelength that can be gradually swept across the visible spectral region.

JTu5A.131
Synthesis and Application of Metal Halide Perovskite Nanocrystals, Xiaoli Zhang\(^{1}\), Bing Xu\(^{1}\), Kai Wang\(^{1}\), Xiao Wei Sun\(^{1}\), SUSTC, China. Metal halide perovskite nanocrystals are fabricated via all-solution method, which exhibit outstanding optoelectronic properties. The application in optoelectronic device demonstrates great improved performance, especially in light-emitting diodes, which display improved activity via proper composition adjustment and device construction modification.

JTu5A.132
Multifold enhancement of graphene interband absorption in a Salisbury screen, Xiangxiao Ying\(^{1}\), Yang Pu\(^{1}\), Yi Luo\(^{1}\), Hao Peng\(^{1}\), Zhe Li\(^{1}\), Yadong Jiang\(^{1}\), Zhijun Liu\(^{1}\), Univ of Electronic Sci & Tech of China, China. An enhancement of graphene interband absorption by more than four-fold is demonstrated in a Salisbury screen configuration. For a monolayer graphene, peak absorptions between 9% and 40% are measured at different incident angles.

CALL FOR CLEO 2018 SYMPOSIUM PROPOSALS

The 2018 CLEO CLEO Program Committee is seeking special symposium proposals for consideration from members of the optics and photonics community. Submissions should consist of timely, cutting-edge topics and/or new material in rapidly advancing areas.

Submissions need to address the following questions.
1. Why is this symposium topic important now and needed in contrast to other years?
2. Which existing topic subcommittees if any, would this topic be most aligned with?
3. Proposed invited speaker list and talk titles.

Submission Deadline: 10 July 2017 at 12:00 EDT (16:00 GMT)

For more information, visit www.cleoconference.org/symposiumproposals
Invited
All-Optical Pulse-Echo Ultrasound Imaging for Guiding Minimally Invasive Procedures, Adrienn Desjardins1, Charles Mose1, Richard Colchester1, Sacha Noimark1, Erwin Alles1, Edward Zhang1, Sebastien Ouseille1, Ivan Parkin1, Ioannis Papakonstantinou1, Paul Beard1, Malcolm Finlay1,2,1 Univ. College London, UK; 2Queen Mary Univ. of London, UK. Recent advances in optical transmission and reception of ultrasound have enabled pulse-echo imaging using fiber-optic probes that are suitable for guiding clinical intracardiac and intravascular procedures. In vivo images from pre-clinical models will be presented.

AW1B.2 • 08:15
Optical Fiber Sensor-Fused Additive Manufacturing and Its Applications in Residual Stress Measurements, Ran Zou1, Xuan Liang2, Rongtiao Cao1, Shuo Li1, Albert To3, Paul Ghodravici1, Michael Buric1, Kevin Chen1, Dept. of Electrical and Computer Engineering, Univ. of Pittsburgh, USA; Dept. of Mechanical Engineering and Materials Science, Univ. of Pittsburgh, USA, National Energy Technology Lab, USA. This paper reports optical fiber embedded in Ti-6Al-4V components using active manufacturing process. Thermal-induced residual stress on the sensor-embedded parts was measured using Rayleigh scattering distributed sensing scheme with 5-mm spatial resolutions.

AW1B.3 • 08:30
High Resolution Optical Fiber Sensor for Quasi-Static Strain Measurement by Strain-Temperature Discrimination, Jiaying Chen1, Qingswen Lui1, Xinyu Fan1, Ziyuan He1, State Key Lab of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China. A high resolution quasi-static strain sensor based on a novel scheme for strain and temperature discrimination has been developed. Within 1600s measurement, resolutions of 0.025 με in strain and 0.0019 °C in temperature are achieved.

SW1C.2 • 08:15
Optoelectronic Control of an External Cavity Quantum Cascade Laser Using a Graphene Loaded Metamaterial Array, Stephen J. Kindness1, David Jessop1, Binbin Wei2, Robert Wallis1, Varun Kamboj1, Long Xiao1, Yuan Ren2, Philipp Braeuninger-Weimer3, Stephan Hofmann4, Harvey E. Beere5, David A. Ritchie6, Riccardo Degl’innocenti7, Univ. of Cambridge, UK; 2Chinese Academy of Sciences, China. We present the optoelectronic frequency and amplitude modulation of a terahertz quantum cascade laser, achieved by implementing a graphene loaded split ring resonator array into an external cavity feedback set-up.

FW1D.2 • 08:15
Nonlinear Interaction of Oppositely Charged Vortices Generating Hollow Gaussian Beams, Apurva Chaitanya Nellikka1, Jabir M. V.1, J Banerji1, Goutam Samanta1, Phys. Research Lab, India. We demonstrate a novel experimental scheme generating high-power, higher-order hollow-Gaussian Beam (HGB) through annihilation of orbital-angular-momentum of the interacting photons in nonlinear process. Also, report a new and only method for characterizing the order of HGBs.

FW1D.3 • 08:30
Control of nonlinear instabilities in Bessel beams using shaped longitudinal intensity profiles, Ismail Ouaighdi Idrissi1, Remo Guast1, John Michael Dudley2, Francois Courvoisier3, ‘FEMTO-ST, France. We show that tailored longitudinal intensity shaping of a non-diffracting Bessel beam can strongly reduce four wave mixing induced oscillations and stabilize nonlinear propagation at ablation-level intensities.
FW1F.1 • 08:00  Invited
Observation of Ten-phonon Entanglement
Using Thin BiB2O3 Crystals, Luo-Kan Chen1, Zheng-Da Li1, Xing-Can Yao1, Miao Huang1, Wei Li1, He Lu1, Xiao Yuan1, Yan-Bao Zhang1, Xiao Jiang1, Cheng-Zhi Peng1, Li Li1, Nai-Le Liu1, Xiongfeng Ma1, Chao-Yang Lu1, Yu-Ao Chen1, Jian-Wei Pan11; 1Univ. of Sci. and Tech. of China, China; 2Tsinghua Univ., China; 3Univ. of Waterloo, Canada. We demonstrate a ten-phonon Greenberger-Horne-Zeilinger state using thin BiB2O3 crystals. The observed fidelity is 0.605 with a standard deviation of 3.6 and a p-value of 3.7×10⁻⁶.

FW1H.2 • 08:15
Real-time Measurement and Control of Multi-Petahertz Currents in Solids, Manish Gang1, Minjie Zhan1, Tran Trung Luu1, Harshit Lakhotia1, Till Klostermann1, Alexander Guggenmos3, Eleftherios Goulielmakis1, Max Planck Inst. for Quantum Optics, Germany. We used attosecond streaking to probe the temporal structure of isolated attosecond EUV pulses generated in a bulk solid using single-cycle optical driver. The encoded chirp correlates to intraband dynamics of electrons emitting EUV radiation.

FW1H.3 • 08:30
Extreme Nonlinear Carrier Dynamics Induced by Intense Quasi-half-cycle THz Pulses in n-doped InGaAs Thin Film, Xin Chai1, Xavier Ropagnol2, Mohsen Raesideh2, Safieeddin Saifavi-Naeini2, Matthew Red1, Marc A. Gauthier1, Tsuneyuki Ozaki1, 1Harvard Univ., USA. TiO2 ALD based metasurfaces with performance comparable to commercial optics has led to a host of applications of increased functionality and compactness. Advances in metasurfaces, miniature spectrometers, chiral imaging, axicons, holograms, vortex plates and polarimeters will be presented.
08:00–09:45
SW1I • Space-Division Multiplexed Optical Communications

Presider: Nicolas Fontaine; Nokia Corporation, USA

08:00–10:00
SW1J • Precision References and Optical Synthesis

Presider: Tara Fortier; NIST, USA

08:00–09:45
SW1I.1 • 08:00
Invited
MIMO-less Space Division Multiplexing Transmission over 1 km Elliptical Core Few Mode Fiber, Francesca Parmigiani1, Yongmin Jung1, Lars Grüner-Nielsen2, Tommy Geisler2, Periklis Petropoulos2, David Richardson3; 1Univ. of Southampton, UK; 2OFS, Denmark. We experimentally demonstrate 10-Gbit/s OOK MIMO-less SDM transmission over 1 km of a three-spatial-mode elliptical-core fiber at 1550 nm. Negligible power penalty is achieved thanks to the low modal crosstalk (<-22 dB) between any pair of the LP_{01}, LP_{11a} and LP_{11b} modes.

08:00–10:00
SW1K • Flexible and Soft Optoelectronics

Presider: Thomas Murphy; Univ. of Maryland at College Park, USA

08:00–10:00
SW1J.1 • 08:00
Invited
1.5 µm Lasers with Sub10 mHz Line-width, Thomas Legero1, Dan-Gheorghita Matei2, Sebastian Häfner2, Christian Grebing2, Robin Weyrich3, Fritz Riehle4, Uwe Stien4, Wei Zhang5, John Robinson6, Lindsay Sonderhouse7, Eric Delker7, Jun Ye7; 1Physikalisch-Technische Bundesanstalt, Germany; 2TRUMPF Scientific Lasers GmbH, Germany; 3JILA, National Inst. of Standards and Technology and Univ. of Colorado, USA. We report on two ultrastable lasers stabilized to single-crystal silicon Fabry-Pérot cavities at 124 K. The lasers show unprecedented thermal noise limited frequency instabilities of 4×10^{-17} and linewidths below 10 mHz.

08:00–10:00
SW1L • Sensing in Dynamic and Extreme Environments, Plasmas, and Explosions

Presider: Todd Stievater; US Naval Research Lab, USA

08:00–10:00
SW1K.1 • 08:00
Tutorial
Recent Advances in Flexible/Stretchable Optoelectronics: From Next-Generation Displays to Skin-Mounted Wearables, John A. Rogers1; 1Materials Science, Northwestern Univ., USA. Advances in materials and device designs enable high performance optoelectronic systems that can flex, bend, twist and even stretch like a rubber band. This talk outlines the key ideas.

08:00–10:00
SW1L.1 • 08:00
Invited
Optical Absorption Spectroscopy in Optically Dense Detonation Products, Nick Glumac1; 1Univ of Illinois at Urbana-Champaign, USA. Recent measurements of absorption of atomic and molecular species in optically thick fireballs generated by detonation of high explosives are presented. Tunable diode lasers, pulsed dye lasers, and broadband sources are used to probe UV and visible regions for critical intermediate species.

08:00–10:00
SW1L.2 • 08:30
Invited
Dual-Comb Spectroscopy of Laser-Induced Plasmas, Jenna Bergevin1, Tsung-Han Wu1, Jeremy Yeak3, Brian Brunfield2, Sivanandan S, Hanila2, Mark C. Phillips2, R. Jason Jones1; 1Univ. of Arizona, USA; 2Pacific Northwest National Lab, USA; 3PM&AM Research, USA. We present the first results using broadband dual-comb spectroscopy in a laser-induced plasma. Preliminary results identifying 87Rb and 85Rb isotopes are shown using this technique.
08:00–10:00
**SW1M • Nonlinear Optics for Spectroscopy and Sensing**  
**Presenter:** Michelle Sander, Boston Univ., USA

**Femtosecond 2D Spectroscopy of Nanomaterials and Photovoltaics, Martin Zanni**

*Univ. of Wisconsin-Madison, USA.* Femtosecond 2D spectroscopies reveal energy transfer, inhomogeneities, quantum coherences, and other photophysics. This talk will cover recent advances in the technology that enables easily obtained 2D spectra and highlight its application to nanomaterials and photovoltaics.

Martin T. Zanni is the Meloche-Bascom Professor of Chemistry at the University of Wisconsin-Madison. He is one of the major developers of ultrafast 2D Infrared and Electronic spectroscopies. His research program encompasses biophysics, photovoltaics, and surface science. He founded PhaseTech Spectroscopy, which is the first company to commercialize 2D spectroscopy.

08:00–10:00
**SW1N • Silicon Photonic Devices and Structures**  
**Presenter:** Qiang Lin, Univ. of Rochester, USA

**High-Radix Silicon Photonic Switches, Ming C. Wu**

*Univ. of California Berkeley, USA.* We review the state of the art of silicon photonic switches, with an emphasis on their scalability. We also describe a high-radix MEMS-actuated silicon photonic switch that is scalable to hundreds of ports.

08:30–10:00
**SW1O • Optical Comb & Integrated Systems**  
**Presenter:** Sasan Fathpour, CREOL, Univ. of Central Florida, USA

**Micro-Integrated Extended Cavity Diode Laser with Integrated Optical Amplifier for Applications in Space, Christian Kubis**

*Institut für Physik, Humboldt-Universität zu Berlin, Germany.* We present a micro-integrated laser module consisting of an extended cavity diode laser and an optical amplifier. The fiber-coupled laser module emits 570 mW from a single mode, polarization maintaining fiber at 1064 nm with a FWHM linewidth of 26 kHz (1 ms).

**Optical Frequency Synthesis by Offset-Locking to a Microresonator Comb, Shamsul Arafin**

*Univ. of California Santa Barbara, USA.* We report on the experimental demonstration of a chip-scale microresonator comb enabled optical frequency synthesizer using an agile and highly-integrated heterodyne optical phase-locked loop with InP-based photonic integrated circuit and commercial-off-the-shelf electronic components.

**Weakly-coupled Si waveguide Bragg reflector enabled by precisely-controlled graphene oxide gratings, Ya-Ching Liang**

*National Sun Yat-sen Univ., Taiwan.* Enabled by atomically thickness control (0.26 nm/min) and loss engineering (0.28 dB/cm/min) of graphene oxide (GO) integrated silicon waveguide via ozone treatment, a low-loss (~5dB/cm) and narrowband (1.1-nm) GO/silicon hybrid waveguide Bragg reflector is demonstrated.
AW1A.3 • 09:00
Custom Thin Film Si Photodiode Arrays for Endoscopic Spatially Resolved Diffuse Reflectance Measurements, Benjamin Lativere¹, ¹ECE-Dept., Duke Univ., USA. The design, fabrication, and initial experimental characterization of the first thin film Si photodiode spatially resolved DRS probe targeting endoscopic applications is reported.

AW1A.5 • 09:30
Comparing digital and Shack-Hartmann wavefront sensing for In-vivo OCT imaging, Abhishek Kumar¹, Rainer A. Leitgeb¹, Wolfgang Drexler¹, Laurin Grinier¹, Matthias Pauliac¹, Lara Wurster¹, ¹Medical Univ. of Vienna, Austria. A small lateral field of view of ~150x150 μm² is scanned on human retina using a swept source OCT at a B-scan rate of ~1.3 kHz and used as a “guide star” to detect optical aberrations using subaperture based digital adaptive optics. The results are compared with Shack-Hartmann sensor measurements.

AW1B.4 • 08:45
Dual-Core Optical Fibers for Simultaneous Measurements of Temperature and Strain Using Brillouin OTDA, Kevin P. Chen¹, Mohamed Zaghloul¹, Mohan Wang¹, Sheping Li¹, Ming-Jun Li¹, Giovanni Milione¹, ¹Univ. of Pittsburgh, USA; ²Corning Incorporate, USA; ³NEC Labs America, Inc., USA. We report a dual-core fiber for simultaneous sensing of strain and temperature using BOTDA. By adjusting dopant compositions, 37% difference in strain-optical coefficient was achieved between two cores to differentiate temperature and strain responses.

AW1B.5 • 09:00
The Application of Laser Off-Gas Analysis for Process Control in Harsh Industrial Environments, Doug Zuliani¹, Aviashok Pal¹, ¹Tenova Goodfellow, Canada. Extrinsic and Intrins Lasers are traditionally employed to analyze process off-gas. Neither method offers a complete solution in harsh industrial situations. A new hybrid method has been developed combining the best features of extractive & lasers to provide multipoint analysis of hot, dirty gases.

AW1C.4 • 09:00
Non-Hermitian Aspects of Coherently Coupled Vertical Cavity Laser Arrays, Zhi Gao¹, Stewart T. Frye¹, Bradley Thompson¹, Hashil Dave¹, Katherine Lakomy¹, P. S. Carney¹, Kent D. Choquette¹, ¹Univ. of Illinois, USA. Coherently coupled 1 x 2 VCSEL arrays with intentional built-in asymmetry have been designed and fabricated. Preliminary characterization shows electrically controlled mode switching and indications of parity-time symmetry breaking.

AW1C.5 • 09:15
Narrow Linewidth Frequency Comb Source based on Self-injected Quantum-Dash Passively Mode-Locked Laser, Kamel Merghemi¹, Vivek Panapakkam¹, Quentin Gaimard¹, Francois Lelarge¹, Abderrahim Ramdane¹, ¹CNRS, France; ²Almea technologies, France. An optical frequency comb generated by an InAs/InP quantum-dash-based passively mode-locked laser spans ~1.5 THz with 25 GHz spacing, and less than 100 kHz optical linewidth for all lines.

AW1D.4 • 08:45
Optimal energy confinement of optical Airy3 bullets, domenico bongiovanni¹, ¹CREOL, Univ. of Central Florida, USA. We present a family of electromagnetic wavepackets that overcomes this tradeoff, abruptly focusing to and defocusing from intensity hotspots of any aspect ratio.

AW1D.5 • 09:00
Nondiffracting Beams in a Thin Liquid Soap Films, Anatoly Patsyk¹, Miguel A. Bandres¹, Mordechai Segev¹, ¹Technion-Israel Inst. of Technology, Israel. We observe non-diffracting beam channels propagating in liquid soap membranes and study this phenomenon experimentally. The channel’s width is determined by the power of the beam and the thickness of the membrane.

AW1D.6 • 09:15
Demonstration of Diffraction-Free Beams with Correlated Spatio-Temporal Spectrum, Hasan E. Kondakci¹, Ayman F. Aboutrum¹, ¹CREOL, Univ. of Central Florida, USA. We experimentally demonstrate diffraction-free pulsed-beams with arbitrary spatial profile by introducing judicious correlations between the spatial and temporal degrees of freedom, which propagate ~200 Rayleigh ranges of a comparable-sized Gaussian beam.

FW1A • Non-diffracting Beams—Continued

FW1D.4 • 08:45
Towards a Scalable Ultrasensitive Optomechanical Magnetometer, Varun Prakash¹, Beibei Li¹, Stefan Forstner¹, Douglas Bulla¹, Scott Foster², Halina Rubinsztein-Dunlop¹, ¹SIMTech, Singapore; ²MIT, USA. We report on compressing the Fourier spectrum. The resulting bullets exhibit a significant enhancement of the peak intensity.

FW1D.5 • 09:00
Abruptly Focusing and Defocusing Needles of Light, Liang Jie Wong¹, Ido Kaminer¹, ¹SIMTech, Singapore; ²MIT, USA. Our Invited optic enforces a tradeoff between length and narrowness in electromagnetic wavepackets. We present a family of electromagnetic wavepackets that overcomes this tradeoff, abruptly focusing to and defocusing from intensity hotspots of any aspect ratio.

FW1D.6 • 09:15
Nondiffracting Beams in a Thin Liquid Soap Films, Anatoly Patsyk¹, Miguel A. Bandres¹, Mordechai Segev¹, ¹Technion-Israel Inst. of Technology, Israel. We observe non-diffracting beam channels propagating in liquid soap membranes and study this phenomenon experimentally. The channel’s width is determined by the power of the beam and the thickness of the membrane.

FW1D.7 • 09:30
Time domain analysis of self-frequency modulated combs in quantum cascade lasers, Nathan C. Henry¹, Jacob Khurgin¹, ¹MIT, USA. We have developed a time domain model confirming that the most efficient mode operation of a free running DCL is a pseudo-random frequency modulated mode with constant intensity.
Toward all-optical control of rare-earth qubits with 97% fidelity is achieved. Storage of time-bin nanophotonic cavity fabricated in a Nd:YVO crystal. We demonstrate previously inaccessible regimes of all-optical interaction creates opportunities within atomic ensembles. These photons are ideal for interacting with atomic quantum nodes in quantum networks. We review how an electronic quantum interference technique for the coherent detection of ultra-broadband THz pulses (0.1-10 THz), state technique for the coherent detection of harmonic generation attained in integrated optical cavity. Anti-Hermitian optical coupling between the metafilm elements facilitates a narrow spectral response (~30 nm) for the different wavelength channels.

Solid state source of non-classical multimode photon pairs with controllable delay. We present the characterization of a DLCZ-type memory with a rare-earth ion-doped crystal (REIC) with photon counting by combining the DLCZ and the AFC protocols. We find second order cross correlation values up to 21±4 and violate Cauchy-Schwarz equality by R = 44 ± 20. We store 11 temporal modes.

Connecting two multiparticle entangled states by entanglement swapping. We experimentally demonstrate the connection of two multiparticle entangled states by quantum entanglement swapping. The results provide a feasible technical reference for constructing more complicated quantum networks.

Two-photon interference with frequency-bin entangled photons, Pooldad Imaniy2,3, Ogasda Odele2,3, Jose Jaramillo-Villegas2,3, Daniel Leard2,3, Andrew Weiner2,3, Purdue Univ., USA; Purdue Quantum Center, Purdue Univ., USA. We present a novel approach to demonstrate coherence between different bins of a frequency-bin entangled photon-pair. The observed interference patterns provide a simple way to verify frequency-bin entanglement using slow single-photon detectors.

We demonstrate the first fully solid-state, anti-Hermitian optical coupling, and nonlinear holography. Prospects for shaping temporal, spectral, and polarization-direction features of sources on a subcycle level.

Multilayered Metamaterials for Functional Light Control, Euclides C. Almeida1, Ori Avayu1, Ta Il-Ellenbogen1, Yehiam Prizm1, Weizmann Inst. of Science, Israel; 2Dept. of Physical Electronics, Tel Aviv Univ., Israel. We demonstrate composite, multiplexed 3D metamaterials for functional light manipulation. Applications include multi-wavelength achromatic metalenses in the visible spectral range, integrated elements for STED microcopy, and nonlinear holography. Prospects for novel applications are discussed.

Affordable, ultra-broadband coherent detection of terahertz pulses via CMOS-compatible solid-state devices, Alessandro Tommasino1,2, Anna Mazonhovac, Matteo Cleric1, Marco Pecci1, Sze Phing Ho5, Robert Busacca1, Yuann Jeste5, Alessia Pasquazi4, Andrey Markov1, Xi Jin2, Riccardo Picolet1, Sebastien Delprat3, Mohamed Chaker3, Alessandro Busacca1, Jaill1, Luca Razzari1, Roberto Morandotti1, Univ. of Palermo, Italy; 2EMT, Univ. of Regensburg, Germany; 3Univ. of Palermo, Italy; 4Emp. of Sussex, UK; 5Universiti Teknologi Malaysia, Malaysia. We demonstrate the first fully solid-state technology for the coherent detection of ultra-broadband THz pulses (0.1-10 THz), relying on the electric-field-induced second-harmonic generation attained in integrated CMOS-compatible devices.
Wednesday, 08:00–10:00

**Multiplexed Optical Communications—Continued**

**SW1J.4 • 09:00**

Experimental Demonstration of 20-Gbit/s Data Transmission Link using a 1.1 km Elliptical-Core Few-Mode Fiber assisted by Mapping from Conventional Amplitude Modulation to Spatial Mode Modulation, Long Zhu, Qi Mo, Jian Wang, Andong Wang; Wuhan National Lab for Optoelectronics, China. We experimentally demonstrate 20 Gbit/s data transmission over a 1.1 km elliptical-core few-mode fiber (EC-FMF) link assisted by mapping from conventional amplitude modulation to spatial mode modulation, and achieve a 0.7 dB OSNR penalty improvement than single mode transmission at a BER of 3.8E-3.

**SW1J.5 • 09:15**

Optical Frequency References for Space, Thilo Schult1, Klaus Dörringhoff2, Markus Oswald3, Evgeny Kovalchuk4, Achim Peters5, Claus Braxmaier1,2, Germany; 1German Aerospace Center (DLR), Germany; 2Institut fur Physik, Humboldt-Universitaet Berlin, Germany; 4Center of Applied Space Technology and Microgravity (ZARM), Uni of Bremen, Germany. We present the development of optical frequency references with frequency instabilities at the 10^-15 level for space applications. Special emphasis is put on compactness and rigidity of the optical systems.

**SW1J.6 • 09:30**

High-efficiency, Large-area and Color-stable Flexible Organic Light-emitting Diodes using an Ultra-thin Metal Electrode, Cheng Zhang, Qingshu Huang, Cheng Guo, Zhiqun Yang, Chao Li, Zhenzhen Zhang, Cheng Guo, Wuhan National Lab for Optoelectronics, China; 1Fiberhome & Fujikura Optics Co, China; 2Univ of Central Florida, USA. 4x10 Gbit/s polarization- and mode group-multiplexing for Data Center Applications, Wei Wang, Jian Zhao, Lin Zhang, Qi Mo, Zhiqun Yang, Chao Li, Zhenzhen Zhang, Cheng Guo, Wuhan National Lab for Optoelectronics, China; 1Fiberhome & Fujikura Optics Co, China; 2Univ of Central Florida, USA. We demonstrate centimeter-size, color-stable flexible OLEDs using an ultra-thin Ag electrode. The device shows ~35% enhanced current efficiencies compared to its ITO counterpart, stable emission colors even at large observation angles, and bending stability over 1000 circles.

**SW1J.7 • 09:45**

Erbfiber frequency comb for optical synthesis with mHz resolution, Holly F. Leopold1, Jasee Davila-Rodriguez1, Franklin Quinlan1, Scott Diddams1,2, Tara M. Fortier1, National Inst of Science and Technology; 1Phys- ics, Univ of Colorado Boulder, USA. We describe an erbium-fiber laser frequency comb that supports optical frequency synthesis at the millihertz level, or fractionally as 3x10^-16 with ensuring all critical fiber paths are within the servo-controlled feedback loop.

**SW1K.2 • 09:00**

Temperature Stable Electro-Optic Polymer Modulator using Ultra-Thin Silicon Waveguide, Shyoshi Yokoyama1, Hiroki Miura, Feng Qiu, Andrew M. Spring; Kyushu Univ., Japan. We demonstrated the hybrid silicon and EO polymer modulator. The driving was 0.9 V at 1550 nm, and the bandwidth of 40 GHz. The modulator showed excellent temperature stability at 85°C for 2000 hours.

**SW1K.3 • 09:15**

Nonlinear Refractive Index of Sulfur Copolymer Materials, Soha Namnabat1, Masoud Babaeian1, Laura E. Anderson1, Michael S. Manchester3, Jeffery Pynn2; 1College of Optical Sciences, Univ of Arizona, USA; 2Chemistry and Biochemistry, Univ of Arizona, USA. Nonlinear refractive indices of novel sulfur copolymers are reported for the first time using a Z-scan setup. These values show a high nonlinearity compared to silica, demonstrating their potential for nonlinear optical applications.

**SW1K.4 • 09:30**

Continuous-Filtering Vernier Spectroscopy at 3.3 μm Using a Femtosecond Optical Parametric Oscillator, Amir Khodabakhsh1, Lucile Rutkowski1,2, Michael S. Manchester3, Shiyoshi Yokoyama1, Hiroki Miura, Feng Qiu, Andrew M. Spring; Univ of Arizona, USA. Using a cavity-enhanced continuous-filtering Vernier spectrometer based on a femtosecond optical parametric oscillator we measure broadband spectra of atmospheric water and CH4 around 3.3 μm reaching 4 ppb detection limit for CH4 in 15 ms.

**SW1K.5 • 09:45**

Two-Dimensional Fluorescence Spectroscopy for Measuring Uranium Isotopes in Femtosecond Laser Ablation, Mark C. Phillips1, Brian Brumfield1, Sivanandan S. Harilal1; 1Pacific Northwest National Lab, USA; 2Dept. of Mechanical and Nuclear Engineering, The Pennsylvania State Univ., USA; 3Dept. of Nuclear Engineering and Radiological Sciences, Univ of Michigan, USA. We present the first two-dimensional fluorescence spectroscopy measurements of uranium isotopes in femtosecond laser ablation plasmas. A new method of signal normalization is presented to reduce noise in absorption-based measurements of laser ablation.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

Marriott Salon III

**SW1M • Nonlinear Optics for Spectroscopy and Sensing—Continued**

**SW1M.2 • 09:00**
Dual-comb Spectral focusing Coherent anti-Stokes Raman spectroscopy, Kun Chen1, Tao Wu1, Tao Chen1, Haojun Wei1, Yan Li1; 1Tsinghua Univ., China. High-speed coherent anti-Stokes Raman spectroscopy with two linearly chirped frequency combs is demonstrated. Multiplex Raman spectra covering most of the fingerprint region are acquired with high resolution on nanosecond measurement time scale.

**SW1M.3 • 09:15**
Transient Ring Opening and Closing of a Two-photon Photochromic Molecule Utilizing Energy Transfer, Peng Zhao1,2, Zhi Liu1,3, Jinfeng Song1,2,3, Chunliang Chen1,2,3; 1Tsinghua University, Beijing, China; 2Data Storage Institute, Singapore; 3Singapore University of Technology and Design. We have developed an efficient two-photon photochromic molecule by coupling a chromene with a donating 2PA chromophore with a donating 2PA chromophore.

**SW1M.4 • 09:30**
Nonlinear Optical Technologies for Frequency-Comb Based Molecular Sensing, Nathalie Pique1; Max-Planck-Institut fur Quantenoptik, Germany. State-of-the-art nonlinear optical technologies for frequency-comb generation provide new powerful instruments for molecular physics and spectroscopy. Selected examples are given.
<table>
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<th>Time</th>
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<tr>
<td>10:00–18:30</td>
<td>Exhibition Open, Exhibit Hall 1, 2 &amp; 3</td>
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<td>10:00–12:00</td>
<td>JW2A • Poster Session II, Exhibit Hall 1, 2 &amp; 3</td>
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<td>10:00–10:30</td>
<td>Coffee Break, Exhibit Hall 1, 2 &amp; 3</td>
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<td>10:00–12:45</td>
<td>OSA Members, Family and Friends Tour – Computer History Museum</td>
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<td>Shuttle transportation will depart from the Hilton's Almaden Avenue entrance at 10:15 (Advanced Registration Required)</td>
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<tr>
<td>10:30–12:00</td>
<td>Market Focus Session IV: How the Changing Political Landscape will Impact your Company, Exhibit Hall Theater</td>
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FW1E • Rare Earth Solid State Quantum Memories—Continued

Stoichiometric Rare-Earth Crystals for Applications in Quantum Information, Matthew Sellars¹, Rose Ashfield², Michael Hušků³; ¹Australian National Univ., Australia; ²School of Engineering and Information Technology, Univ. of New South Wales, Australia. We demonstrate that in stoichiometric rare-earth crystals the excitation induced interactions between ions can be resolved over the optical inhomogeneous linewidth, introducing the possibility of utilizing many-body effects for quantum information applications.

FW1F • Quantum Entanglement—Continued

FW1G • Symposium on Advances in Metaphotonic Devices I—Continued

JW1G.5 • 09:45
Extreme Anisotropy, Spectral Modification, and Intensity Enhancement in Luminescent Hyperbolic Metasurfaces, Joseph S. Smalley¹, Felipe Vallini¹, Sergio Montoya¹, Lorenzo Ferrari¹, Shiva Shahin¹, Conor T. Riley¹, Bou-bacar Kante¹, Eric E. Fullerton¹, Zhaowei Liu¹, Yedfarahu Fanman¹; ¹Univ. of California San Diego, USA. We report the demonstration of luminescent hyperbolic metasurfaces (LuHMS) fabricated from deeply subwavelength multilayer metal-semiconductor nanostructures. The LuHMS exhibit extreme polarization anisotropy of absorption and emission, modified emission spectra, and enhanced emission intensity.

FW1H • Extreme Electromagnetic Radiation - THz to EUV: Generation, Detection & Applications—Continued

FW1H.8 • 09:45
Nanoscale Imaging of Magnetic Domains using a High-Harmonic Source, Sergey Zayko², Ofer Kfir²¹, Christina Nolte²¹, Murat Sivis²¹; ¹Solid State Inst. and Physics Dept., Technion Israel Inst. of Technology, Israel; ²IV. Physical Inst., Georg-August Univ. of Göttingen, Germany; ³I. Physical Inst., Georg-August Univ. of Göttingen, Germany; ⁴Inst. of Physics, Univ. of Augsburg, Germany. We demonstrate the first implementation of magnetic imaging using high harmonic radiation. Out-of-plane magnetization patterns of worm-like domains in a Co/Pd multilayer are imaged via Fourier transform holography with circularly polarized high harmonic radiation.
SW1J • Precision References and Optical Synthesis—Continued

SW1J.6 • 09:45 Dispersion-Engineered Silicon Nitride Supercontinuum for Frequency Comb Metrology at the $10^{-15}$ Level, David R. Carlson1, Daniel Hickstein1, Alex Lind1, Judith B. Olson1, Richard Fox1, Andrew Ludlow1, Qing Li1, Daron Westly1, Holly Leopardi1, Tara M. Fortier1, Kartik Srinivasan1, Scott Diddams1, Scott Papp1; 1NIST, USA; 2NIST, USA. Supercontinuum generation in dispersion engineered silicon nitride waveguides is used to perform frequency comb metrology by measuring the relative stability of two cavity-referenced optical clock lasers at $3.8 \times 10^{-15}$ at $\tau = 2$ seconds.

SW1K • Flexible and Soft Optoelectronics—Continued

SW1K.5 • 09:45 All-carbon flexible photodetectors, Yujie Liu1, Yuanda Liu1, Shuchao Qin1, Yongbing Xu1, Rong Zhang1, Frank (Fengqiu) Wang1; 1Nanjing Univ., China. We demonstrate a graphene-nanotube hybrid flexible photodetector with a high photoresponsivity (~51 A/W) and a fast response (~40 ms) over the visible range. The devices remain stable under severe bending conditions and repetitive bending cycles.

SW1L • Sensing in Dynamic and Extreme Environments, Plasmas, and Explosions—Continued

SW1L.7 • 09:45 Resolving Gas Temperature Distributions with Single-beam Dual-comb Absorption Spectroscopy, Nathan Malarich1, Gregory B. Rieker1; 1Univ. of Colorado Boulder, USA. We assess the potential to resolve line-of-sight gas temperature distributions with single-beam, broadband, dual-comb absorption spectroscopy. The technique shows promise for single-optical-port, spatially-resolved temperature diagnostics for harsh environments.

10:00–18:30  Exhibition Open, Exhibit Hall 1, 2 & 3

10:00–12:00  JW2A • Poster Session II, Exhibit Hall 1, 2 & 3

10:00–10:30  Coffee Break, Exhibit Hall 1, 2 & 3

10:00–12:45  OSA Members, Family and Friends Tour – Computer History Museum
Shuttle transportation will depart from the Hilton’s Almaden Avenue entrance at 10:15 (Advanced Registration Required)

10:30–12:00  Market Focus Session IV: How the Changing Political Landscape will Impact your Company, Exhibit Hall Theater
Marriott 
Salon III
Marriott 
Salon IV
Marriott 
Salon V & VI
CLEO: Science & Innovations

SW1 M • Nonlinear Optics for Spectroscopy and Sensing—Continued

SW1 N • Silicon Photonic Devices and Structures—Continued

SW1 O • Optical Comb & Integrated Systems—Continued

10:00–18:30 Exhibition Open, Exhibit Hall 1, 2 & 3

10:00–12:00 JW2 A • Poster Session II, Exhibit Hall 1, 2 & 3

10:00–10:30 Coffee Break, Exhibit Hall 1, 2 & 3

10:00–12:45 OSA Members, Family and Friends Tour – Computer History Museum
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- Download the app.
- Log in to use app features such as contacting fellow conference attendees—using your registration I.D. and email address.
JW2A.2 Detection of strain induced temperature variations based on a four-core optical fiber, Belkis Gokbulut1, 2, Sema Guvenç1, Naci Ilican1, 2. BBogazici Univ., Turkey. A four-core optical fiber is introduced as a strain based temperature sensor to explore the phase shift corresponding to the temperature variations. A phase shift of 20.4 ± 0.29 rad occurs for a temperature increment of 42°C.

JW2A.3 Electro-optic measurement of averaged duty ratio for periodically poled crystals, Inaki Mirov1, 2, Bernard Grychtol1, 2. Inst. of Optics and Photonics, National Superconducting Cyclotron Laboratory, Michigan State University, U.S.A. We propose a new gas detection method with optical wave microchannel (OM). It generates OPM signal without installing conventional microchannel where acoustic wave stands. We successfully detected acoustic signal from C/H2 with OWM.

JW2A.4 Bound state operation of an all-polarization maintaining Er-doped fiber laser, Zhuang Zhao1, 2, Daniel Pope1, Bo Fu1, Syed Hussain1, Andrea Ferrari2, 3, 1Engineering, Univ. of Cambridge, UK. We report single pulse and harmonic mode locking of two-soliton bound states from an all-polarization maintaining mode-locked laser based on a nanotube saturable absorber that could aid increased telecom bandwidths.

JW2A.5 Self-starting, turn-key dual-mode comb mode-locked fiber laser with a few-mode fiber filter, Jie Chen1, 2, Bultu Wang1, Ting Li1, Cui Li1, 2, Yingling Pan1, Xin Zhao1, Jiansheng Liu1, Zheng Zheng1, 2. School of Electronic and Information Engineering, Beihang Univ., China. 1Collaborative Innovation Center of Geospatial Technology, China. A simple, self-starting, turn-key dual-l wavelength comb mode-locked fiber laser is realized with a dual-mode-fiber-based filter. The cost-effective, multimode interference filter fiber with low spectral modulation depth enables relatively wide spectral bandwidths in the mode-locking windows.

JW2A.6 Attosecond Synchronization of Passive mode-Locked Lasers Using Optical Heterodyne Techniques, Shujun Chen1, 2, Jie Tian1, Dawei Chen1, Qiang Chen1, Qingsong Bai1, Fuyu Sun1, Dong Hou1, 2. 1ZTE Corporation, China; 2China Academy of Engineering Physics, China; 3Univ. of Electronic Science & Tech China. We demonstrate an attosecond synchronization of mode-locked lasers using optical heterodyne technique. The measured RMS timing fluctuation between two mode-locked Er fiber lasers with same color was about 800 attosecond within 60 s.

JW2A.7 Remote Photo-Acoustic Spectroscopy (PAS) with an Optical Pickup Microphone, Kazuhide Sato1, Kazuyuki Terui1, Shigeru Yamaguchi1, Masaki Asobe1, Yoshiho sonoda1, 2Tokai Univ., Japan. We propose a new gas detection method with optical wave microchannel (OM). It generates OPM signal without installing conventional microchannel where acoustic wave stands. We successfully detected acoustic signal from CH4 with OWM.

JW2A.8 Optical-controlled Pencil-Beam Steering Phased-Array Based On FD-OP, Mutong Xie1, XiuL Gao1, Mingyang Zhao1, Wensheng Zhai1, Wenjing Xu1, Jinwang Qian1, Mingzheng Lei1, Shanguo Huang1, 2Beijing Univ. of Posts & Telecom, China. A pencil-beam steering phased-array based on optical-controlling scheme is proposed. FD-OP is used to gain flexibility and high tunability. Experiments are conducted at 17 GHz to validate the 2D beams-steering ability of the system.

JW2A.9 An 8x8 Heterodyne Lens-less OPA Camera, Reza Fatemi1, Behrooz Abini1, Ali Hajimiri1, 2. Stanford Univ., 1Palo Alto, CA, USA. We present a high spatial resolution and a fast frequency distribution sensor based on Mach-Zehnder-OTDR, Yunhong Tong1, Zhengying Li1, 2, Jiaqi Wang2, 3. 1National Lab of Fiber Optic Sensing Technology, China; 2Univ. of Maryland Univ College, USA. In many complex environments, it is imperative to monitor various information and complex processes. We propose to use nanophotonic devices such as plasmonic structures and dielectric photonic crystals for simultaneous detection and discrimination of multiple parameters.

JW2A.10 Highly Sensitive Back-Focal-Plane Interferometry for Tracking Nanoparticle Position, Shuzo Masui1, 2, Masaki Iwasaki1, Takamichi Takamatsu1, Satoru takashashi1, 2, Precision Engineering, The Univ. of Tokyo, Japan; 1Research Center for Advanced Science and Technology, The Univ. of Tokyo, Japan. Recently, nanoparticles have played important roles in various fields. Back-focal-plane interferometry is a widely used method for nanoparticle tracking. We proposed and demonstrated a method to improve the sensitivity of back-focal-plane interferometry.

JW2A.11 High-order Suppression of Quasi-triangle Array Transmission Gratings, Tanchao Pu1, Zhen Li1, 2, Lina Shi1, Changxing Xie1, Guoxue Wang1, 2, Inst of Microelectronics of CAS, China; 3Univ. of Chinese Academy of Sciences, China. We propose a binary grating based on a membrane to solve the overlapping in the spectrum measurement. By optimizing the shape, size and position of the holes, a self-standing single-order diffraction gratings have been achieved.

JW2A.12 Thermally-induced optical bistability in Cr ranging systems by supporting the relative linewidth, Zebin Zhu1, Kai Ni1, Qian Zhou1, Guanhao Wu1, Tsinghua Univ., China. We use an intra-cavity EOM to realize high speed synchronization of dual-comb. The relative linewidth is dramatically suppressed from 300kHz to sub-hertz without ultra-stable CW laser and the ranging accuracy is greatly improved.

JW2A.13 Investigation of anti-reflexion wall coatings beyond melting temperatures, Wenhao Li1, 2, Mikhail Babalas1, Xiang Peng1, Saymon Pustelny1, Arne Wickenbrock1, Yucheng Yang1, Hong Guo1, Dmitry Budker1, 2, Peking Univ., China; 2Dept. of Physics, Univ. of California, Berkeley, USA; 3St. Petersburg State Univ., Russia; 1Inst. of Physics, Jagiellonian University, 2Institut für Physik der Universität Hamburg, Germany; 3Helmholtz Inst. Mainz, Germany. We investigate vapor cells with anti-reflexion wall coatings by measuring their relaxation properties beyond the melting temperatures and compare with the melting behavior of the coating material as observed with differential scanning calorimetry.

JW2A.14 A High Performance Optomechanical Mass Sensor, Yipeng Zhang1, 2, Jie Ai1, 2, Yanjun Xiang1, Qinghua He1, 2, Tuo Li1, 2, Inst. of Fluid Physics, China Academy of Engineering Physics, China. A mass sensor based on split-nonabeam optomechanical cavity with effective motion mass below 10 mg and mechanical frequency exceed 10GHz is proposed. Based on our simulation, exceed 10MHz/g detection sensitivity can be realized.

JW2A.15 Multi-parameter Sensing Platforms based on Plasmonic Structures and Planar Photonic Crystals, Yongao Chen1, 2, Miao Yu1, 2, 1Univ of Maryland Univ College, USA. In many complex environments, it is imperative to monitor various information and complex processes. We propose to use nanophotonic devices such as plasmonic structures and dielectric photonic crystals for simultaneous detection and discrimination of multiple parameters.

JW2A.16 Improved distributed optical fiber vibration sensor based on Mach-Zehnder-OTDR, Yunheng Tong1, Zhengying Li1, 2, Jiaqi Wang2, 3, Chun Zhang1, 2, National Engineering Lab for Fiber Optic Sensing Technology, China; 1Key Lab of Fiber Optic Sensing Technology and Information Processing, China. A high-speed distributed vibration sensor based on balanced Mach-Zehnder interferometer and optical time-domain reflectometer is introduced to distinguish multiple vibration simultaneously. The experimental results show a high spatial resolution and a fast frequency response.

JW2A.17 Improving the accuracy of dual-comb ranging system by supporting the relative linewidth, Ze bin Zhu1, Kai Ni1, Qian Zhou1, Guanhao Wu1, Tsinghua Univ., China. We use an intra-cavity EOM to realize high speed synchronization of dual-comb. The relative linewidth is dramatically suppressed from 300kHz to sub-hertz without ultra-stable CW laser and the ranging accuracy is greatly improved.

JW2A.18 Reversible mapping of spin to orbital angular momentum degree of freedom of one photon of an entangled pair, Brian T. Kirby1, Michael Brodsky1, 2, Nenad Bozinovic1, 2, Sidharth Ramachandran1, US Army Research Lab, USA; 2Dept. of Electrical & Computer Engineering, Boston Univ., USA; 3Berkeley Lights Inc, USA. We demonstrate high fidelity conversion of a polarization-entangled photon pair into a hybrid OAM-polarization entangled pair by using a special multi-mode vortex fiber. A new model accounting for frequency-dependent modal loss fits the data.

JW2A.19 Heralded Photons for Quantum Teleportation, Francisco A. Dominguez-Serna1, 2, Kanai Gayrat, Paimet1, 2, Reza Fatemi1, 2, Andrea Ferrari1, 2, 1Optica, CICESE, Mexico; 2CNyN-UNAM, Mexico. We present a quantum teleportation protocol based on a hybrid entangled resource (HER) able to transport photons and coherent states. High efficiency of teleportation can be obtained by adjusting spectral detection windows.

JW2A.20 Photon-pair Generation by Spontaneous Four-Wave Mixing in Integrated Optical Waveguides: A Nonlinear Time-Domain Model, Gary Sinclair1, 2, Mark Thompson2, 3, 1Quantum Engineering Technology Labs, H.H. Wills Physics Lab, Univ. of Bristol, UK. In this work, we present a kinetic model for the generation in the presence of parasitic nonlinearities such as self- and cross-phase modulation. The effect of these nonlinearities on the pair production rate and heralded photon purity is explored.

JW2A.21 Two-qubits Controlled-unity Quantum Gates for Quantum Computing by Silicon Photonic Chip, Jianguo Huang1, 2, Leong Mirov1, 3, 1Univ. of Electronics & Technology, The Univ. of Tokyo, Japan; 2Dept. of Physics, Univ. of Toronto, Canada. We present two-qubits controlled unitary quantum gates in a single silicon photonic chip. It can greatly reduce the size and complexity of the functional quantum circuits without decomposition it into plenty of elementary logic gates.

JW2A.22 An approach to the generation of GHZ states by interference of multiple integrated sources on a single chip, Nicola Bergamasco1, Matteo Menotti1, 2, Marco Lidicin1, 2, 1Dept. of Physics, Univ. of Pa- via, Italy; 2Dept. of Physics, Univ. of Toronto, Canada. We present an approach to the generation of path-encoded Greenberger-Horne-Zeilinger states in a single chip, by interfering four integrated microring resonators in which degenerate spontaneous four-wave mixing takes place.
We consider the P-function of generating Biphoton Frequency Combs experiment for three coherent pump-lines sinks and monitoring the evolution allows us to demonstrate the mid-infrared supercontinuum generation in the normal dispersion regime at a wavelength of 2.5-terahertz with a pulse width of 1.5 picoseconds. We report generation of Terahertz repetition rate pulse genera-
tion in Erbium-doped fiber, Siang Yang1, Zhahou Wu1, Yi Yang1, Yu Li1, Hongwei Chen1, Minghua Chen1, Tsinghung Hua1, China. We report generation of terahertz repetition rate pulse directly from Erbium-Ytterbium co-doped fiber based on the combination effect of amplification and nonlinear phase locking. The repetition rate is up to 2.75 terahertz and the pulse width is 100 femtosecond.
JW2A.45 Nonlinear Propagation of 100 ps, UV Laser Pulses in Water with Strong Stimulated Raman Stokes Coupling, Yu-hsin Chen1, Alexander Stamm1, John Palastro1, Bahman Halaf1, Theodore Jones1, Dmitri Kaganovich1; 1Naval Research Lab, USA; Underwater UV laser pulse propagation experiments were performed at intensities spanning the linear and nonlinear regimes. Measurements and simulations show strong coupling to molecular Raman modes and suggest strong ionization-induced refraction near the beam focus.

JW2A.46 Periodical Soliton Bunches in a Passively Mode-locked Fiber Laser by the Optomechanical Effect in Microfiber, Zhenhong Wang1; 1Nankai Univ., China. We experimentally observe periodical soliton bunches in a microfiber-based graphene saturable absorber mode-locked fiber laser. The optomechanical effect and dispersive wave are responsible for the inter- and intra-soliton-bunch interaction in the laser, respectively.

JW2A.47 Robust Mid-Infrared Photothermal Imaging System for Characterization of Thin Films at High Spatial Resolution, Atcha Totachanta1,2, Di Huang1, Keith A. Watanabe1; 1Department of Physics, Universidade Federal de Pernambuco, Brazil; 2Graduate Program in Dentistry, Universidade Federal de Pernambuco, Brazil. We present the application of optical coherence tomography as an auxiliary tool for periodical disease diagnosis, and demonstrated in three stages: animal modeling, healthy patients and follow up of disease regression upon treatment.

JW2A.51 Label-free ucesulation in systemic sec- nosis using optical coherence tomography, Natália S. Pires1, Andrea T. Dantas2, Angela L. Duarte3, Marcello M. Amaral2, Luana O. Fernandez1, Tereza J. Dias1, Luciana S. Melo1, Claudia C. Mota1, Patricia F. Silva1, Anderson Gomes1,2; 1Faculty of Dentistry, Centro Universitário Tabosa de Almeida, Brazil; 2Dept. of Physics, Universidade Federal de Pernambuco, Brazil; 3Graduate Program in Dentistry, Universidade Federal de Pernambuco, Brazil. A clinical study was developed to evaluate the label-free ucesulation using optical coherence tomography in 33 systemic sclerosis patients and 35 healthy control. The ucesules presented statistically significant differences between the groups.

JW2A.52 Optical Clearing Agents Associated with Nanoparticles for Scanning Dental Structures with Optical Coherence Tomography, Vanda S. Carneiro1,2, Claudia C. Mota1, Anderson Gomes2, Alex F. Souza1, Natasha C. Araujo1, Rebecca F. Melo2, Marlene F. Soares1, Tereza J. Dias1, Luciana S. Melo1, Claudine C. Mota1; 1Faculty of Dentistry, Centro Universitário Tabosa de Almeida, Brazil; 2Dept. of Restorative Den- tistry, Universidade Federal de Pernambuco, Brazil; 3Dept. of Physics, Universidade Federal de Pernambuco, Brazil. We propose a self-pulsing ring cavity ultra-long Erbium Fiber laser of 1.8-Hz linewidth and ~125 dB Hz -1 phase noise at 1 kHz (normalized to -1 optical path difference) is demonstrated, utilizing 4-erbium-doped fiber as both Brillouin and linear gain media.

JW2A.57 Ultra-narrow-linewidth Brillouin/Erbium Fi- ber Laser, Mo Chen1, Chenyu Wang1, Jianfei Wang1, Hong Luo1, Zhou Meng1; 1National Univ of Defense Technology, China. A Brillouin/erbium fiber laser of 1.8-Hz linewidth and ~125 dB Hz -1 phase noise at 1 kHz (normalized to -1 optical path difference) is demonstrated, utilizing 4-erbium-doped fiber as both Brillouin and linear gain media.

JW2A.58 Self-pulsing Ring Cavity Ultra-long Raman Fiber Laser, Mohd Z. Zulkifli1, kuen yao lasu1, Hani Khashi1, Mohd Azidir Mahdi2, Sergei Turitsyn2; 1Aston Univ, Aston Inst of Photonic Technologies, UK; 2AIST, Japan; 3University of Tokyo, Japan. We propose a self-pulsing ring cavity ultra-long Raman fiber laser using TrueWave® REÅCH Fiber as the gain medium. This work shows its alternative prospect to linear laser cavity configuration or ring laser cavity employing other gain medium.

JW2A.59 Electrical polarization in micro optical fiber and its applications in kilovolt sensing, Nan-Kuang Chen1,2, Cheng Y. Li1, Raman Kashyap1, Yi-Ning Chen1, Chunlin Lin1, Xiaoguang Zhang; 1National United Univ., Taiwan. We demonstrate interesting electrical polarization phenomenon in silica micro fiber to make kilovolt sensors. The micro fiber can be intrinsically polarized and then physically moved by an external kilovolt- age source to change its spectral responses.

JW2A.60 All-polarization maintaining optical fre- quency comb based on Er doped fiber laser with carbon nanotube, Motohiro Togashi1, Takeru Nagakake1, Lei Jin1, Youichi Sakakibara1, Emiko Omote1, Hiromichi Katayama1, Yousuke Ozeki1, Norhiro Nishizawa1; 1Nagoya Univ., Japan; 2AIST, Japan; 3Univ of Tokyo, Japan. All polarization maintaining optical frequency comb was demonstrated based on Er-doped ultrashort pulse fiber laser with carbon nano- tube. The and were stabilized and their linewidths were compressed below 1 Hz by phase locking.

JW2A.61 Low Nonlinearity Yb-Doped Fluoresceric Optical Fiber With Ultra-Flat Absorption Spectrum, Peter D. Dragi1, Maxime Cavill- lon2, Courtney Kucer3, Thomas Hawkins1, John Ballatori1; 1Univ of Illinois at Urbana- Champaign, USA; 2Clemson Univ, USA. We report on new Yb-doped fluorosceric optical fibers with reduced strength of Brillouin, Raman, and thermal Rayleigh scattering. Yb absorption spectra strongly resemble borate glasses, with ultra-flat absorption in the 940nm region.

JW2A.62 Time-Range-Extended Spatiotemporal Measurement Technique for Multi-Mode Fiber Pulse, Bing Zuo1,2, Travis Jones1, Rick Trebino1; 1National Lab on High Power Laser and Physics, Shanghai Inst. of Optics and Fine Mechanics, Chinese Academy of Science, China; 2School of Physics, Georgia Inst. of Technology, USA. A multi-delay, multi-path spatiotem- poral measurement technique is introduced to characterize multi-mode fiber long pulses without extra pulse pre-compression. Two- mode fibers were tested with extended temporal measurement range, indicating different modes experienc- ing different dispersion.

JW2A.63 Integrated chiral long period gratings in multicore fiber, Ruoxia Wang1, Ming Tang1, Songlian Fu1, Haiiang Zhang2, Deming Li1, Perry Shum1; 1Huazhong Univ. of Sci.&Tech., China; 2School of Electrical and Electronics Engineering., Nanyang Technological Univ., Singapore. We developed a novel approach to inscribe integrated chiral long period gratings into multicore fiber with electrical arc discharge method. Transmission spectra and polarization characteristics are measured through spatial division multiplexing fan-in/ fan-out devices.

Wednesday 10:00-12:00
JW2A.64
Extended linear cavity 2 μm single-frequency fiber laser using Tm-doped fiber saturable absorbers, Shijie Fu1, Wei Shi1, guanann shi1, Quan Sheng1, haiwei zhang1, jianquan yao1, Tianjin Univ., China. An extended linear cavity single-frequency fiber laser at 2 μm was investigated using Tm-doped fiber as saturable absorber. More than 60 mW laser power was achieved with the linewidth of ~40 kHz.

JW2A.65
Optical wavelength-swept source at 2 μm and its application for ultrafast microscopy, Sisi Tan1, Xiaoming Wei1, lingxiao yang1, can li1, nan chen1, Kenneth Kin-Yip Wong1; 1Univ. of Hong Kong, China. We report an optical wavelength-swept source at 2 μm at a sweeping rate of ~18.9 kHz over 30 nm Bragg grating. Application in time-stretch microscopy is subsequently demonstrated.

JW2A.66
Telbot Laser with Tunable Gtz Repetition Rate using an Electro-Optic Frequency Shifter, Lian Wang1, Sophie LaRoche1; 1Université Laval, Canada. We use an electro-optic frequency shifter in a Talbot laser to demonstrate pulse multiplication factors up to five using temporal fractional Talbot effect and achieve pulse repetition rates of tens of GHz.

JW2A.67
Low-noise Optical Multi-carrier Generation using Brillouin Amplification in a Frequency-Shifted Recirculating Loop, Lianxan Wang1, Jiachuan Lin1, Leslie A. Rusch1, Sophie LaRoche1; 1Université Laval, Canada. Brillouin amplification is used in a frequency-shifted recirculating optical fiber loop to generate a low-noise multi-carrier optical signal. We minimize ASE noise through numerical simulations and we perform a proof-of-concept experimental demonstration.

JW2A.68
Elliptical-core Mode-selective Photonic Lanterns for MIMO-free Mode Division Multiplexing, Xiaoyu Ji1, Xiaoming Wei1, lingxiao yang1, can li1, nan chen1, Kenneth Kin-Yip Wong1; 1Univ. of Hong Kong, China. We report an optical wavelength-swept source at 2 μm with an experimental demonstration.

JW2A.70
Measurements of Polarization Crosstalk in a Polarization-Maintaining Few-Mode Optical Fiber, Zhen Wang1, Xiaolong Hui1, Myung Lyu1, Qi Mo1; 1China University of Science and Technology, China; 2School of Precision Instrument and Optoelectronic Engineering, Tianjin Univ., China; 3Fiberhome & Fujikura Optics Co., China. 1School of Optical and Electromagnetic Information, Huazhong Univ. of Science and Technology, China; 4The College of Optics & Photonics, Univ. of Central Florida, USA. We experimentally demonstrate the measure of the intra- and inter-state-modal polarization crosstalk in a polarization-maintaining few-mode optical fiber using optical time-domain reflectometry.

JW2A.71
Temperature and Strain Sensing in BOTDA Fiber Sensor by Utilizing Wavelength-Sweeping BGS, Zongli Li1, Liyuan Yan1, Lijiang Shao1, Jiangwei Liang1, Wei Pan1, Bin Luo1; 1Southwest Jiaotong Univ., China. We present a fiber optical temperature and strain sensing platform utilizing a relatively narrow-wavelength-swept optical parametric oscillator (OPO). The wavelength-sweeping is proposed for BGS measurement, based on which the decoded Brillouin wavelength shift exhibits sensing coefficients of 0.3%/℃ and 160μm/℃ in standard SMF.

JW2A.72
Dual-Mode Immunoassay using Photonic Crystal Biosilica, Alan X. Wang1; 1Oregon State Univ., USA. We demonstrate an ultra-sensitive immunoassay biosensor through photonic crystal enhanced fluorescence and surface-enhanced Raman scattering (SERS) using diatom biosilica. We experimentally achieved enhanced detection limit down to 10^{-10} M and 10^{-12} M respectively.

JW2A.73
Low-cost thermal infrared detector based on surface plasmon resonance imaging, Honghong Ji1, Felipe Vallin1, Cheng-Yi Fang1, Amin Alasad1, Yeshiahu Fanman1; 1Electrical and Computer Engineering, Univ. of California San Diego, USA; 2Materials Science and Engineering, Univ. of California San Diego, USA; 3Center of Excellence for Telecommunication, King Abdulaziz City for Science and Technology, Saudi Arabia. We present an uncooled thermal infrared detector based on SPR imaging. IR induced thermo-optic shifts in polymer-clad metal gratings are detected by visible SPR readout, and an experimentally predicted NETD of 22 K is obtained.

JW2A.74
Silicon On-chip Ultrafast Integrated Sensor Array Based on High-Q Photonic Crystal Nanobeam Cavities with Very Large Free Spectral Range, Daquan Lin1, Tingting Wu1, Xiujuan Zhang1, Lei Wang1, Quan Sheng1, Jinping Chen1, Qinghai Guo1, Tianjin Univ., China. We present a novel method for multiplexed on-chip integrated sensor array, which are based on ultrafast one-dimensional photonic-crystal nanobeam cavities with ultrahigh-Q and very large free-spectral-range (FSR~200nm). The proposed sensor array exhibits refractive-index sensitivities of 166.4nm/RIU can be achieved.

JW2A.75
Plasmonic Nanoantenna of Hole-Sphere Nanopads for Surface Enhanced Raman Scattering Sensing, Jiqing Lee1, Jong M. Lee1, Chanwoo Hong1, Samir Adhikari1, Hyuck Jeong1, Yu D. Jang1, Jong S. Baek1, Ison Yoon1, Donghan Lee1; 1Chungnam National Univ., South Korea; 2Centre for Nanoscale Science and Technology, Poland. We report gap-dependent strong SERS enhancements and plasmonic couplings of hole-sphere nanostructures. The structure shows uniform sensitivity of less than 10% over the entire substrate, which comes from uniform narrow gaps over the substrate.

JW2A.76
Experimental Demonstration of Using Orbital Angular Momentum Based Spatial Spectrum Analysis for Object Parameter Estimation, Guodong Xie1, Xiaoming Wei1, lingxiao yang1, Zhe Zhao1, Yongqiong Ren1, Cong Liu1, Runzhong Zhang1, Long Li1, Zhe Wang1, Kai Pang1, Mosur Tur1, Alan E. Willner1; 3University of Southern California, USA; 4Tel Aviv Univ., Israel. We demonstrate the use of orbital angular momentum based spatial spectrum analysis for the estimation of object parameters. The high sensitivity of this method is insensitive to object rotation or probing beam diffraction caused by object truncation.

JW2A.77
Exploiting Shock Wave and Self-Absorption for High Resolution Laser Induced Breakdown Spectroscopy, Ali Rastegar1, Matthias Lenzner1, Chengyong Feng1, Jadan Ainsw1, Jean-Claude M. Diels1, Kristen Peterson1; 1Univ. of New Mexico, USA; 2Lenzner Research, USA; 3Southwest Sciences, Inc, USA. The shock wave created by a high energy UV filament is sufficient to create a low pressure absorber enabling higher resolution laser induced breakdown spectroscopy, through reduction of pressure broadening. Isotropic selectivity is demonstrated.

JW2A.78
Low Q-factor Ring Resonators With Ultra-Low Limit of Detection Based on FFT Processing of Spectral Scanning Data, Leften Gounaris1, Panos Goumas1, Erik Jonsson1, Lazar Bekdemir1, George Economou1, Nikolaos Kontoulos1; 1National Technical Univ. of Athens, Greece; 2LioniX B.V, Netherlands; 3Biomedical Research Foundation of the Academy of Athens, Greece. We extend the simulations for sensors with micro-ring resonators and FFT-based processing of the measurement data. We experimentally demonstrate a system with low Q-factor resonators and coarse scanning steps, achieving limit of detection 7x10^{-7} RIU.

JW2A.79
Time-Wavelength Optical Sensing Based on Laser Cavity Tuning, Lin Yang1, Lei Wang1, Xiujuan Zhang1, Tianjin Univ., China. We report a new time-wavelength mapping scheme based on optical sampling by cavity tuning and demonstrate its application in absorption spectroscopy.

JW2A.80
Computational Adaptive Sampling for Multiheterodyne Spectroscopy, Lukasz A. Sterczewski1, Jonas Westberg1, Linh Patrick1, Gerard Wysocki1; 1Dep. of Electrical Engineering, Princeton Univ., USA; 2Faculty of Electronics, Wroclaw Univ. of Science and Technology, Poland. We present a fast computational technique based on digital filtering, mixing, and linear resampling to enable high resolution multiheterodyne spectroscopy in any dual-comb system affected by frequency instabilities of the laser sources.

JW2A.81
Compressive sampling for spectral imaging, Luke Maidment1, Adam Polak2; 1Univ. of New Mexico, USA; 2Lenzner Research, USA. We design a Band-selective silicon Photonic Fourier Transform Spectrometer using Slow Light, Shayan Mokhbernej1; 1Univ. of California San Diego, USA. A silicon-photonic Fourier Transform Spectrometer is designed based on coupled-microresonators forming a slow-light waveguide, which scans the propagation delay electrically. The simulated device is compact, fast and achieves high spectral resolution in targeted bands.

JW2A.83
3D Temperature Mapping of Cellular Passive Cooling Structures Fabricated by Additive Manufacturing for Lasers, Lin Yang1, ran zou1, aido gan1, lin cheng1, albert tu1, kevin P. Chen1; 1Electrical and Computer Engineering, Univ. of Pittsburgh, USA; 2Mechanical Engineering & Materials Science, Univ. of Pittsburgh, USA. 3D temperature mapping of passive cooling structures built by additive manufacturing was interrogated by in-fiber Rayleigh backscattering using optical frequency domain reflectometry for therm-mechanic structure optimization for laser and photonic systems.

JW2A.84
Tunable Resonant Graphene Plasmonics for Mid-infrared Biosensing, Tingting Wu1, Lei Wei1; 1Nanyang Technological Univ., Singapore. Tunable resonant surface plasmons based on graphene nanoribbon are studied to detect nanoscale protein molecules in mid-infrared region. High sensitivity in the detection of the refractive index and the protein chemical vibrations is achieved.

JW2A.85
All-fiber GEPAS Sensor and Its Application for Spatially Resolved Trace Gas Detection, Yufei Ma1, Ying He1, Yin Xu1, Rui Sun1, Frank Tittel1; 1Harbin Inst. of Technology, China; 2Rice Univ., USA. A compact all-fiber GEPAS sensor using quartz tuning fork (QTF) with a resonant frequency of 37.92 kHz was demonstrated. Three QTFs were used for H2O detection simultaneously to demonstrate the potential of spatially resolved measurements.
JW2A.86
Explore on Inorganic Cladding of Neodymium Phosphate Glass Used in Slab Amplifier, Bingang Wang1, Jiangqiang Zhu1, Li Haiyuan1, Xiong Hua1, SIOM, CAS, China. Polymer cladding is conventionally employed for neodymium phosphate glass in slab amplifier. But the organic polymer is easy to fracture under high flashlamp radiation. An inorganic cladding is proposed, and the conformationary experiment is accomplished.

JW2A.87
High Energy Pulse Recompression Techniques for Petawatt Class Lasers, Elin A. Khazanov1, Sergey Mironov1, Vlad Grabourg1, Ivan Yakoulev1, Anton Kochetkov1, Andrey Shaykin1, Gerard Mourou1, Inst. of Applied Physics, Russia; International Center for Zetta-Exawatt Science and Technology, France. Using of Thin Film Compressor for shortening of PW laser pulses was investigated in experiments. Cascade quadratic nonlinearity in a single KDP crystal can be applied for control temporal parameters of the laser pulses.

JW2A.92
Filter-driven four-wave mixing ultrafast chirp compensation, Babak Bahrami1,2, Tigran Sanamyan1, Pathak1,2, Sapienza Univ. Of Rome, Italy. We demonstrate a stable ultrafast all-fiber laser based on filter-driven four wave mixing using a microfiber resonator which serves both as filter and a high nonlinear element.

JW2A.93
A Burst-mode Nd:YVO4:Nd:YAG MOPA Laser with High-Repetition-Rate and High-Pulse-Energy, Xu Dong1, Li peng1, zhang hui2, yu hui2, ying chen2, zhong xiang hou1, harbin inst. of Technol., China. We demonstrated a burst-mode Nd:YVO4:Nd:YAG MOPA laser A.D pumped Nd:YVO4: A Q-switched laser works as oscillator and Nd:YAG modules as amplifiers. During 1ms burst duration, maximum pulse burst energy of 730 mJ at 10 kHz is obtained with single pulse energy of 73 mJ and a pulse width of 9.3 ns.

JW2A.94
Path to Doubling the Efficiency of Mid-IR Erbium Lasers, Tigran Sanamyan1, ’US Army Research Lab, USA. Absorption and emission spectra of Cr:ZnSe host are perfectly positioned to amplify the output of the cascade Er:Y2O3, or any cascade erbium laser, when pumped by 1.5μm and seeded by 2.7μm component of the laser.

JW2A.95
Double Layer Hollow Core Anti-reflective Fiber for Small Core and Low Loss Characteristics, Xiaohong Huang1, Dang Li1, Wenhong Qi1, Seong Yoo1, Nanyang Technological Univ., Singapore. We study the function of second cladding layer of the tubular fiber (TLF) and experimentally demonstrate the important role of the second layer in the reduction of both confinement loss (CL) and bending loss.

JW2A.96
Tri-wave Diagnostics with Single Diffraction Pattern Based on Coherent Phase Modulation in High Power Laser Systems, Xingchen Pan1, Cheng Liu1, Jiaqiang Zhu1, Shanghai Inst of Optics and Fine Mech, China. A novel algorithm for on-line three-wave measurements based on phase modulation and coherent iterative engine with single diffraction pattern. It could be a potential technique for pulse laser diagnostic in high power laser systems.

JW2A.97
A 97-ps laser-pulse generation by two-stage stimulated Brillouin and Raman scattering, Zahong Liu1, Yulei Wang1, Hengkang Zhang2, Xi You3, Han Xian Chen4, Weizhou Chen5, Harbin Inst. of technology, China. We demonstrate a pulse temporal compression technique based on a combination of Stimulated Brillouin scattering and subsequently Stimulated Raman scattering. A 97-ps pulse compressed from an 8.3 μs Q-switched Nd:YAG laser pulse is obtained.

JW2A.98
Functional Topological THz devices using ultrashort pulses in a Silicon–Nanomaterials composite, Kanskar1,2, Elias Towe1; École Polytechnique de Montréal, Canada. We proposed, fabricated, and characterized. The demonstrated sensitivity is found to be 0.12GHz/μm to changes in the defect layer thickness.

JW2A.99
Photo-thermal-acoustic THz detection based on 3-dimensional graphene, Mostafa Shalaby1, C. Vivarico1, Flavio Giorgianni1, Francesco Lupi1, Christopher F. Haut1; Paul Scherrer Institute, Switzerland; Dept. of Physics, Sapienza Univ. Of Rome, Italy. We report on a novel, simple and efficient THz energy and intensity profile diagnostic tool which is based on the photo-thermo-acoustic (PTA) effect in a 3-dimensional graphene sponge.

JW2A.100
Enhanced Sensitivity of Terahertz Allergen Sensors Based on Complex Metamaterial Surfaces, Guillermo A. Naraino1, Xun Liu1, Youjin Li2, Xin Li2, Jun Dong3, Panhui Yu4, Anh Tran3, Guangyu Qian5, Weidong Jiang6, Kai Liu7, 1US Army Research Lab, USA; 2Dept. of Physics, Sapienza Univ. Of Rome, Italy; 3Univ. of North Texas, USA; 4ECE, Oklahoma State Univ., USA. We presented a novel quad-wavelength multi-focused lens, in which four focusing spots could be arbitrarily controlled at four frequencies independently. A prototype quad-wavelength lens has been designed and numerically verified at terahertz frequencies.

JW2A.101
Graphene-based Metasurfaces for Multimode Tunable Terahertz Modulators, Thomas A. Seacars1, Mehdi Rezaee1, Amirhasan Shams-Arani1, Erin Strickland1, Tina Brower-Thomson2, Gary Harris1, Riad Yahiaoui1, Howard Univ., USA; Université Paris Ouest, France. We present a hybrid graphene meta-surface and its modulation by electrostatically tuning the conductivity of the graphene. Through modification of unit cell symmetry, tunable resonance frequencies are achieved for all modes over a 300 GHz range.

JW2A.102
3D Printed Hollow-Core Terahertz Optical Waveguides with Hyperuniform Disordered Dielectric Reflectors, Tian Ma1, Michem Guerboukha1, Maxim Skorobogaty1, 1Paul Scherrer Institut, Switzerland; 2Dept. of Engineering Physics, École Polytechnique de Montréal, Canada. Novel hollow-core THz waveguides featuring hyperuniform disordered reflectors are proposed, fabricated, and characterized. The results confirm that proposed waveguide exhibit sizable photonic band gaps (20%) even when relatively low refractive index contrast used (resin/air).

JW2A.103
Terahertz Emission in One-Dimensional Disordered Phosphonitrilic and Sila-Phosphonitrilic Crystals, Shuhong Li1, guozhen liang1, hui kai ping2, 1Huazhong Univ. Of Science and Technology, China. An off-axis THz-wave detection bandwidth of 5 THz is achieved. Imaging system. The wave confinement and standing wave modes are clearly observed.

JW2A.104
Quad-Wavelength Multi-Focused Lens with Dual-Wavelength Meta-Atoms, sen song1, jun ding1, bing wen zhang2, yuan kun lin2, wei ze zhang1, huai liang zhang1, 1ECE, Univ. of Massachusetts Lowell, USA; 2Physics, Univ. of North Texas, USA; 3ECE, Oklahoma State Univ., USA. We proposed a novel quad-wavelength multi-focused lens, in which four focusing spots could be arbitrarily controlled at four frequencies independently. A prototype quad-wavelength lens has been designed and numerically verified at terahertz frequencies.

JW2A.105
Quad-Wavelength Multi-Focused Lens with Dual-Wavelength Meta-Atoms, sen song1, jun ding1, bing wen zhang2, yuan kun lin2, wei ze zhang1, huai liang zhang1, 1ECE, Univ. of Massachusetts Lowell, USA; 2Physics, Univ. of North Texas, USA; 3ECE, Oklahoma State Univ., USA. We proposed a novel quad-wavelength multi-focused lens, in which four focusing spots could be arbitrarily controlled at four frequencies independently. A prototype quad-wavelength lens has been designed and numerically verified at terahertz frequencies.

JW2A.106
3D Printed Hollow-Core Terahertz Optical Waveguides with Hyperuniform Disordered Dielectric Reflectors, Tian Ma1, Michem Guerboukha1, Maxim Skorobogaty1, 1Paul Scherrer Institut, Switzerland; 2Dept. of Engineering Physics, École Polytechnique de Montréal, Canada. Novel hollow-core THz waveguides featuring hyperuniform disordered reflectors are proposed, fabricated, and characterized. The results confirm that proposed waveguide exhibit sizable photonic band gaps (20%) even when relatively low refractive index contrast used (resin/air).

JW2A.107
Terahertz Emission in One-Dimensional Disordered Phosphonitrilic and Sila-Phosphonitrilic Crystals, Shuhong Li1, guozhen liang1, hui kai ping2, 1Huazhong Univ. Of Science and Technology, China. An off-axis THz-wave detection bandwidth of 5 THz is achieved. Imaging system. The wave confinement and standing wave modes are clearly observed.
**JW2A.131**
Experimental demonstration of silicon strip and slot waveguides for 2 μm chip-scale optical data transmission, Li Shen1, Zhengwen Ruan1, Shuang Zhen1, Andong Wang1, Jun Liu1, Shuhui Li1, Jian Wang2, Wuhan National Lab for Optoelectronics, Huazhong Univ. of Science and Technology, China. Silicon strip and slot waveguides are fabricated and 5 Gb/s directly-modulated data transmission is demonstrated in 2 μm waveband. The results indicate the suitability of SOI platform for data transmission applications in this mid-infrared wavelength.

**JW2A.132**
Experimental Study of Electro-Optic Crosstalk in Parallel Silicon Photonic Mach-Zehnder Modulators, Lingsong Jiang1, Xi Chen1, Kwangwoong Kim2, Guillaume de Valcour1, Zhaoran R. Huang1, Po Dong1, ‘Nokia Bell Labs, USA; ‘Dept. of Electrical, Computer and Systems Engineering, Rensselaer Polytechnic Inst., USA. The electro-optic crosstalk between two parallel silicon Mach-Zehnder modulators is characterized. Up to 1.6 dB power penalty is observed for 38-Gb/s on-off-keying signals with a ~20 dB crosstalk, posing challenge to dense photonic integration.

**JW2A.133**
Frequency and stability analysis of two mutually delay-coupled semiconductor lasers in photonic integrated circuits, Masoud Seifkari2, Andreas Amann1, Frank Peters1, ‘Tyndall National Inst., Ireland; ‘Dept. of Physics, Univ. College Cork, Ireland; ‘School of Mathematical Sciences, Univ. College Cork, Ireland. A system of two mutually delay-coupled semiconductor lasers for integration in a photonic integrated circuit is investigated. Multi-stabilities and bifurcation scenarios are presented, followed by a comprehensive frequency analysis of the symmetric and symmetry-broken, 1-colour and 2-colour states.

**JW2A.134**
Silicon Nitride Polarization Beam Splitter Based on MM with Phase Delay Line, Min TENG1, Sangsik Kim1, Kyung hun Han2, Ben Niu1, Yunjo Lee1, Minghao Qi1, ‘Purdue Univ., USA. We purpose a nitrogen polarization beam splitter which shows 21 dB extinction over 100 nm bandwidth and 30 dB at C band. With two-stage cascade, 38 dB flat-band extinction can be achieved for both polarizations.

**JW2A.135**
Scalable, Low-Power-Penalty Nanosecond Reconfigurable Hybrid Optical Switches for Data Centre Networks, Minsheng Ding1, Adrian Wonfor1, Xiangcheng Cheng2, Richard V. Penty1, Ian White1, ‘Univ. of Cambridge, UK. A quantitative analysis shows for the first time that a Clos-Benes MZI-SOA based switch with a hybrid fibre-integration approach can achieve a record 2048 port count with 1.15 dB penalty when using soft decision FEC.

**JW2A.136**
Low-loss Arbitrary-arity 1×N Power Splitter, Ping Xue1, Zhixin Wang1, Che Zhao1, Fe Chen1, Weizhe Hu1, ‘Peking Univ., China; ‘Inst. of Telecommunication Satellites, China Academy of Space Technology, China. An arbitrary-arity 1×N power splitter is demonstrated. The power distribution of N-way outputs can be freely customized based on demand. It also has the features of low loss, compact size, easy configuration and wide band.

**JW2A.137**
Fabrication of Lightwave Circuits on Flat Fibers: System-in-Fiber, Sheng Huang1, Mohammad H. Hashemi2, ‘U.C. San Diego, USA. We report ultrafast laser fabrication of waveguide circuits in optical fibers with rectangular cross-section and flat large area surface designed for on-fiber integration. Low-loss coupler and WDM devices are directly integrated in fibers.

**JW2A.138**
Chasing Moore’s Law with CLEAR, Shuai Sun1, Vikram Narayana 1, Tarek El-Ghazawi1, Volker J. Sorge1, ‘George Washington Univ., USA. We introduce a multi-hierarchical FOM termed CLEAR (Capability-to-Latency-Energy-Amount-Resistance) applying to the devices, interconnect, and system levels which accurately predicts technology developments since 1940s, and predicts photonic technology extension to keep up the pace of evolution.

**JW2A.139**
Robust photonic differentiator employing slow light effect in photonic crystal waveguide, Siyuan Yu1, Zhe Wang1, Laoshi Liu1, Yi-Rou Liou1, Golam Haider1, Shu-Yi Cai2, Ching-Min Lai2, ‘Purdue Univ., USA; ‘Univ. of Texas at Austin, USA. The coupling efficiencies of -1.8dB and with 90% coupling are obtained experimentally.

**JW2A.140**
Full Control of Farfield Radiation via Photonic Integrated Circuits Decorated with Plasmonic Nano-antennae, Yi-Zhi Sun1,2, Renaud Bachelot1, Sylvain Blaise1, Lishuang Feng1, Wei Ding1, ‘School of Instrumentation Science and Opto-electronics Engineering, Beihang Univ., China; ‘CAS Inst. of Physics, China; ‘Laboratoire de Nanotechnologie et d’Instrumentation Optique (LUNI), Universite de Technologie de Troyes, France. We introduce a PIC/plasmonic-antenna hybrid structure to fully control phase, amplitude, and polarization of far-field radiation. Out-of-plane light collimating (0° to 0.23rad), high-NA (~0.65) beam focusing, and high-purity (~99%) vector/vortex mode generation are demonstrated in simulation.

**JW2A.141**
Fast circuit modeling of heat transfer in photonic integrated circuits, Xiaowei Wang1, Shayan Mousavijerdi1, ‘U.C. San Diego, USA. We demonstrate a fast method of modeling heat transfer in photonic integrated circuits by simple thermal resistance circuits that use a conical surface area approximation for effective thermal resistance. We show with Spectre simulations accuracy with Lab measurements within 1-K to 2-K.

**JW2A.142**
Microwave Photonic Interrogation of a High-resolution and Temperature-insensitive Refractive Index Sensor, Yuan Cao1, Xudong Wang1, Xinhuan Feng1, Kevin Chen1, ‘Univ. of Pittsburgh, USA; ‘Coming Inc., USA. A system of two mutually delay-coupled semiconductor lasers for integration in a photonic integrated circuit is investigated. Multi-stabilities and bifurcation scenarios are presented, followed by a comprehensive frequency analysis of the symmetric and symmetry-broken, 1-colour and 2-colour states.

**JW2A.143**
Low-loss Two-dimensional Grating Coupler on SOI Platform with Bonded Metal Mirror, Zhihao Nong1, Siyuan Yu1, Yan n. Luo1, ‘Purdue Univ., USA. We design and fabricate low loss 2D grating couplers on the silicon-on-insulator platform with bonded metal mirror. The coupling efficiencies of －11dB and with 1dB bandwidth of 32nm was achieved.

**JW2A.144**
A Microwave Photonic-based Inverse Synthesis Aperture Radar System, Xuedi Xiao1, Shuangyan Li1, Boyu Chen2,2, Xiaoyi Yang1, Dixin Wu2,2, Xiaoxiao Xue1,1, Xiaoping Zheng1,1, Bingkun Zhou1,1, Tinghua National Lab for Information Science and Technology, China; ‘Dept. of Electronic Engineering, Tsinghua Univ., China. We demonstrate a microwave imaging radar experimental platform, using photonic generation of linear frequency modulated waveform centered at 10GHz with 4GHz bandwidth. Distance and velocity resolution of about 5cm and 2m/s are obtained experimentally.

**JW2A.145**
High performance light emitting memories: multifunctional devices for unveiling information by optical and electrical detection, Yi-Rou Liou1, Golam Haider1, Shu-Yi Cai2, Ching-Min Lai2, ‘Purdue Univ., USA; ‘Univ. of Texas at Austin, USA. We propose a ripple-carry electro-optic full adder using microring resonators, taking advantage of unique properties of light on chip. This proposed design with larger bandwidth and lower power consumption paves the way to future optical computing.
High-Speed Subsampled Optical Coherence Tomography Imaging with Frequency Comb Lasers, Meena Siddiqui, Benjamin J. Vakoc, Ahhyun Nam, Norman Lippok; a Wellman Center for Photomedicine, USA; b Harvard Medical School, USA. We demonstrate how frequency comb lasers can be used to induce optical-domain compression in optical ranging. In the context of coherent tomography, this compression enables ultra-high-speed volumetric microscopy. We describe this concept and a novel high-speed laser based on stretched-pulse mode locking (SPML).

Broadly Tunable Semiconductor Laser with Self-Imaging Three-Branch Multi-Mode Interferometer, Guan-Lin Su, Ming C. Wu, a Naval Research Lab, USA; b University of California, Santa Barbara, USA; c Key Lab of Semiconductor Materials Science, City Univ. of Hong Kong, Hong Kong. We present preliminary results on a widely-tunable laser with monolithically integrated high-Q ring based on heterogeneous silicon integration platform. The laser exhibits > 43 nm tuning range with side mode suppression ratio larger than 40 dB in the O-band.
15:30–17:30  
**FW4E • Quantum State Generation and Characterization**  
**Presider: Shengwang Du; Hong Kong Univ of Science & Technology, Hong Kong**

*Generation and characterization of factorable biphotons with 99% spectral purity.*  
Changchen Chen1, Bo Cao2, Yuehen Niu3, Feihu Xu4, Zheshen Zhang4, Jeffrey H. Shapiro1, Franco Wong1; 1MIT, USA; 2Electrical Engineering, Tohoku Univ., Japan. We generate biphotons via pulsed spontaneous parametric downconversion under extended Gaussian phase matching, and measure their joint spectral intensity at high resolution using a low-loss dispersion compensation module to obtain a 99% heralded-state spectral purity.

16:00–17:30  
**FW4F • Quantum States and Sensing with Optomechanical Systems**  
**Presider: Thomas Purdy; NIST, USA**

*Joint Spectral Intensity of 1.55 µm photonic crystal microresonator.*  
Joint Spectral Intensity of 1.55 µm photonic crystal microresonator.  

15:30–17:30  
**FW4G • Symposium on Advances in Metaphotonics Devices II**  
**Presider: Andrea Alu; Univ. of Texas at Austin, USA**

*Extensive Platforms for Metaphotonics.*  
Nader Engheta1, Brian E. Edwards1, Inigo Libert1, Nasim Mohammadi Estakhri1, Ahmed M. Mahmoud1, Yaakov Lumer1; 1Univ. of Pennsylvania, USA. We have been investigating light-matter interaction in extreme-parameter structures. We have found that metamaterials with unconventional material parameters provide us with unique platforms exhibiting unprecedented classical and quantum metaphotonic features with various potential applications.

16:00–17:30  
**FW4H • Ultrafast Optics and Plasmonics in Nanostructures**  
**Presider: Christopher Petoukhoff; Okinawa Inst. of Science and Technol, Japan**

*Active Upconverters for Biological Force and Field Sensing.*  
Invited Active Upconverters for Biological Force and Field Sensing. Jennifer Dionne1; 1Stanford Univ., USA. Most upconverters suffer from low efficiencies and minimal active tunability with external forces or fields. Here, we develop novel upconverting materials that address these limitations, and utilize them for in-vivo biological force and field sensing.

**Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.**
SW4J.2 • 15:45
Parasitic Effect of TE and TM modes in OAM-DM Demultiplexed Transmission over an Inverse-Parabolic Graded Index Fiber, Jiangbo Zhu1, Xuyang Wang1, Shuangyi Yan1, Yanni Ou1, Ziyang Hu1, Younes Messadegh1, Sophie LaRochelle1, Leslie Rusch1, Dimitra Simeonidou1, Siyuan Yu1; 1Univ. of Bristol, UK; 2Universite Laval, Canada. We demonstrate MIMO-free two-dimensional multiplexing and de-multiplexing over 4 OAM modes (including two modes of \(|l|=2\)) and 15 wavelengths through 100-meter inverse-parabolic graded-index fiber, with aggregated total capacity of 3.36-Tbit/s.

SW4J.3 • 16:00
Invited
3.36-Tbit/s OAM and Wavelength Multiplexed Transmission over an Inverse-Parabolic Graded Index Fiber, Joseph Shaw1, Ingmar Hartl1, Piotr Maslowski2, 1Univ. of Bristol, UK; 2Inst. of Physics, Nicolaus Copernicus Univ., Poland. We present an optical frequency comb based Fourier Transform Spectrometer, covering 3.0 to 5.2 µm with 2 nm optical path delay and a signal-to-noise ratio of 800 in 40 s acquisition time at 4.6 μm.

SW4K.1 • 15:30
Demonstration of Hybrid Orbital Angular Momentum (OAM) and Gaussian Mode Encoding/Decoding for 10-Gbit/s Data Transmission through a 2.6-km Conventional-Mode Multimode (OM3) Fiber, Lung Zhu1, Jian Wang1, Andong Wang1; 1Wuhan National Lab for Optoelectronics, China. We experimentally demonstrate hybrid orbital angular momentum (OAM) Mode and Gaussian mode encoding/decoding for 10-Gbit/s data transmission through a 2.6-km conventional-mode graded-index multimode Fiber (OM3), and achieve bit-error rate (BER) below 3.8×10⁻³.

SW4K.3 • 16:00
Invited
Nanoscale Nonlinear Optics with Low-dimensional Nanomaterials, Zhipei Sun1; 1Dept. of Micro- and Nanosciences, Aalto Univ., Finland. I will discuss our recent nanoscale nonlinear optic experiments (e.g., quantum emitters, wavelength converters, ultrafast lasers) with one-dimensional (e.g., carbon nanotubes), two-dimensional (e.g., graphene, MoS2), and three-dimensional (e.g., heterostructures, plasmonic structures, silicon/fibre integrated structures).

Joseph Shaw is the director of the Optical Technology Center and professor of electrical engineering, physics, and optics and photonics at Montana State University in Bozeman, Montana. He has been developing optical and infrared remote sensing instruments for nearly three decades for a wide range of applications ranging from measuring atmospheric clouds and aerosols to mapping insects and fish. He is a Fellow of the OSA and SPIE.

SW4L.1 • 15:30
Tutorial
Lidar Instruments and Applications, Joseph Shaw1, 1Montana State Univ., USA. This tutorial will review the basic design of LIDAR systems for elastic and inelastic scattering in remote sensing applications ranging from airborne mapping of fish in lakes to differential-absorption measurements of gas concentration in the atmosphere.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

15:30–17:30  
**SW4M • Concepts & Advances in Quasi-phase Matching**  
**Presider:** Irina Sorokina; Norges Teknisk Naturvitenskapelige Univ., Norway

**SW4M.1 • 15:30**  
Simultaneous Second and Fourth Harmonic Generation of a Carbon dioxide laser in a single Orientation-Patterned Gallium Phosphide Crystal, Shekhar Guha1, Joel Murray1, Jacob Barnes2, P.G. Schunemann2, US Air Force Research Lab, USA; 3UES, Inc., USA; 4BAE Systems, USA. First demonstration of simultaneous frequency doubling and quadrupling of a pulsed carbon-dioxide laser in a single-grating orientation-patterned Gallium Phosphide crystal grown by hydride vapor phase epitaxy is reported.

**SW4M.2 • 15:45**  
Mid-Infrared Picosecond Difference Frequency Generation in Orientation-Patterned Gallium Phosphide, Josep C. Casals1, Shahzad Pana1, Chaitanya Kumar Suddapalli1, Kavita Dev1, P.G. Schunemann2, Majid Ebrahim-Zadeh3, IFCO-The Inst. of Photonic Sciences, Spain; 2Radiantis, Spain; 3BAE Systems, Incorporated, USA. The first temperature-dependent Sellmeier equation for GaP was fit to extensive refractive index data measured on thin GaP plates for wavelengths between 1 and 200 to 450K.

**SW4M.3 • 16:00**  
Temperature Dependent Sellmeier Equation for the Refractive Index of GaP, Shekhar Guha1, Joel Wei1, Joel Murray1, Jacob Barnes2, P.G. Schunemann2, Douglas Krein3, US Air Force Research Lab, USA; 3UES, Inc., USA; 4BAE Systems, USA; 5BAE Systems, USA. The first temperature-dependent Sellmeier equation for GaP was fit to extensive refractive index data measured on thin GaP plates for wavelengths between 1 and 12 microns over a temperature range of 200 to 450K.

15:30–17:30  
**SW4N • Microresonator Frequency Comb**  
**Presider:** Takasumi Tanabe; Keio Univ., Japan

**SW4N.1 • 15:30**  
Experimental Demonstration of Dual-Comb Generation by XPM Between Two Polarization States in a Microresonator, Changle Gu1, Kerry Vahala3, Kartik Srinivasan2, Scott Didier1; 1US Air Force Research Lab, USA; 2UES, Inc., USA; 3California Inst. of Technology, USA. Soliton pulse generation in a dual-core As2Se3/PMMA fiber could excite a comb with the assistance of a soliton.

**SW4N.2 • 15:45**  
Single mode dispersive waves and soliton microcomb dynamics, Xu Yi1, Qifan Wang1, Xueyue Zhang1, Qifan Wang1, Kerry Vahala1; 1California Inst. of Technology, USA. Dispersive-wave scattering from dissipative Kerr solitons is induced by spatialmode interactions within a high-Q micro-resonator. A limiting case, single-mode dispersive waves, are observed and their interaction with the soliton causes hysteretic behavior.

**SW4N.3 • 16:00 Invited**  
Optical Frequency Synthesis Using a Dual-Kerr-Microresonator Frequency Comb, Travis C. Briles1, Taral Drake1, Daryl Spencer1, Jordan R. Stone1, Connor Fredrick1, Qing Li1, Daron Westly2, B.R. Ilic2, Xu Yi3, Ki Y. Yang3, Kerr Vahala1, Kartik Srinivasan1, Scott Diddams1, Scott Papp1; 1Time and Frequency, NIST, USA; 2Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland; 3School of Physics, Univ. of Adelaide, Australia; 4Griffith Univ., Australia. Atom-trap trace analysis (ATTA) is an ultra-sensitive technique for measurement of noble-gas radio-nuclide ratios at the 10^{-12} level, with application to environmental science. We explore laser-based metastable excitation techniques to improve measurement efficiency, accuracy and speed.

15:30–17:30  
**SW4O • Laser Induced Excitations in Matter**  
**Presider:** Emmanuel Haro-Poniatowski; UAM-Iztapalapa, Mexico

**SW4O.1 • 15:30**  
Laser-based Noble-gas Metastable Excitation Techniques with Application to Atom Trap Trace Analysis, Philip S. Light1, Milad A. Dabkak2, Rohan Glover1, Robert Sang1, Andre N. Luiten2; 1School of Physical Sciences, Univ. of Adelaide, Australia; 2Griffith Univ., Australia. Atom-trap trace analysis (ATTA) is an ultra-sensitive technique for measurement of noble-gas radio-nuclide ratios at the 10^{-12} level, with application to environmental science. We explore laser-based metastable excitation techniques to improve measurement efficiency, accuracy and speed.

**SW4O.2 • 15:45**  
Generation of sub-THz surface wave on a metal wire by intense laser interaction with a foil target, Kensuke Teramoto1, Shunsuke Inoue1, Shigeki Tokita1, Ryo Yasuhara3, Takeshi Nagashima4, Yoshihide Nakamura1, Kazuaki Mori1, Masaki Hashida1, Shuji Sakabe1, Kyoto Univ., Japan; 2Osaka Univ., Japan; 3National Inst. for Fusion Science, Japan, 4Setsunan Univ., Japan. It has been demonstrated that the electric field associated with electrons generated by an intense femtosecond laser pulse in a foil can induce intense sub-THz surface wave on a wire waveguide adjacent to the foil.

**SW4O.3 • 16:00**  
Pulse-induced permanent group-velocity matching in a dual-core As2Se3/PMMA fiber, Chams Baker1, Song Gao1, Liang Chen1, Xiaoyi Bao1, Univ. of Ottawa, Canada. We report that transmission of pulses in tapered dual-core As2Se3/PMMA fibers induces permanent effective group-velocity matching between the field propagating in the fiber.
Continued

**AW4A.4 • 16:45**

**Evaluation of Optical Coherence Tomography Distal Sensor with High-index Elliptical Cone Epoxy Lens**  
Soohyun Lee, Changho Lee, 1, Jeremy Chae, 1, Gyeongwoo Cheon, 1, Berk Goren, 1, Peter L. Geibich, 1, Jin U. Kang, 1  
1Johns Hopkins University, USA.

In this paper, we demonstrate common-path swept source optical coherence tomography (CP-SSOCT) distal sensor with high-index elliptical cone epoxy lens. The elliptical cone epoxy lens terminated fiber sensor exhibits enhanced SMR in water over a wide range of incident angles.

**AW4A.6 • 16:45**

**Novel Long-Period Fiber Gratings: Fabrication and Sensing Applications**  
Liyong Ren, Kaile Ren, Xudong Kong, Jian Liang, Huijuan Ju, Zhaoxin Wu, Xi’an Inst. of Opt. & Precision Mech., China; Xi’an Jiaotong Univ., China.  
We presented two novel schemes for fabricating micro-tapered long-period fiber gratings (LPFGs) and helical LPFGs, respectively, by periodically tapering and by directly twisting single mode fibers. Superior sensing characteristics of them are also demonstrated experimentally.

**AW44 • Biomedical Imaging—Continued**

**AW4B.4 • 16:15**

**Pulsed-Laser Induced Rayleigh-Taylor Instabilities of Ultrathin Metal Films Inside Homogeneous Liquid Mixtures**  
Rami Kalyanaraman, 1 Verkataratnamarayana Prasad Sandireddy, 1 Sagar P. Yadavali, 2 Chemical and Biomedical Engineering, Univ. of Tennessee, USA; 2Dept. of Materials Science and Engineering, Univ. of Tennessee, USA.  
We developed a technique to enhance optical pressure in liquid mixtures using a pulsed laser. This approach provides a new route for enhanced optical phenomena.

**AW4B.5 • 16:30**

**Integration of Ultrafast Laser-inscribed Optical Waveguides and Renewable Ring Lasers**  
Hengyi Chandralalim, 1 Stephen C. Rand, 1 Xudong Fan, 1 Univ. of Michigan, USA.  
We demonstrated the monolithic integration of renewable and wavelength reconfigurable ring lasers and waveguides of arbitrary shapes. This work enables reconfigurable optical devices for on-chip lasers, flexible optical processing, and the investigation of new optical phenomena.

**AW4B.6 • 16:45**

**Differential Frequency Tunable Dual-Mode Heterogeneous QD Laser with Si PIC**  
Atsushi Matsumoto, 1 Toshimasa Umezawa, 1 Kouchi Akahane, 1 Naokatsu Yamamoto, 1 Hirohito Yamada, 1 Tomohiro Kita, 2 NIC, Japan; 3Tokohu Univ., Japan.  
We proposed a tunable dual-mode heterogeneously quantum dot laser diode with a Si-photonics-based photonic integrated circuit, and successfully demonstrated dual-mode lasing oscillation by tuning the differential frequency from approximately 20 GHz to 200 GHz.

**AW4C.4 • 16:45**

**Novel Long-Period Fiber Gratings: Fabrication and Sensing Applications**  
Liyong Ren, Kaile Ren, Xudong Kong, Jian Liang, Huijuan Ju, Zhaoxin Wu, Xi’an Inst. of Opt. & Precision Mech., China; Xi’an Jiaotong Univ., China.  
We presented two novel schemes for fabricating micro-tapered long-period fiber gratings (LPFGs) and helical LPFGs, respectively, by periodically tapering and by directly twisting single mode fibers. Superior sensing characteristics of them are also demonstrated experimentally.

**AW4C.5 • 16:30**

**A 20 GHz colliding pulse mode-locked heterogeneous InP-silicon laser**  
Sangtao Liu, 1 Michael Davenport, 1 John Bowers, 1 Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA; 2Key Lab of Semiconductor Materials Science, Inst. of Semiconductors, CAS, China.  
We demonstrated that a colliding pulse mode-locked laser based on heterogeneous InP-silicon platform, working in the passive mode locking regime with a 20 GHz repetition rate. The laser outputs nearly transform limited pulses with record narrow pulse width of 1.37 ps on the silicon platform.

**FW4A.3 • 16:30**

**High-Sensitivity Contrast-Enhanced in vivo Imaging with Optical Coherence Tomography (OCT)**  
Orly Liba, 1, Elliott Soffel, 1, Debashis Sen, 1, Adam de la Zerda, 2, 4  
1Electrical Engineering, Stanford Univ., USA; 2Structural Biology, Stanford Univ., USA; 3Biophysics, Stanford Univ., USA; 4Molecular Imaging Program, Stanford Univ., USA.  
We developed custom spectral detection algorithms and highly-scattering large gold nanorods for sub-nanometer sensitivity contrast-enhanced optical coherence tomography (OCT). We used this approach for noninvasive 3D imaging of blood and lymph vessels in living mice.

**FW4A.4 • 16:45**

**Evaluation of Optical Coherence Tomography Distal Sensor with High-index Elliptical Cone Epoxy Lens**  
Soohyun Lee, Changho Lee, 1, Jeremy Chae, 1, Gyeongwoo Cheon, 1, Berk Goren, 1, Peter L. Geibich, 1, Jin U. Kang, 1  
1Johns Hopkins University, USA.  
In this paper, we demonstrate common-path swept source optical coherence tomography (CP-SSOCT) distal sensor with high-index elliptical cone epoxy lens. The elliptical cone epoxy lens terminated fiber sensor exhibits enhanced SNR in water over a wide range of incident angles.

**FW4B.4 • 16:15**

**Difference-Frequency Generation Quan tum Cascade Laser Sources on Silicon**  
Seunggyong Jung, 1 Jae Hyun Kim, 1 Yifan Jiang, 1 Karun Vijayaraghavan, 1 Mikhail A. Belkin, 1 Univ. of Texas at Austin, USA.  
We demonstrate that a heterogeneous integration of Cherenkov terahertz quantum cascade laser sources on a high-resilient silicon substrate enables 5 times improvement in terahertz power compared to that of devices on a native InP substrate.

**FW4B.5 • 16:30**

**Yb:YAG regenerative thin-disk amplifiers as an ideal pump and seed source for OPCPA**  
Joerg Neuhaus, 1 Florian Fink, 1 Gregor Hehl, 1 Mikhail Larionov, 1 Robert Riedel, 1 Michael Schulz, 1 Dausinger + Giesen GmbH, Germany; 2Class 5 Photonics GmbH, Germany.  
We present experimental and theoretical results for parallel amplification of 350 fs and 2.7 ps in the same Yb:YAG regenerative thin-disk amplifier for high energy OPCPA pumping and stable supercontinuum generation for OPCPA seeding.
FW4E.4 • 16:30
Pulsed Quantum Frequency Combs from an Actively Mode-Locked Intra-Cavity Generation Scheme, Pieter Roztocki1, Michael Kues1,2, Christian Reimer1, Benjamin Wetzel1, Brent Little3, Sai Chu1,2, Steven Connell1,2, Steven Gensemer1,2, Mirko Solomon1,2, Edward Flagg1,2,3, Joseph Irudayaraj1,2, Erik W. Werschler1, Florian Wiesner1, Konstanz, Germany; 1Purdue Univ., USA; 2Texas A&M Univ., USA; 3South Dakota School of Mines & Technology, USA. We demonstrate a narrow-linewidth, low-threshold surface-plasmon-polariton (SPP) laser based on a low-loss open cavity resonator leveraging grating-coupled SPPs to pump the lasing SPPs with strong spatial overlap and minimum perturbation.

FW4A.3 • 16:30 Invited
Lifetime Shortening and Photoluminescence Emission Enhancement of Single CdSe/ CdS/PMMA Quantum Emitters Coupled to Plasmonic Bullseye Resonators, Florian Wierschler1, Benjamin Lindner1, Christopher Hinz1, Tjaard de Roo1, Stefan Mecking1, Denis Seletskiy1, Alfred Leitenstorfer1, Univ. of Konstanz, Germany. An order-of-magnitude enhancement in the radiative recombination rate is observed in single CdSe/CdS/PMMA colloidal quantum dots when coupled to gold plasmonic resonators, consistent with the measured increase in the excitonic photoluminescence signal.

FW4F.4 • 16:45
Polarization-dependent interference of coherent scattering from orthogonal dipole moments of a resonantly excited quantum dot, Disheng Chen1, Gary Lander1, Glenn Solomon1,2, Edward Flagg1,2,3, West Virginia University, USA; 2University of Maryland, USA; 3NIST, USA. Interference between coherent scattering from the two fine structure split excitation states in a neutral InGaAs quantum dot causes an unconventional excitation line shape. Analysis allows the extraction of steady-state coherence between the excitation states.
SW4I • orbital angular-momentum based optical communications—continued

**SW4I.4 • 16:30**
Invited Experimental Demonstration of an Orbital-Angular-Momentum Encoded Quantum Communication Link Co-propagating with a Classical Channel, Yongxiong Ren¹, Cong Liu, Kai Pang, Jiapeng Zhao, Yanwen Cao, Guodong Xie, Long Li, Zhe Zhao, Zhe Wang, Moshe Tur², Robert Boyd³, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²Dept. of Physics and Astronomy, The Inst. of Optics, Univ. of Rochester, Rochester, USA; ³Tel Aviv Univ., Israel. We experimentally demonstrate an OAM-based quantum communication link populated by a classical channel. OAM enables an up to 100-Mbit/s quantum data rate as well as an additional 18.5-dB separation between the quantum and classical channels.

**SW4J.4 • 16:15**
Line-shapes and intensities of carbon monoxide transitions in the (3 ← 0) and (4 ← 1) bands, Zachary D. Reed¹, Joseph T. Hodges², Oleg Polyansky³; ¹NIST, USA; ²Univ. College London, UK. We present line shape parameters and intensities of air-broadened CD (3 ← 0) and (4 ← 1) band transitions using frequency-stabilized cavity ringdown spectroscopy at room temperature. Measurements are compared to ab initio calculations.

**SW4K.4 • 16:30**
Near Infrared Emission from Defect States of Atomically Thin Phosphorene, Shahriar Aghaeimeibodi¹, Jehyung Kim¹, Edo Waks¹; ¹Univ. of Maryland, USA. We demonstrate a new class of near infrared localized defects in few layer phosphorene. This work highlights the significance of defect states of phosphorene for near infrared optoelectronic applications.

**SW4L.2 • 16:30**
Nonmechanical Beam Steering Using Tunable Lenses, Mo Zohrabi¹, Robert H. Cormack¹, Juliet T. Gopinath¹; ¹Dept. of Electrical, Computer, and Energy Engineering, Univ. of Colorado, USA. We have used three tunable liquid lenses to demonstrate nonmechanical beam steering of ±75° using a fisheye lens, in two dimensions. The system can control the beam divergence and provide two-dimensional beam steering.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

**MW4M.4 • 16:15**
Highly-Efficient Cascaded Mirrorless OPO in Sub-µm Periodically-Poled RbKTP Crystals, Andrius Zukauskas¹, Charlotte Liljestrand¹, Anne-Lise Viotti¹, Valdis Pasiskevics¹, Carlota Canalas¹, Christina Holmström¹, Carina Gullström¹, Charlotte Mårtensson¹, Carolina Takamori¹, Elena Smirnova¹, Joonhyuk Lee¹, Hongi Sato¹, Armin Fath-Habib², César Peralta³, Jonas Källén³, Ulf Sköld³, Elin Melin⁴, Ugur Gedik⁵, Xiaoyong Jia⁶, Joonhyuk Lee⁷, Takeshi Miyake⁸, and Dennis Kroll⁹. We design a high-efficiency cascaded mirrorless optical parametric oscillator (OPO) in sub-µm periodically-poled RbKTP crystals reaching an efficiency of 43%. The generated signal serves as a pump in a cascaded MOPO process in the same crystal.

**MW4N.4 • 16:15**
Liquid crystal-modulated spontaneous emission via plasmonic waveguide cladded with low index metamaterials, He Hao¹, Jiuqian Ren¹, Hongyi Chen¹, and Minghao Qi¹, Andrew Weiner¹, Yi Xuan¹, Kyunghun Han¹, Daniel Leaird¹, Cong Wang¹, Chengying Bao¹, Gaal¹,², Roman Bauer¹, Mathias Sander¹, Taras Slobozhanskyi¹, Wolfgang Hansen¹, ²Peking Univ., China; ³Pennsylvania State Univ., USA. Using the liquid crystal-metal-low index metamaterial waveguide which supports surface plasmon polaritons, we theoretically demonstrate an active modulation of spontaneous emission. It can be modulated from 313g0 to 327g0 by varying optical axis.

**MW4O.4 • 16:45**
Elastic and thermal properties of strain-tailored air-gap heterostructures, Peter Gaal¹,², Roman Bauer¹, Mathias Sander¹, Taras Slobozhanskyi¹, Wolfgang Hansen¹, ²Institute for Solid-State and Nanostructure Physics, Universität Hamburg, Germany; ³Heinrich-Hertz-Institut für Elektromagnetische Technik, Berlin, Germany; ⁴Institut de Physique et Astronomie, Universität Potsdam, Germany. The temperature-dependent expansion coefficient in strain-tailored semiconductor air-gap heterostructures (AGHs) has been measured via static x-ray diffraction (XRD). Time-dependent XRD measurements reveal different thermal transport regimes on picosecond and nanosecond timescales.

**MW4O.6 • 16:45**
Normal Dispersion High Conversion Efficiency Kerr Comb with 50 GHz Repetition Rate, Cang Wang¹, Chengying Bao¹, Yi Xuan¹, Kyoung Hun Han¹, Daniel Leaird¹, Minghao Qi¹, Andrew Weiner¹. We demonstrate a 50 GHz, low noise Kerr comb with 34% conversion of the pump light into the comb based on a normal dispersion, silicon nitride microring resonator.

**MW4M.6 • 16:45**
Hybrid Lithium Niobate Waveguide for Efficient Quasi-Phase-Matched Optical Frequency Conversion, Peter Wengel¹, Marc Savanier¹, Shayan Mookherjea¹, Shu-Wei Huang¹, Jin-ghuai Yang¹, Qihuang Gong¹, ²Inst. of Microelectronics, Singapore; ³Columbia Univ., USA. We report a nonlinear waveguide for 2f-to-3f optical frequency conversion based on silicon nitride-lithium niobate and calculate high nonlinear conversion efficiencies of 898, 623, and 3169 %/(W·cm²) for the processes discussed.

**MW4N.6 • 16:45**
Ultrafast Adiabatic Second Harmonic Generation, Asaf Dahan¹,², Assaf Levanon¹, Mordechai Katz¹, Haim Suchowski¹, Raymond and Beverly Sackler School of Physics and Astronomy Tel Aviv Univ., Israel; ²Solid State Physics Dept., Electro-Optics Division, Soreq NRC, Israel. We report an efficient and robust frequency doubling with 70 nm bandwidth with thermal acceptance of 100°C and chirp variation of 300 fs-3.5 ps. This was achieved by adiabatic SHG crystal, designed by a generalized nonlinear spatiotemporal simulation.
AW4A • Biomedical Imaging I—Continued

AW4A.5 • 17:00
Characterizing Cardiomyocytes Motion with Quantitative Phase Imaging, Christine E. Cordeiro1, Oscar Abilez1, Tushar Gupta1, Georges Goetz1, Olav Solgaard1, Daniel Palanker1, 1Stanford Univ., USA. Characterizing cardiomyocytes activity is important for drug development, but traditional patch clamping analysis is destructive and slow. A label-free method for extracting timing and motion characteristics of cardiomyocytes using quantitative phase imaging is presented.

AW4B • Lasers and Applications—Continued

AW4B.7 • 17:00
Design and Deployment of Mobile FSO Communication System, Wael Alheadary1, Yujian Guo1, Edgar Stegenburgs1, Ki-Hong Park1, Tien Khee Ng2, Boon S. Ooi3, Mohamed-Slim Alouini3, 1KAUST, Saudi Arabia. As a potential solution to many applications, we developed a mobile free-space optical (FSO) system that achieves 1Gbps with transmission distance of 70 m. This system needs minimal preparation to be deployed within an hour.

AW4C • Semiconductor Lasers on Silicon—Continued

SW4C.7 • 17:00
Optical Feedback Sensitivity of Heterogeneously Integrated Silicon/III-V Lasers, Mark Harfouche1, Dongwan Kim1, Huolei Wang1, Naresh Satyan1, George Rakulic2, Amnon Yariv2, 1Electrical Engineering, California Inst. of Technology, USA; 2Applied Physics and Materials Science, California Inst. of Technology, USA; 3Telaris Inc., USA. The feedback sensitivity of a high coherence silicon/III-V laser is quantified using an interferometer. High fringe visibility is maintained up to a reflectivity of -21 dB, a 10 dB improvement compared to a high end commercially available DBR laser.

SW4C.8 • 17:15
Suppression of Linewidth Enhancement Factor in High-coherence Heterogeneously Integrated Silicon/III-V Lasers, Dongwan Kim1, Mark Harfouche1, Huolei Wang1, Naresh Satyan1, George Rakulic2, Amnon Yariv2, 1Electrical Engineering, California Inst. of Technology, USA; 2Applied Physics and Materials Science, California Inst. of Technology, USA; 3Telaris Inc., USA. We observe a relaxation resonance frequency of hundreds of MHz in high-coherence Si/III-V lasers, up to 5x less than commercial III-V lasers. This results in very low frequency noise PSD of 720 Hz^2 Hz above the relaxation resonance frequency due to the suppression of linewidth enhancement factor.

AW4D • Nonlinear Optical Sources—Continued

FW4D.6 • 17:00
Thermal equilibrium of Photons and Lasing without an Overall Inversion in Standard Erbium-Doped Fibers, Ralf Weill1, Alexander Bekker1, Boris Levit1, Michael Zhurahov1, Baruch Fischer1, "Technion Israel Inst. of Technology, Israel. We show thermal-equilibrium (TE) and Bose-Einstein distribution of photons in standard erbium-doped fibers. We also find a coexistence of TE with oscillation without an overall inversion that can be attributed to lasing or BEC.

FW4D.7 • 17:15
Synchronization of Mutually Coupled High-ß Quantum Dot Microlasers, Sören Kreinberg1, Felix Küger1, Steffen Holzinger1, Elisabeth Schlottmann1, Martin Kamp2, Christian Schneider3, Sven Höfling3, Xavier Porte1, Stephan Rettenste1n1, Technische Universität Berlin, Germany; 2Julius-Maximilians Universität Würzburg, Germany; 3Univ. of St Andrews, UK. We perform experiments on mutual coupling and synchronization of high-ß microlasers and show phenomena like partial, unidirectional and mutual locking, as well as synchronization of mode switching dynamics. We demonstrate qualitative deviations from classical expectations.

16:30–18:30 Happy Hour in Exhibit Hall, Exhibit Hall 1, 2 & 3

18:00–19:00 OSA Nanophotonics Technical Group 20x20, Executive Ballroom 210 A
FW4E • Quantum State Generation and Characterization—Continued

**FW4E.7 • 17:15**

*Generation and characterization of energy-entangled W states, Matteo Menotti,1 Bin Fang,2 Virginia O. Lorenz,1 John Sipe1, Marco Liscidini1,2 Dept. of Physics, Univ. of Pavia, Italy; 1Dept. of Physics and Astronomy, Univ. of Delaware, USA.*

We demonstrate the generation of W states entangled in the energy degree of freedom. Using a reduced density matrix approach, these states are characterized without the need for frequency conversion.

**FW4F • Quantum States and Sensing with Optomechanical Systems—Continued**

**FW4F.5 • 17:00**

*Multimode Quantum Optomechanics with Ultra-coherent Nanomechanical Resonators, Yeghishe Tsaturyan,1, William H. Nielsen,1 Christoffer B. Møller2, Andreas Barg3, Jutrin Chen1, Yannick Sesi1, Eugene S. Polzik1, Albert Schliesser1,2 Niels Bohr Inst., Univ. of Copenhagen, Denmark.*

Mechanical resonators with “soft” phononic clamping dilute the material’s intrinsic dissipation by five orders of magnitude. Decoherence rates comparable to trapped ions ensue, enabling quantum optomechanical experiments with multimode hybrid systems.

**FW4G • Symposium on Advances in Metaphotonic Devices II—Continued**

**FW4G.4 • 17:00**

*Enhancing Light-Matter Interaction with high-Q Fano Dielectric Metasurfaces, Sheng Liu,1 Sadhvikas Addamane1,2, Michael Sinclair1,2, Gordon Keeler1, Ganesh Balakrishnan1,2, Igal Brener1,3 Sandia National Labs, USA; 2The MOE Key Lab of Weak Light Nonlinear Optics and Quantum Imaging with Dielectric Meta-surfaces, School of Physics and TEDA Applied Physics Inst., Nankai Univ., China; 3Center for Nanophase Materials Sciences, Oak Ridge National Lab, USA.*

We suggest and realize experimentally dielectric metasurfaces with high transmission efficiency for quantum multi-photon tomography, allowing for full reconstruction of pure or mixed quantum polarization states across a broad bandwidth.

**FW4H • Ultrafast Optics and Plasmonics in Nanostructures—Continued**

**FW4H.6 • 17:00**

*Double Quantum Coherence in Individual Quantum Dots Enhanced by Weak Excitation of Delocalized States, Eric Martin1, Steven T. Cundiff2,1 Univ. of Michigan, USA.*

Two-quantum multidimensional coherent spectroscopy is used to probe few quantum dots in a diffraction limited spot. Creating a small number of carriers in the quasi-continuum levels enhances the signal and controls coherent coupling between states.
SW4J.6 • 17:00
Mechanical Fourier Transform Spectrometer with kHz Resolution, Lucile Rutkowski1, Alexandra C. Johansson1, Amir Khodabakhsh1, Aleksandra Foltynowicz1; 'Umea Univ., Sweden. We measure simultaneously 11000 resonances of a high-finesse cavity with kHz level resolution using optical frequency comb Fourier transform spectroscopy and retrieve the dispersion of the cavity mirrors from the cavity mode spacing.

SW4K.6 • 17:00
Demonstration of a New Technique for the Transfer Printing of Graphene on Photonic Devices, Leili Abdollahi Shiramin1, Alexander Bazin1, Steven Venisty1, Sylvia Lyrck1, Peter Vandenberghe1, Gunther Roelkens1, Dries Van Thourhout1; 'Ghent Univ.-IMEC, Belgium; 'Ghent Univ., Belgium. We demonstrate an automated method for transfer printing of micron sized graphene patterns on predefined sites on a photonic chip. Silicon nitride waveguides with graphene transferred on top exhibit an absorption loss of 0.054dB/µm, in line with simulation results.

SW4K.7 • 17:15
A 1000-fold contrast enhancement in Fabry-Perot interferometers, Giuseppe Antonacci1, Simone De Persio1, Giuseppe Di Domenico1, Eugenio Delle1, Giancarlo Ruocco1; 'Istituto Italiano di Tecnologia, Italy; 'Università di Roma “Sapienza”, Italy. Spectral contrast in Fabry-Perot interferometers is key to measure weak signals. Using a high-resolution, high-throughput VIPA spectrometer, we demonstrate an intensity-equalization method to achieve an unprecedented 1000-fold increase in spectral contrast in a single-pass configuration.

SW4L.4 • 17:00
Wide Field-of-View and Mid-Range Distance Imaging LIDAR by Digital Micro-Mirror Device, Brandon Heiman1, Braden Smith1, Adley Giri1, Young-sik Kim1, Guang-hao Chen1, Paul Winkler1, Yuzuru Takashima1; 'Univ. of Arizona, USA. A Digital Micro-mirror Device enables a fast, wide field-of-view, mid-range distance mapping while minimizing requirements for mechanical scanning components. The optical architecture offers a compact, low-cost solution to an imaging LIDAR with a single detector.

SW4L.5 • 17:15
Heterodyne Efficiency in Chirped Laser Dispersion Spectroscopy, Yifeng Chen1, Genevieve Plant11,2, Gerard Wysocki1, and Paul Winkler1, Yuzuru Takashima1; 'Univ. of Arizona, USA. We present an analysis of diffusive reflection and its effect on heterodyne efficiency in conventional and heterodyne-enhanced chirped laser dispersion spectroscopy motivated by applications in stand-off chemical detection.
### CLEO: Science & Innovations

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<td>Large Aperture Quasi-phase Matched Nonlinear Material for Functional Power Lasers, Takunori Taira(^1), Hideki Ishizuki(^1); (^1)Laser Research Center, Inst. for Molecular Science, Japan. High-power and high-energy nonlinear optics, which includes optical parametric process and based on large-aperture periodically poled Mg-doped LiNbO(_3), for mid-infrared-to-terahertz wave region are discussed. Topics include few cycles ultrafast pulse treatments with regarding HHG sources.</td>
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| **SW4O • Laser Induced Excitations in Matter—Continued** |
| **SW4N.6 • 17:00** | **SW4O.8 • 17:15** |
| Competition Between Raman and Kerr Effects in Microresonators, Yoshitomo Okawachi\(^1\), Mengjie Yu\(^2,3\), Vivek Venkataraman\(^1\), Pawel M. Latweic\(^1\), Marko Lončar\(^3\), Alexander L. Gaeta\(^1\); \(^1\)Columbia Univ., USA; \(^2\)Harvard Univ., USA; \(^3\)DTU Fotonik, Denmark. We investigate competing effects of Raman and Kerr gain in diamond microresonators. Strong, narrowband Raman gain inherent in crystalline materials determines a maximum microresonator size allowable to achieve Kerr combs. |

| **SW4N.7 • 17:15** | **SW4O.7 • 17:00** |
| 10 GHz Frequency Comb Spectral Broadening in AlGaAs-On-Insulator Nano-Waveguide with Ultra-Low Pump Power, Hao Hu\(^1\), Minhao Pu\(^1\), Kresten Yvind\(^1\), Leif K. Oxenløwe\(^1\); \(^1\)DTU Fotonik, Denmark. We experimentally demonstrated 10 GHz frequency comb spectral broadening with a 30-dB bandwidth of 238 nm in an 11-mm long AlGaAsO\(_3\) nano-waveguide. The 10-GHz 230-fs pump pulse has an average power of only 12 mW. |

| **SW4O.7 • 17:00** |
| Plasmonically Induced Coherent and Polarized Random Laser Emissions in Colloidal CdSe/ZnS Quantum Dots with Ellipsoidal Ag Nanoparticles, Yung-Chi Yao\(^1\), Zu-Po Yang\(^1\), Jing-Yu Haung\(^1\), Ming-Hung Lee\(^1\), Meng-Tian Tsai\(^1\); Inst. of Electro-Optical Science and Technology, National Taiwan Normal Univ., Taiwan; \(^2\)Inst. of Photonic System, National Chiao-Tung Univ., Taiwan; \(^3\)Dept. of Electrical Engineering, Chang Gung Univ., Taiwan. We demonstrate the capability of controlling the optical anisotropy by manipulating the coupling strength between the oscillated electric field and the localized surface plasmon resonance for a random lasing medium composed of CdSe/ZnS quantum dots and ellipsoidal Ag nanoparticles. |

| **SW4N.7 • 17:15** |
| Optical vortex illumination to form polymeric twisted fiber, Junhyung Lee\(^1\), Shunsuke Togoshima\(^1\), Katsuhiko Miyamoto\(^1,2\), Yoshihiko Arita\(^3\), Kishan Dhokia\(^2\), Takashige Osamura\(^1\); \(^1\)Chiba Univ., Japan; \(^2\)Molecular Chirality Research Center, Chiba Univ., Japan; \(^3\)Univ. of St. Andrews, UK. We fabricated the twisted fiber by 405nm optical vortex illumination onto ultraviolet curing resin. Twisted direction and branching number of the fiber were assigned based on the hand-edness and topological charge of illuminated optical vortex. |

### Schedule

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<tr>
<td>16:30–18:30</td>
<td>Happy Hour in Exhibit Hall, Exhibit Hall 1, 2 &amp; 3</td>
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<tr>
<td>18:00–19:00</td>
<td>OSA Nanophotonics Technical Group 20x20, Executive Ballroom 210 A</td>
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Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
In Vivo Cellular Imaging with Spectrally Enhanced STED Super-resolution

DongKyun Lee

1Massachusetts General Hospital, USA; 210A

Through reflective interference, the axial resolution of this supercontinuum source will be shown. The design and performance of this supercontinuum source will be shown as well as its importance for a novel LIDAR approach.

Multispectral polarimetric modulation spectroscopy for species and sex determination of Malaria disease vectors, Alem K. Gebre1, Samuel Jansson1, Russell D. Dupuis1, Kuo-Bin Hong1, Tien-Chang Lu1, Hao-Chung Kuo1, Miguel A. Bandres1, Mordechai Segev1, 1Technion, Israel. We show that, counterintuitive, it is possible to control the properties of photonic topological insulators by tailoring defects. In the extreme case, a lattice of defects inside a topological insulator creates a totally new topological insulator.

FTh1D.2 • 08:30
Embedded Photonic Topological Insulators, Miguel A. Bandres1, Mordechai Segev1, 1Technion, Israel. We show that, counterintuitive, it is possible to control the properties of photonic topological insulators by tailoring defects. In the extreme case, a lattice of defects inside a topological insulator creates a totally new topological insulator.

FTh1D.1 • 08:00
Observation of Photonic Topological Valley Transport, Jiho Nah1, Sheng Huang1, Kevin P. Chen1, Mikael C. Rechtsman1, 1Dept. of Physics, The Pennsylvania State Univ., USA, 2Dept. of Electrical and Computer Engineering, Univ. of Pittsburgh, USA. We present the experimental realization of valley Hall topological edge states in armchair and bearded edge domain walls of inversion symmetry broken honeycomb lattices.

UV-Vis-NIR white light LIDAR using polarization-controlled laser filamentation, Shermineh Rostami1, Matthieu Baudelet2,1, Carsten Kirkeby1,2,1, Lund Laser Centre, Dept. of Physics, Lund Univ., Sweden; 2Chemical Ecology Unit, Dept. of Plant Protection Biology, Swedish Agricultural Sciences Univ., Sweden; 3National Veterinary Inst., Denmark Technical Univ., Denmark; 4FaunaPhotonics WS, Denmark. A multispectral polarimetric optical detection system with kHz sample rates was implemented to determine mosquitos species and sex based on their wing-beat frequency (WBF), harmonic overtones, optical cross-section and melanization in flight.

Growth and Characterization of III-N Ultraviolet Lasers and Avalanche Photodiodes by MOCVD, Russell D. Dupuis1, Mi-Hee Ji1, Yuh-Shiuan Liu1, Jeomoh Kim1, Young-Jae Park1, Theeradetch Detchprohm1, Tsung-Ting Kao1, Shyh-Chiang Shien1, Karan Mehta1, P. Douglas Yoder1, Hongen Xie2, Fernando Ponce1, Ashok Sood1, Nitin Dhar1, Jay Lewis1, 1Georgia Inst. of Technology, USA, 2Dept. of Physics and Astronomy, Arizona State Univ., USA, 3Magnolia Optical Technologies, USA, 4Night Vision Sensors and Electronic Division, USA. 1DARPA MTO, USA. 110A

Monolithic GaN-InGaN Core-shell Lasers in Submicron Scale, Chia-Yen Huang1, Jing-Jie Lin1, Tsu-Chi Chang1, Che-Yu Liu1, Tzu-Ying Dai1, Kuo-Bin Hong1, Tien-Chang Lu1, Hao-Chung Kuo1, 1Dept. of Photonics, NCTU, Taiwan. We demonstrated a GaN-InGaN core-shell nanorod periodic array lasing under room temperature. Optical simulations and photoluminescence measurement revealed optically-coupled whisper gallery modes. The threshold pumping density was 80 kW/cm² with a quality factor of 1940.

5DARPA MTO, USA. 1DARPA MTO, USA. 1Night Vision Sensors and Electronic Division, USA. 1DARPA MTO, USA. III-N UV lasers and APDs are demonstrated operating at 80 kW/cm² with a quality factor of 1940.

invited

invited

Executive Ballroom
210A
08:00–10:00
Th1A • Biomedical Imaging II
Presider: Jin Kang, Johns Hopkins Univ., USA

invited

Executive Ballroom
210B
08:00–10:00
Th1B • Active Remote Environmental Sensing
Presider: To be Determined

invited
Jeremy O’Brien is the director of the Centre for Quantum Photonics (CQP) at the University of Bristol. CQP’s efforts are focused on the fundamental and applied quantum mechanics at the heart of quantum information science and technology, ranging from prototypes for scalable quantum computing to generalised quantum measurements, quantum control, and quantum metrology. He received his PhD in physics from the University of New South Wales in 2002 for experimental work on correlated and confined electrons in organic conductors, superconductors and semiconductor nanostructures, as well as progress towards the fabrication of a phosphorus in silicon quantum computer. As a research fellow at the University of Queensland (2001-2006) he worked on quantum optics and quantum information science with single photons. He is currently Professor in Physics and Electrical Engineering at the University of Bristol.

FTh1F.1 • 08:00 Invited
Exciton Spectroscopy in Monolayer Transition Metal Dichalcogenides and Van der Waals Heterostructures, Bernhard Urbaszek1, CNRS - Toulouse Univ., France. Excitons dominate the strong light-matter interaction in transition metal dichalcogenide monolayers and present exciting opportunities for applications and new physics. Here we investigate carrier dynamics and valley properties in optical spectroscopy on high-quality samples.

FTh1G.1 • 08:00 Invited
Engineering Optical Density of States with Nonlocal Metamaterials, Viktor A. Podolskiy1, Pavel Grinburg2, Diane Roth3, Alexey Krasavin4, Brian Wells5, Anatoly Zayats1, Univ. of Massachusetts Lowell, USA; 2Dept of Physics, Kings College London, UK; 3Tel Aviv Univ, Israel; 4Univ. of Hartford, USA. We present theoretical, numerical, and experimental analysis of optical density of states in plasmonic nanowire metamaterials. Averaged Purcell factors of the order of 30, attributed to nonlocal electromagnetic response of metamaterials, are reported.

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
Tobias J. Kippenberg1; Ryan Schilling1, Anshuman Kumar1, Matteo Federale de Lausanne, Switzerland; 2Cambridge Graphene Centre, Univ. of Cambridge, UK. We report the functionalization of two-dimensional materials with the aim of manufacturing miniaturized devices for high technology applications (printed electronics, smart systems, tissue engineering).

Two-dimensional Materials, Tony F. Heinz1,2; Optical Properties of Atomically Thin Systems, Ilya Goykhman2, Andrea Ferrari2, Clément Javerzac-Galy1, Nicolas Piro1, Shinji Yamashita1; 1Ecole Polytechnique, France; 2TRUMPF Scientific Lasers GmbH + Co. KG, Germany; 3Dept. für Physik, Ludwig-Maximilians-Universität München, Germany; 4Max-Planck Inst. of Quantum Optics, Germany. A thin disk-based regenerative amplifier with a compressed output power of more than 1 kW is presented. At a wavelength of 1031 nm pulse energies ≥100 mJ are demonstrated at a repetition rate of 10 kHz with pulse durations of <1 ps.

STh1L.2 • 08:30 High Diode-Pumped, High-repetition-rate Advanced Petawatt Laser System (HAPLS), Emily F. Sistrunk1, Thomas Spinka1, Andrew Bayramian1, Paul Armstrong1, Salmaan Bamasu1, Shawn Betts1, Darrell Bopp1, Samuel Buck1, Ken Charron1, Josef Cupal2, Robert Demaret1, Robert Deri1, Jean-Michelle Di Nicol1, Marc Drouin2, Al Erlandson1, Steve Fulkerson1, Chris Gates1, Jeff Jarboe1, Karel Kasl2, Danny Kim1, Edward Koh1, Lucia Koubikova2, Rod Lanning1, Jeremy Luk1, William Manarville1, Chris Marshall1, Dan Mason1, Petre Mazurek1, Joe Menapace1, Phil Miller1, Jack Naylon1, James Nissen1, Jakub Novak1, Davorkin Peceli1, Paul Rosso1, Kathleen Schaffers1, Tara Silva1, Daniel Smith1, Joel Stanley1, Rusty Steele1, Chris Stolz1, Steve Telford1, Jiri Thoma1, Diana VanBlarcom1, Jiri Weiss1, Paul Wegner1, Bedrich Rus1, Constantin Haefner1; 1Lawrence Livermore National Lab, USA; 2EU-Beamlines, Czech Republic. The HAPLS laser system has been commissioned to its first integrated performance milestone, delivering laser pulses with 16J sub-30fs duration at a 334Hz repetition rate. This first all-diode-pumped petawatt-class laser offers the average powers required for secondary source applications.
Marriott Salon III

08:00–10:00
STh1M • Phased Arrays Related Device
President: Wei Jiang; Rutgers Univ., USA

STh1M.1 • 08:00
Large-Scale Visible and Infrared Optical Phased Arrays in Silicon Nitride, Christopher V. Poulton1, Matthew Byrd2, Manan Raval3, Zhan Su4, Nanxi Li5, Eman Timurdogan6, Douglas Coolbaugh7, Diedrik Vermeulen7, Michael Watts7; ‘MIT, USA; ‘College of Nanoscale Science and Engineering, Univ. at Albany, USA; ‘Harvard University, USA.

Large-scale optical phased arrays at 635nm and 1550nm wavelengths are demonstrated with aperture sizes up to 4x4mm2. A diffractive Instantaneous-Field-of-View, 1x256 Multi-layer, low-loss, Si3N4 waveguide optical phased arrays with 0.050 divergence and output powers as high as 400mW are shown.

STh1M.2 • 08:15
1x256 Multi-layer, low-loss, Si3N4 waveguide optical phased arrays with 0.050 Instantaneous-Field-of-View, Chuan Qin1, Kuanping Shang2, Nanx Li3, Emman Timurdogan4, Douglas Coolbaugh5, Michael Watts6, ‘MIT, USA; ‘College of Nanoscale Science and Engineering, Univ. at Albany, USA; ‘Harvard University, USA.

We report multilayer 1x256 Si3N4 optical phased arrays with 8-stage multimode interferometer (MMI) tree. The device shows 4.5 µm mode size, 3 dB excess loss and far field pattern with 0.050 beam width.

STh1M.3 • 08:30
Fresnel-Lens-Inspired Focusing Phased Arrays for Optical Trapping Applications, Jelena Notaros1, Christopher V. Poulton2, Manan Raval3, Matthew. Byrd4, Douglas Coolbaugh5, Michael Watts6; Research Lab of Electronics, MIT, USA; ‘College of Nanoscale Science and Engineering, Univ. at Albany, USA.

An integrated optical phased array which focuses radiated light in one dimension to a tightly confined spot in the near field is demonstrated for the first time and proposed for chip-scale optical trapping applications.

Marriott Salon IV

08:00–10:00
STh1N • Optical Computing & Communications using Photonic Nanostructures
President: Dirk Englund; MIT, USA

STh1N.1 • 08:00
Integrated Nanophotonics for Optical Computation, Masaya Notomi1,2; ‘NTT Basic Research Labs, Japan; ‘NTT Nanophotonics Center, Japan.

Recent advances of integrated nanophotonic devices in terms of energy consumption and latency, especially about OE/EO conversion, are reviewed, and their potential application to ultralow-latency optical computing based on optical pass-gate logic will be discussed.

STh1N.2 • 08:15
Colorless Laser Diode Uniform Transmission for DWDM-PON Channels, Zu-Kai Weng1, Hua-Tung Wang1, Hsuan-Yun Kao1, Cheng-Ting Tsai2, Yu-Chieh Chi3, Gong-Ru Lin4; ‘Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan.

Directly 64-QAM OFDM encoding the colorless laser diode with power-to-frequency pre-leveling is demonstrated for 60-Gbit/s BiB and 55.8-Gbit/s 25-km fiber transmissions with its selectable channel wavelength to construct uniform transmitter for DWDM-PON channels.

Marriott Salon V & VI

08:00–10:00
STh1O • Direct Detection Multicarrier Optical Communications
President: Yue-Kai Huang; NEC Labs America Inc, USA

STh1O.1 • 08:00
The High Power Budget IMDD OFDM-PON Down-stream Scheme Employing Sparse Volette Filter-based Nonlinear Impairment Mitigation, Nan Feng1, Nan Liu1, Chang Liu2, Xue Chen1, Pengfei Yang1; ‘Beijing Univ. of Posts and Telecommunications, China.

This paper focuses on sparse Volterra filter in high power budget IMDD OFDM-PON. The simulation results show that the power budget @ 50Gbps is up to 32dB with low complexity equalizer in ONU receivers. The experimental results show that this scheme could achieve 20 Gbps transmission over 95-km SMF.

STh1O.2 • 08:15
60-Gbit/s QAM-OFDM Direct-Encoded Colorless Laser Diode Uniform Transmitter for DWDM-PON Channels, Zu-Kai Weng1, Hua-Tung Wang1, Hsuan-Yun Kao1, Cheng-Ting Tsai2, Yu-Chieh Chi3, Gong-Ru Lin4; ‘Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan.

Directly 64-QAM OFDM encoding the colorless laser diode with power-to-frequency pre-leveling is demonstrated for 60-Gbit/s BiB and 55.8-Gbit/s 25-km fiber transmissions with its selectable channel wavelength to construct uniform transmitter for DWDM-PON channels.

STh1O.3 • 08:30
Sensitivity Improvement in IM-DD OFDM-PON by Amplitude Scaling and Subcarrier Enabled PAPR Reduction, Jizong Peng1, Shaohua An1, Qingming Zhu1, Ciyuan Qiu1, Yang Zhang2, Yikai Su3; ‘Shanghai Jiao Tong Univ, China.

An effective sensitivity-improving scheme combining symbol-amplitude scaling and peak-amplitude reduction is proposed for IM-DD OFDM-PONs. Sensitivity improvements of 3.8 dB and 4 dB are observed in two ONUs with 40-km and 80-km transmission distances, respectively.
ATH1A • Biomedical Imaging

ATH1A.4 • 09:15
Fiber supercontinuum source for broadband-CARS microscopy based on an all-normal-dispersion mode-locked laser, Yan Li1; Xiaosheng Xiao1; Lingjie Kong1; Changxi Yang1; 1Tsinghua Univ., China. We propose and demonstrate a fiber supercontinuum source for broadband coherent anti-Stokes Raman scattering microscopy, seeded by an all-normal-dispersion mode-locked laser. We achieve 700-1900 cm⁻¹ spectral range, and show its application in analyzing complex mixture.

ATH1A.3 • 09:00
Sparsity-based On-chip Holographic Microscopy, Yair Rivenson1, Yichen Wu1, Hongda Wang1, Yibo Zhang1, Alborz Feizi1, Aydogan Ozcan1; 1Univ. of California Los Angeles, USA. We demonstrate a sparsity-based phase reconstruction technique implemented in wavelet domain to achieve at least 2-fold reduction in the number of holographic measurements for coherent imaging of samples.

ATH1B • Active Remote Environmental Sensing—Continued

ATH1B.4 • 08:45
High precision 2.0 μm Photoacoustic Spectrometer for Determination of the ¹² CO₂/¹³ CO₂ Isotope Ratio, Zachary D. Reed1, Joseph T. Hodges1; 1NIST, USA. A photoacoustic spectrometer operating near 2.0 μm has been developed for high precision measurements of the ¹² CO₂/¹³ CO₂ isotope ratio. The instrument performance and effects of water vapor on the photoacoustic signal are discussed.

ATH1B.3 • 09:00
Invited
Locating Methane Leaks Across Large Areas with Frequency Comb Lasers, Gregory B. Recker1, Sean Coburn1, Caroline Alden1, Robert Wright1; Kuldeep Prasad1, Subhromoy Ghosh1, Garwin Truong1, Kevin Cassel1, Esther Baumann1, Ian Coddington1, Nate Newbury1; 1Univ. of Colorado at Boulder, USA; 2National Inst. of Standards and Technology, USA; 3National Inst. of Standards and Technology, USA. Recent advancements in mobile frequency comb technology and inverse methods are enabling the location and sizing of small methane leaks across large regions.

ATH1C • III-V Lasers—Continued

ATH1C.4 • 09:00
Circular Polarized Lasing Characteristics in Metal/GaN Double-Spiral Nanowire Cavity, Cheng L. Yu1; Shu-Wei Liao1, Yu-Hao Lin1; 1Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan; 2Dept. of Electronic Engineering, National Taiwan Univ., Taiwan; 3National Chiao Tung Univ., Taiwan; 4Research Center for Applied Sciences, Academia Sinica, Taiwan. Room temperature highly circular polarized laser was demonstrated with a compact metal/GaN double-spiral nanowire cavity. The lasing action was observed with a UV wavelength of 363 nm and a high disymmetry factor of 1.05.

ATH1C.5 • 09:15
17.6-Gbps Universal Filtered Multi-Carrier Encoding of GaN Blue LD for Visible Light Communication, Yu-Fang Huang1, Cheng-Ting Tsai1, Hsuan-Yun Kao1, Yu-Chieh Chi1, Hui-Yang Wang1, Tien-Tsorng Shih2, Gong-Ru Lin1; 1Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan; 2Dept. of Electronic Engineering, National Kaohsiung Univ. of Applied Sciences, Taiwan. TO-can packed GaN LD connected with impedance-matched transmission-line circuit board enhances the UFMC additive 16-QAM OFDM bandwidth to enable 17.6-Gbps VLC at 4.4-bit/s/Hz spectral-usage efficiency with suppressed inter-OFDM-carrier interference and improved BER of 1.07×10⁻⁶.

ATH1D • Topological Photonics—Continued

ATH1D.3 • 08:45
Towards the Experimental Realization of the Topological Insulator Laser, Steffen Witte1, Gal Haran1, Miguel A. Bandres1, Hossein Hodaei1, Midya Parto1, Parinaz Alehmadi1, Mikael C. Rechtsman1, Yidong Chong1, Demetrios Christodoulides2, Mercedes Khajavikhan1, Mordechai Segev1; 1Technion, Israel; 2Univ. of Central Florida, USA; 3The Pennsylvania State Univ., USA; 4Nanyang Technological Univ., Singapore. We propose a practical design to implement of a topological insulator laser. Due to the topological protection, the topological laser maintains a high slope efficiency and single mode lasing even in the presence of defects and disorder.

ATH1D.4 • 09:00
Topological Aharonov-Bohm Suppression of Optical Tunneling in Twisted Multicore Fibers, Midya Parto1, Helena E. Lopez Aviles2, Mercedes Khajavikhan1, Rodrigo A. Correa1, Demetrios Christodoulides2; 1CREOL, USA. We show that the Aharonov-Bohm-like suppression of optical tunneling in twisted multicore fibers can persist under highly nonlinear conditions. The energy exchange dynamics are analyzed and possible arrangements to experimentally observe this effect are presented.

ATH1D.5 • 09:15
Recasting Hamiltonians with gauged-driving, Hanan H. Herzog Sheinfux1, Stella Tal-lulah Schindler1, Yaakov Lumer2, Mordechai Segev1; 1Technion Inst. of Technology, Israel; 2Dept. of Electrical and Systems Engineering, Univ. of Pennsylvania, USA. We show how to modify the effective Hamiltonian of a dynamic system in an almost arbitrary fashion, using periodic gauge and driving. As an example, we generalize dynamic localization; counteract disorder effects in waveguide lattices.
An Integrated Source of Truly Unentangled Photons for Efficient Single Photon heralding, Zachary Vernon1, Matteo Menotti2, Christopher Tison3,4, J.A. Steidle1, M.L. Fant05, P.M. Thomas1, Stefan F. Preble1, G.A. Howland6, A.M. Smith6, P.M. Alsing6, Christopher Tison3,4, J.A. Steidle5, M.L. Smith6, John Sipe1; USA; 6Air Force Research Lab, Information the parametric fluorescence process.

We show the generation of fully uncorrelated photon pairs in an integrated device. A fully separable state is guaranteed, USA; 6Air Force Research Lab, Information the parametric fluorescence process.

We de -

Our works on nanowire quantum-WDM channel on-chip. We demonstrate a novel approach to metamaterial-based super-resolution imaging, where optical pulse shaping allows to dramatically reduce the influence of material loss.

FTh1F • 08:45 Ultrafast anisotropic dynamics of non-degenerated excitons in atomically-thin ReS2. We report the first anisotropic two excitons dynamics in bulk ReS2. Both exciton states show anisotropic dynamics upon carrier injection with a stronger response in higher exciton state than the lower state.

Hybrid Quantum Photonics, Ali W. Elshaari1, Iman Esmaeili Zadeh1, Andreas Fognini2, Michael E. Reimer1, Dan Dalac1, Philip J. Poole1, Val Zwier1, Klaus D. Jons1, Quantum Nano Photonics Group, Applied Physics, Kungliga Tekniska Hochskolan (KTH), Sweden; 2Kavli Inst. of Nanoscience, TU Delft, Netherlands; 3Inst. for Quantum Computing and Dept. of Electrical & Computer Engineering, Univ. of Waterloo, Canada; National Research Council Canada, Canada. We deterministically integrate nanowire quantum-emitters in SiN photonic circuits. We generate single-photon, suppress excitation-laser, and isolate specific transitions in the quantum-emitter all on-chip with electrically-tunable filter. Finally, we demonstrate a novel Quantum-WDM channel on-chip.
### StH11 • 2D Materials and Devices II—Continued

**StH11.3 • 08:45**
**Tungsten disulphide saturable absorber for ultrashort pulse generation in all-fiber lasers**, Wen Liu1, Zhiyong Wei2; 1School of Science, Beijing Univ. of Posts and Telecommunications, China; 2Chinese Academy of Sciences, China. The WS2 SA is manufactured with large nonlinearity and high reliability. The modulation depth, SNR and bandwidth are 25.48%, 92 dB and 57 nm, respectively. The pulse duration is 246 fs, which is the shortest pulse duration among all-fiber lasers with WS SAs.

**StH11.4 • 09:00**
**Inkjet-Printing of Graphene Saturable Absorbers for ~2 μm Bulk and Waveguide Lasers**, Xavier Mateos1, Pavel Lokor1, Josep M. Serras1, Soymon S. Deleka1, Esrom Kifle1, Alexander Baranov3, Magdalena Aguiló1, Frank (Fengqiu) Wang1; 1Universitat Rovira i Virgili, Spain; 2SAs. Using graphene-SA in a microchip Q-switching of ~2-μm bulk and waveguide saturable absorbers (SAs) suitable for passive operations. We report on inkjet-printing of graphene generated at 1917 nm.

**StH11.5 • 09:15**
**Influence of substrates on photocarrier dynamics in monolayer TMDs**, Zhanghui Nie1, Yang Cui2, Yuzhe Meng2, Yongbing Xu2, Frank (Fengqiu) Wang1, Nanjing Univ., China. We demonstrate that dielectric screening from substrates has a strong influence on photocarrier dynamics in monolayer TMDs. In particular, the interband recombination time is found dramatically shortened with the increase of substrate dielectric constants.

### StH12 • Laser Ablation Fundamentals and Applications—Continued

**StH12.2 • 09:00**
**Strong Enhancement of Nanosecond Laser Ablation of Silicon by Axial Magnetic Field**, Hamid Farokhi1, Vitaly Gruzdev2, Hongyu Zheng2, Wei Zhu1; 1School of Mechanical and Aerospace Engineering, Nanyang Technological Univ., Singapore; 2Wellman Center for Photomedicine, Massachusetts General Hospital and Harvard Medical School, USA; 3Max Born Inst., Germany; 4IMT Ecole polytechnique, France. The increase of substrate dielectric constants. In particular, the interband recombination mechanisms suggests strong combined effects from magneto-absorption and propagation through magnetized ablation plasma.

**StH12.3 • 09:15**
**High Frequency Core Inductor Using Sintered Aluminum Nano-paste with Aluminum Nano-poly crystalline Structure**, Shinichiro Masuda1, Takeo Saki2, Yukio Iida2, Mitsuru Inada1; 1Hamamatsu Photonics K.K., Japan. We fabricated core inductors with an aluminum nano-poly-crystalline structure, which is a ferromagnetic body, for the first time. The modulation depth, SNR and bandwidth are 25.48%, 92 dB and 57 nm, respectively. The pulse duration is 246 fs, which is the shortest pulse duration among all-fiber lasers with WS SAs.

### StH13 • Nonlinear Fiber Photonics I—Continued

**StH13.5 • 09:00**
**Efficient Mid-Infrared Supercontinuum Generation in Tapered Large Mode Area Chalcogenide Photonic Crystal Fibers**, Christian R. Petersen1, Rasmus E. Dybbro2, Ole Bang3, Shreyas Kharitonov3, Camille-Sophie Bres1; 1Université Rennes, France; 2DTU Fotonik, Technical Univ. of Denmark, Denmark; 3Mid-infrared, Sweden. We demonstrate parametric amplification around 2 μm in a dispersion engineered tapered microstructured chalcogenide fiber. Almost 5 dB of signal amplification was achieved by 125 mW coupled power from a thulium-doped fiber pump laser.

**StH13.4 • 08:45**
**All-fibered chalcogenide based continuous-wave parametric amplification in the mid-infrared**, Sida Xing1, Davide Grassani2, Svyatoslav Kharitonov3, Camille-Sophie Bres1; 1Ecole Polytechnique Federale de Lausanne, Switzerland; 2University of Basel; 3Université Rennes, France. We demonstrate parametric amplification around 2 μm in a dispersion engineered tapered microstructured chalcogenide fiber. Almost 5 dB of signal amplification was achieved by 125 mW coupled power from a thulium-doped fiber pump laser.

**StH13.1 • 09:00**
**A Compressor for High Average Power Ultrafast Laser Pulses with High Energies**, David Alessi1, Emily F. Sistrunk1, Hoang Nguyen1, 2, Paul Rosso3, Thomas Spinka4, Michael Aasen1, Sandrine Herriot1, Jerald Britten1, Constantin Haefner1; 1Lawrence Livermore National Lab, USA. We have developed a high-efficiency (~90%), broad-bandwidth low-absorption pulse compressor suitable for high energy pulses. This technology is a significant step in enabling high peak power laser systems to operate at high repetition rates.

### StH14 • High Average Power Lasers—Continued

**StH14.1 • 09:15**
**64J Output Energy in 10ns Pulse from Cryogenic Yb:YAG Ceramic Laser**, Takashi Sekine1, Yasuki Takeuchi2, Yuma Hatano2, Yuki Muramatsu1, Takashi Kurita1, Takashi Morita1, Yoshio Mizuta1, Yuki Kabeya1, Masateru Kurita1, Kazuki Kawai1, Takuto Iguchi1, Yoshihiro Tamaki1, Koichi Iyama1, Kyu Shin1, Yoshinori Kato1; 1Hamamatsu Photonics K.K., Japan. A 64J at 10 ns output was demonstrated by diode-pumped cryogenically cooled Yb:YAG ceramic laser amplifier. An extraction efficiency was evaluated 43.3% at stored energy of 148J with small-signal gain of 20.4.
Si3N4 and engineered grating duty cycle to match a desired profile of the output beam. Single-photon detectors to behave as spiking neurons.

We demonstrate a millimeter long grating coupler with a hybrid semiconductor-superconductor platform for large-scale neuromorphic computing. The platform combines semiconductor single-photon detectors to behave as spiking neurons.

We report an optical switch based architecture for realizing optical computing. Numerical simulation has been performed to validate the architecture by adopting CMOS compatible PN depletion micro-ring resonator as the approach for optical switching.

Unidirectional waveguide grating antennas for nanophotonic phased arrays, demonstrating over 90% directionality. Unidirectional waveguide grating antennas for nanophotonic phased arrays are demonstrated with over 90% directionality. Unidirectional emission eliminates the fundamental problem of element factor blind spots due to reflections of the antenna radiation within the substrate.

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Millimeter long grating coupler with uniform spatial output based on a platform formed by both silicon and Si3N4, and engineered grating duty cycle to match a desired profile of the output beam.

Superconducting Optoelectronic Platform for Neuromorphic Computing, achieving single-shot photon sensitivity and high-end uncertainty experiments.

First Investigation of Set-Partition Format based IM/DD OFDM for Fiber Communications, demonstrating 16QAM and 8QAM OFDM.

We propose, for the first time, set-partition (SP) format based optical OFDM and experimentally show that SP-64QAM/SP-128QAM intensity-modulation direct-detection OFDM exhibits greatly improved performance over conventional 16QAM and 8QAM OFDM.
ATh1A • Biomedical Imaging II—Continued

ATh1A.5 • 09:30 On-chip Microscopy and Nano-particle Detection Using Ultraviolet Light, Mustafa Dalgıç1, Aniruddha Ray1, Zoltán Göröcs1, Matthew Xiong1, Ravinder Malik1, Gal Bitan1, Evan McLeod1, Aydogan Ozcan1; ‘Univ. of California, Los Angeles, USA; ‘The Univ. of Arizona, USA. Ultraviolet light enhances particle imaging capabilities of on-chip microscopy, increasing the detection sensitivity to sub-30 nm particles. Ultraviolet illumination also enables high contrast imaging of biomolecules, e.g., protein aggregates, over a large field-of-view.

ATh1A.6 • 09:45 Pixel Super-Resolution in Coherent Microscopy Systems Through Out-of-Focus Imaging, Hongda Wang1, Zoltán Göröcs1, Wei Luo1, Yao Zhang1, Yair Rivenson1, Aydogan Ozcan1; ‘UCLA, USA. We introduce a wide-field pixel super-resolution method that uses a stack of out-of-focus images to provide better utilization of the space-bandwidth product of an objective-lens and improve the throughput of lens-based coherent imaging and holography systems.

ATh1B • Active Remote Environmental Sensing—Continued

ATh1B.6 • 09:30 Invited Chirped-laser Dispersion Spectroscopy for Large-area Methane Detection, Gerard Lee1, SM Islam1, Vladimir Protsenko1, Halli (Grace) Xing1, Debdeep Jena1; ‘Electrical and Computer Engineering, Cornell Univ., USA. We demonstrate a 243 nm deep-ultraviolet (deep-UV) GaN/AlN heterostructure light-emitting diode with and without a tunnel-junction p-contact. Optical emission occurs from 2 monolayer thick GaN quantum structure active regions. Use of a tunnel-junction enhances the current density under forward bias.

STh1C • III-V Lasers—Continued

STh1C.6 • 09:30 Tunnel-Junction p-Contact Sub-250 nm Deep-UV LEDs, Shyam Bharadwaj1, Kevin Lee1, SM Islam1, Vladimir Protsenko1, Halli (Grace) Xing1, Debdeep Jena1; ‘Electrical Engineering, Princeton Univ., USA. We demonstrate a 243 nm deep-ultraviolet (deep-UV) GaN/AlN heterostructure light-emitting diode with and without a tunnel-junction p-contact. Optical emission occurs from 2 monolayer thick GaN quantum structure active regions. Use of a tunnel-junction enhances the current density under forward bias.

STh1C.7 • 09:45 High-Speed Nonpolar InGaN/GaN LEDs for Visible-Light Communication, Arman Rashid1, Mortezza Monavarian1, Andrew Argon1, Sendal Okur1, Mohsen Nami1, Ashwin Rishinaramangalam1, Saadat Mishkat-Ul Masabih1, Daniel Fette1; ‘Center for High Technology Materials, Univ. of New Mexico, USA. High-speed nonpolar InGaN/GaN LEDs on free-standing GaN substrates with a peak emission wavelength between 455-465 nm were fabricated. A large frequency modulation bandwidth of 524 MHz and an output power of 1.5 mW are obtained.

FTh1D • Topological Photonics—Continued

FTh1D.6 • 09:30 Topologically protected photonic propagation in the bulk, Eran Lustig1, Steffen Weimann2, Yonatan Plotnik1, Yakov Lumer1, Miguel Bandres1, Alexander Szameit1, Mordechai Segev1; ‘Technion, Israel; ‘Friedrich-Schiller-Universitat, Germany; ‘Univ. of Pennsylvania, USA. We propose a new class of photonic topological insulators, for which we use synthetic dimensions to induce topologically-protected photonic propagation in the bulk of the lattice instead of around the edge.

FTh1D.7 • 09:45 Weak Localization Due to Disordered Nonlinearity, Yonatan Sharabi1, Hanan H. Hersz Sheinfux1, Mordechai Segev1, Gadi Eisenstein1; ‘Physics, Technion, Israel. We suggest weak localization in a medium with a disordered nonlinearity: Kerr or saturated. Anomalous localization behavior with polynomially decaying wave function is found in simulation and theory.
Executive Ballroom 210E

JTh1E • Quantum Photonics I—Continued

JTh1E.4 • 09:30
Time-Domain Observation of Vacuum Rabi Oscillations in a Strongly Coupled Quantum Dot-Nanocavity System, Kaushy Kuruma1, Yasutomo Ota1, Masahiro Kakuda1, Satoshi Iwamoto1, Yasuhiko Arakawa1; 1Univ. of Tokyo, Japan. We report the time-domain observation of vacuum Rabi oscillations in a single quantum dot-photonic crystal nanocavity system under optical carrier injection. A significantly-improved cavity Q-factor facilitates the direct access to the ultrafast exciton-photon dynamics.

JTh1E.5 • 09:45
Determining the Optical Nonlinearity of Silicon at Cryogenic Temperatures for Applications in Integrated Photonics, Nicola A. Tyler1, Gary Sinclair1, Gerardo E. Villarreal1, Geraint Gough1, Jorge Baretto1, Döndü Sahin1, Mark Thompson1; 1HH Wills Physics Lab, Bristol, UK. We determine the nonlinear coefficient of a silicon wire waveguide from room temperature down to 3.8K. Measurements are taken of the self-phase modulation and two-photon absorption.

Executive Ballroom 210F

CLEO: QELS-Fundamental Science

FTh1F • Ultrafast Exciton Dynamics in Van Der Waals Materials—Continued

FTh1F.6 • 09:30 • Invited
Ultrafast XUV ARPES Studies of Electron and Exciton Dynamics in the Transition-Metal Dichalcogenide MoSe2, Jan H. Buss1, Frederic Joucken1, Julian Maklar1, He Wang1, Yiming Xu1, Rohit Urmi1, Changhun Yu2, Sefaattin Tongay2, Junqiao Wu1, Robert A. Kaindl1; 1Materials Sciences Division, Lawrence Berkeley National Lab, USA; 2Dept. of Materials Science and Engineering, UC Berkeley, USA. We report the first evidence for the observation of band-gap excitons in ARPES.

Executive Ballroom 210G

FTh1G • Nonlinear and Hyperbolic Metamaterials—Continued

FTh1G.6 • 09:30 • Invited
Nonlinear Optics of Plasmonic Metamaterials, Anatoly Zayats1; 1King’s College London, UK. Nonlinear optical properties of plasmonic metamaterials will be overviewed focusing on achieving enhanced Kerr-type nonlinearity in a desired spectral range and with controlled ultrafast response. Nonlinear control of light polarization will be discussed.

Executive Ballroom 210H

FTh1H • Nanoscale Optomechanics—Continued

FTh1H.4 • 09:30
Optical Pulling Force in Periodic Backward-wave Waveguides, Danlu Wang1, Zheng Wang2; 1Dept. of Physics, The Univ. of Texas at Austin, USA; 2Dept. of Electrical and Computer Engineering, The Univ. of Texas at Austin, USA. We use periodic waveguide to achieve single-mode backward-wave that supports long-range optical pulling forces. We explore the ambiguity of backward-waves in the periodic system and eliminate aliased backward-waves that only generates pushing forces.
STh11 • 2D Materials and Devices II—Continued

STh11.6 • 09:30
Realizing thermal strain of patterned sapphire substrates dominate the bandgap-shifted of bilayer MoS₂, Sheng-Wen Wang¹, Henry Medina¹, Kuo-Bin Hong², Chun-Chia Wu¹, Manikandan Arumugam¹, Teng-Yu Su¹, Po-Tsung Lee¹, Yu-Lun Chueh², Hao-chung Kuo¹;¹Dept. of Photonics & Inst. of Electro-Optical Engineering, National Chiao Tung Univ., Taiwan, ²Dept. of Materials Science and Engineering, National Tsing Hua Univ., Taiwan. Using thermal strain concept, we can tune the bandgap of bilayer MoS₂ through the two different thermal expansion coefficients of sapphire. Also, we propose a simple model to explain and precisely predict the bandgap-shifted behavior.

STh11.7 • 09:45
Dipole aligned energy transfer between excitons in 2D semiconductors and organic materials, Jie Gu¹,², Xiao Liu³, Yi-Hsien Lee³;¹Dept. of Physics, City College of the City Univ. of New York, New York, USA; ²Dept. of Physics, Graduate Center of the City Univ. of New York, New York, USA; ³Dept. of Electrical Engineering and Computer Science and Physics, Univ. of Michigan, USA. Energy transfer from low mobility material to high mobility material is essential for optoelectronic application. We demonstrate Foster energy transfer from organic material (PTCDA) to monolayer MoSe2 through steady state and transient photoluminescence spectroscopy.

STh11.4 • 09:30
Fabrication of Superconducting Micro Particles by Laser Ablation in Superfluid Helium, Masaki Ashida¹, Yosuke Minowa¹, Mitsutaka Kumakura², Yuta Takahashi¹, Fusakazu Matsushima¹, Yoshiki Moriwaki¹;¹Graduate School of Engineering Science, Osaka Univ., Japan; ²Dept. of Applied Physics, Univ. of Fukui, Japan. We experimentally demonstrate the two different thermal expansion coefficients of sapphire. Also, we propose a simple model to explain and precisely predict the bandgap-shifted behavior.

STh11.5 • 09:45
Imaging Nanosecond Ablation of Copper at Low Ambient Pressure, Alexander W. Raymond¹, Eric Mazur¹;¹Harvard Univ., USA. The ablation of copper at low pressure by nanosecond pulses is imaged in a shadowgraph experiment. The ambient pressure affects the expansion dynamics as evidenced by the shock wave and damage spot.

STh11.8 • 09:45
Broadband supercontinuum generation in tapered multimode graded-index optical fibers, Mohammad Amin Eftekhar¹, Z. Sanjari Eznaveh¹, Jose E. Antonio-Lopez¹, Juan Carlos Alvarado Zacarías¹, Axel Schülzgen¹, Mike Mirov¹, Igor Moskalev¹, Sergey B. Mirov¹, Z. Sanjari Eznaveh¹, Jose E. Antonio-Lopez¹, Juan Carlos Alvarado Zacarías¹, Axel Schülzgen¹, Mike Mirov¹, Igor Moskalev¹, Sergey B. Mirov¹;¹IPG Photonics Mid-IR Lasers, USA. We report to the best of our knowledge the highest output power of 9.2 W Fe:ZnSe laser, Dmitry V. Martyshkin¹, Vladimir V. Fedorov¹, Mike Mirov¹, Igor Moskalev¹, Sergey Vasilyev¹, Viktor Smolka¹, Andrei Zakrevskiy¹, Sergey B. Mirov¹;¹IPG Photonics Mid-IR Lasers, USA. We report to the best of our knowledge the highest output power of 9.2 W Fe:ZnSe laser operating in CW regime. The lasing wavelength was at 4.15 μm in non-selective cavity at 77K.
STh1M • 09:45
Nanotriangle Decorated Silicon Nitride Waveguides for Integrated Surface-Enhanced Raman Spectroscopy, Pieter Wuytens1,2,3, Andre G. Skirtach2,3, Roel Baets1,3; 1INTEC - Photonics Research Group, Ghent Univ. - imec, Belgium; 2Dept. of Molecular Biotechnology, Ghent Univ, Belgium; 3Center for Nano- and BioPhotonics, Ghent Univ., Belgium. Nanosphere lithography provides an e-beam free method for patterning gold nanoplasmonic antennas. By combining this technique with deep-UV photolithography, we fabricate Si3N4 waveguides interfaced to plasmonic antennas capable of exciting and collecting surface-enhanced Raman spectra.

STh1N • 09:45
Encrypted Communication using Chaotic Silicon Photonic Microcavities, Brian C. Grubel1, Bryan Bosworth1, Michael Kossey1, Amy Foster1, A. Brinton Cooper1, Mark A. Foster1; 1The Johns Hopkins Univ., USA. We demonstrate encrypted two-party communications using a physically-secure one time pad incorporating two CMOS-compatible chaotic silicon photonic microcavities.

STh1O • 09:45
0.18-dB Ultra-flat Optical Frequency Comb Generation Using Cascaded Modulators with Low Driving RF Power, XU XIAO 1, Kan Wu 1, Jianping Chen1; 1Shanghai Jiao Tong Univ., China. An improved modulation scheme is proposed for ultra-flat optical frequency comb generation. A comb with 15 lines and only 0.18 dB spectral power variation is demonstrated near 1550nm by using only two modulators.

STh1M.7 • 09:30
Low-loss arrayed waveguide grating at 2.0 μm, Eric J. Stanton1, Nicolas Volet1, John Bowers1; 1Univ. of California Santa Barbara, USA. A low-loss arrayed waveguide grating operating at 2.0-μm wavelength is demonstrated with an average on-chip loss of 0.5 dB and crosstalk per channel of -30.2 dB. These are the lowest reported values for a silicon AWG at 2.0-μm wavelength.

STh1N.4 • 09:30
Photonic Physical Unclonable Functions using Silicon Nitride Spiral Cavities, Hongcheng Sun1, Milad Alemohammad1, Bryan Bosworth1, Brian C. Grubel1, A. Brinton Cooper1, Mark A. Foster1, Amy Foster1; 1The Johns Hopkins Univ., USA. We demonstrate an on-chip photonic physical uncloneable function using integrated evanescently coupled multimode spiral cavities formed in silicon nitride.

STh1O.4 • 09:30
Direct Detection Multicarrier Optical Communications—Continued

STh1N.5 • 09:45
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STh1O.7 • 09:30
80 Gbit/s Single-Channel Direct Detection Optical FBMC Signal Generation and Transmission at 2-μm, Qiong Wu 2, Yongqiang Xie1, Ke Xu1, Ruoxu Wang1, Ming Tang1, Songnian Fu1, Deming Liu1; 1Harbin Inst. of Technology, Shenzhen, China; 2Huazhong Univ. of Science and Technology, China. We experimentally generated single wavelength 80 Gbit/s signals at 1952 nm with intensity modulated filter bank multicarrier scheme. Its transmission over 100m solid core SMFs was demonstrated with BER below FEC limit of 3.8×10-3. 

STh1M.8 • 09:45
Nanotriangle Decorated Silicon Nitride Waveguides for Integrated Surface-Enhanced Raman Spectroscopy, Pieter Wuytens1,2,3, Andre G. Skirtach2,3, Roel Baets1,3; 1INTEC - Photonics Research Group, Ghent Univ. - imec, Belgium; 2Dept. of Molecular Biotechnology, Ghent Univ, Belgium; 3Center for Nano- and BioPhotonics, Ghent Univ., Belgium. Nanosphere lithography provides an e-beam free method for patterning gold nanoplasmonic antennas. By combining this technique with deep-UV photolithography, we fabricate Si3N4 waveguides interfaced to plasmonic antennas capable of exciting and collecting surface-enhanced Raman spectra.

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Temperature gradient inside a solid-oxide fuel cells (SOFC) using Fiber with Enhanced Rayleigh scattering profiles, B. Amini S. Kabir, 1, Nimmi Sharma, 2, John E. Barnes, 1, Jalal Butt, 1, Univ. of the Bahamas, 1; Central Connecticut State Univ, 2, USA; 1DOAA/ESRL/Global Monitoring Division, USA. A wide-angle camera based bistatic lidar is used to profile aerosols in the Bahamas. Aerosol extinction was derived and boundary layer top agreed with radiosonde relative humidity demonstrating CLDAR utility for in-situ environmental characterization.

Refillable and Reconfigurable Dye-doped Ring Lasers, Hengkly Chandrahimal, 1, Stephen C. Rand, 1, Audong Fan, 1, Univ. of Michigan, USA. We present refillable, ultralow-thresholds, and wavelength reconfigurable ring lasers on a fused-silica chip. These devices will enable various photonic and biochemical sensing applications that require sustainable, configurable, and low-threshold coherent light sources on a chip.

Non-Imaging Perceptual Hashing Recognition Based on Ghost Imaging System., Hu c. Chen, 1, Jianrong Shi, 1, Guihua Zeng, 1, Shanghai Jiao Tong Univ, China. We propose and experimentally demonstrate a non-imaging perceptual hashing algorithm based on ghost imaging system can realize non-imaging recognition of images. This technique could find applications in image recognition.

Polarization invariance in beam propagation for space-to-ground optical communication downlink, Jiajie Wu, 1, Jing Ma, 1, Liying Tan, 1, Siyuan Yu, 1, Univ. of the Bahamas, 1; National Energy Technology Lab, USA; 2National Energy Technology Lab, USA. We report a numerical study of the carrier-envelope-occurrence (CEO) dependence on the substrate. While similarities have been observed during the operation of a SOFC with 4-mm thickness, the CEO depends on the material, the excitation power, and the operating conditions.

Probing Temperature Gradient inside SOFC using Fiber with Enhanced Rayleigh Scattering Profiles, Kevin P Chen, 1, Sheng Huang, 1, Aidong Yan, 1, Michael Burić, 1, Paul Hodnikčič, 1, Shiwoon Lee, 1, Univ. of Pittsburgh, USA; National Energy Technology Lab, USA. Temperature gradient inside a solidoxide fuel-cell interconnector was measured using a distributed fiber sensor with enhanced Rayleigh scattering profile. Reliable temperature measurements were achieved during the operation of a SOFC with 4-mm spatial resolution.

Light-Emitting Diode (LED) Laser Threshold estimation for organic VCSEL, LEI ZENG, 1, Mahmoud Chakaroun, 1, Azzedine Boudrioua, 1, Laboratoire de Physique des Lasers, France. The organic VCSEL is modeled by the transfer matrix method. This method is capable to calculate the eigenmode and estimate the laser threshold. The excited population density at threshold for a typical organic VCSEL is 1.4×10^17 cm^-3. With a complete OLED structure, the threshold rises to 6×10^16 cm^-3 due to the absorption of charge injection and transport layers.
Photo-Induced Correlated Spin-Density Wave State Formation in Overdoped Pristine Superconductors, Martin Mootz1, Ilia E. Perakis1, Luan Lu2, Aaron Patz3, Xu Yang4, Sergey L. Bud’ko2, Paul C. Canfield1, Jagang Wang2,3, Dept. of Physics, Univ. of Alabama at Birmingham, USA; 2Dept. of Physics and Astronomy, Iowa State Univ., USA; 3Ames Lab, U.S. DOE, USA. The non-equilibrium dynamics of superconducting order after the ultrafast gap quenching is analyzed. Evidence is shown for the formation of a photo-excited correlated spin-density wave state that can be controlled by adjusting pump laser's intensity.

Crystallographic Orientation-Dependent Dynamics in Individual Silicon Nanowires, Michael R. Williams1, Mel E. Hainey Jr., Aidan O. Beirne1, Joan M. Redwing2, Rohit A. Moses3, Luis Velasquez-Garcia, Franz Kaertner1, Electrical Eng. and Computer Science, MIT and Research Lab. of Electronics, MIT, Massachusetts Inst. of Technology, Cambridge, USA. A detailed comparison of ultrafast electron emission from structured, silicon-nanowires driven by 800 nm and 2.1 μm pulses was performed. In the low energy portion of the spectrum, a saturation of the direct electron energy bandwidth to ~1.6 eV for 800 nm and ~1.2 eV for 2.1 μm was observed.

First-principles calculations for saturable absorption in graphite, Mitsuharu Uemoto1, Shintaro Kurata2, Norifumi Kawaguchi1, Kazuhiro Yabana1, Center for Computational Sciences, Univ. of Tsukuba, Japan; Advanced Applied Science Dept., Research Lab, IHI Corporation, Japan. We present first-principles calculations for saturable absorption in graphite based on time-dependent density functional theory. It is found that the saturation takes place for ultrashort pulses stronger than 1012 W/cm2.

Tunable Magnonic spectra in two dimensional NiFe2P, annular lattices, Prasanta K. Das, Mini P. Prasanna Ponval1, Physics and Meteorology, Indian Inst. of Technology Kharagpur, India. Investigation on ultrafast time resolved spin wave (SW) dynamics of 2-D NiFe2P (Py) annular photonic lattice with varying external magnetic field has been performed. Multiple frequency modes observed in experiment are verified by micromagnetic simulations.

Modification of Energy Bands of a Dielectric Crystal by Ponderomotive Potential of Gaussian Ultrashort Laser Pulse, Olga N. Sergueeva1, Vitaly Grudzen2,1, Vitaly Grudzen2,1, Univ. of Missouri, USA. Ultrafast modification of direct-gap parabolic energy bands of a dielectric crystal by high-intensity Gaussian ultrashort laser pulse is theoretically studied. Non-trivial dynamics of laser-driven Bloch oscillations of electrons result in formation of transient indirect bands.

Generation of Cooler, Ultrafast Electron And Antenna Mid-IR Driven Nanostructures, Phillip D. Keatley1, Peter Krogan2, William Putnam2, Michael Swanwick3, Jeffrey A. Moses4, Luis Velasquez-Garcia4, Franz Kaertner1, Electrical Eng. and Computer Science, MIT and Research Lab. of Electronics, MIT, Cambridge, USA. A detailed comparison of ultrafast electron emission from structured, silicon-nanowires driven by 800 nm and 2.1 μm pulses was performed. In the low energy portion of the spectrum, a saturation of the direct electron energy bandwidth to ~1.6 eV for 800 nm and ~1.2 eV for 2.1 μm was observed.

Excited-state nonlinearities of Ir(III) complexes, Salim Saber1, Vitaly Gruzdev1, Sergaeva1, Vitaly Gruzdev1, Gaussian Ultrashort Laser Pulse, tric Crystal by Pondermotive Potential of Investigations on ultrafast time resolved than 1010 W/cm2. transient damping in the nonlinearity.

Tunable excited states in plasmonic nanowires, An investigation of Ir(III) complexes has been performed using double-pump probe (DPP) experiments to decouple the triplet quantum yield and triplet cross section of these complexes. Both femtosecond and picosecond DPP measurements are presented.

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Backward volume and perpendicular emission of a graphene based plasmonic antenna in terms of chemical potential μ and relaxation time τ. We demonstrated unidirectional Directional and enhanced emission by modem graphene antenna based on the minimum material requirements for an operational graphene antenna in terms of chemical potential μ and relaxation time t.

A Graphene Based Plasmonic Antenna Design for Communication in the THz Regime, Christoph Suessmeier1, Stephan Schaeffer1, Sergi Abadal2, Eduard Alarcón2, Daniel Stock1, Stefan Wagner1, Albert Cabellos-Aparicio1, Max Lemme1, Peter Haning1,1, Universitat Siegen, Germany; 2NanoNetworking Center (NANOC), Universitat de la Rovira i Virgili, Spain. We show the first THz emission of a graphene based plasmonic antenna structure. Furthermore we present the minimum material requirements for an operational graphene antenna in terms of chemical potential μ and relaxation time τ.

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Concita Sibilia 2; Jade Griffin 1, Natalia Noginova 1; Jieying Mao 1, Sara Arezoomandan 1, Berardi Italy. phene, JTh2A.49 asymmetrically Au-coated nanowires. we demonstrate chiral optical response in RES, JTh2A.48 absorption in III-V semiconductor nanow- JTh2A.46 arrays. Interaction of graphene pi-plasmons films transferred on top of aluminum hole- transmission through monolayer graphene In this work we study the UV-Vis transient absorption, we investigate and vinder Sandhu1; 4Stanford Univ., USA; 5Tel Aviv Univ., Israel. A fiber loop with an internal frequency shifter is used to produce the delayed copies of an incoming data signal. The linear phase response of the system is verified and the spurious free dynamic range (SFDR) is measured. Also, the BER and constellation diagrams of 10Gbaud QPSK signals are obtained.

Enhanced soft X-ray high-harmonic genera- tion driven by two-color (xiu-Bi) mid-IR la- ser pulses, Anne-Laure Calendron1, Jonathanas Siquiera1, Cheng Jin1, Peter Krogs 1, Thomas Krohi1, Philip D. Keathley1, Houkang Li1, Edson Falcão-Filho1, Chi-Dong Lin1, Xueling Han1, Frank X. Kärtner2,3; Research Lab of Electronics, MIT, USA; 2Center for Free-Electron Laser Science, Deutsches Elektronen Synchrotron, Germany; 3Group of Foundtica, Instituto de Fisica de Sao Carlos, Brazil; 3J. R. Macdonald Lab. Dept. of Physics, Kansas State Univ., USA, “Departamento de Fisica, Universidade Federal de Pernambuco, Brazil. We demonstrate efficiency enhancement of soft X-ray high-harmonic generation from Ar in the range of 40-200 eV using two-color (xiu-Bi) mid-infrared to visible pulses with relative phase control, which is in qualitative agreement with 3D simulations.

Control of Laser Induced Couplings in Au- toionizing States by XUV Transient Absorp- tion, Chen-Ting Liao1, Nathan Harkema1, Ar- echi, 1Tyndall National Inst., Ireland; 2State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Central Florida, USA. We propose 8-dimensional 8192QAM to balance the nonlinear transmission performance and add/drop induced optical filtering. Simulations show that this format outperforms conventional PDM-16QAM, PDM-8QAM, and 4-dimensional 128QAM for 200-Gbit/s channel optical networks with cascaded add/drop nodes.

Estimating the Performance of Fully Loaded DWDM Systems with Multidimen- sional Modulation, Ahmed I. Abd El-Rahman1, John C. Cartledge1; “Queen’s Univ. at Kingston, Canada. An efficient procedure is presented for estimating the performance of multidimensional modulation formats. It allows the explicit properties of signal constella- tions to be captured and is applicable to fully loaded DWDM transmission systems.

Analog and Digital Performance of Multiple Discrete Time Delays based on a Fiber Loop with an Internal Frequency Shifter, Fatehm Alahishi1, Amirhossein Mohajer-Ansari, Ahmed Almallama1, Morteza Ziyadi1, Yinwen Cao1, Peicheng Liao1, Ahmad Fal- lahpoor1, Changing Bao1, Bishara Shameem1, Shlomo Zach1, Nadav Cohen1, Moshe Tur1, Alan E. Willner1; 1Univ. of Southern California, USA; 2Tel Aviv Univ., Israel. A fiber loop with an internal frequency shifter is used to produce the delayed copies of an incoming data signal. The linear phase response of the system is verified and the spurious free dynamic range (SFDR) is measured. Also, the BER and constellation diagrams of 10Gbaud QPSK signals are obtained.

Multi- Dimensional Formats for Flexible Optical Networks with Cascaded Optical Add/Drop Nodes, Yuku Yu2, Wei Jia1, Ning Deng1, Wei Wang1, Jian Zhao1, Tyndall National Inst., Ireland; 2Harbin Engineering Univ., China; “Huawei Technologies Co. Ltd., China. We propose 8-dimensional 8192QAM to balance the nonlinear transmission performance and add/drop induced optical filtering. Simulations show that this format outperforms conventional PDM-16QAM, PDM-8QAM, and 4-dimensional 128QAM for 200-Gbit/s channel optical networks with cascaded add/drop nodes.

Implementation of Nyquist OTDM Signal Demultiplexing Using a Single IQ Modula- tor, Lei Yue1, Deming Kang1, Yan Li1, Astron Univ., UK. We experimentally validate an analytical description of four wave mixing generated in lumped amplification systems that employ optical phase conjugation. The experimental results show good agreement with theoretical predictions within an error margin of 0.5dB.
Optical and Electrical Equalizers for Fiber Optic Links, Xuhan Guo1, David Cunninghamham2, Richard V. Pentty3, Jan White1; 1Univ. of Cambridge, UK, 2Optical and electrical equalizers for a fiber link has been explicitly studied and compared. The results demonstrate that both can improve optical links significantly but optical equalizers can perform better in terms of noise enhancement.

Mode-Dependent Loss Mitigation Scheme for PDM-64QAM, Wen-Fong Su, Chun-Yi Wang1, Junyi Wang2, 1Electrical and Computer Engineering, University of Michigan, USA; 2Physics, University of Massachusetts, Amherst, MA, USA. We measured the mode de-correlation effect in a 100km-long PDM-64QAM transmission link. The mode evaluation and loss mitigation scheme can compensate for mode de-correlation and reduce the transmission loss by 3dB.

Digital holography using multiple synthesized wavlengths cascaded by optical frequency synthesizers, Masatomo Yamagawa1, Takayuki Ogawa1, Yusuke Kawahito1, Takeo Minakawa1, Hirotsugu Yamamotot1, Takeshi Yasui1, Clement Torovato1, Toshihisa Umemiya1, Japan; 2Utsunomiya University, Japan; 3Univ. of Bordeaux, France. To expand the dynamic range of depth in digital holography, 4 synthesized wavelengths were cascaded within the range of 1.5 µm to 3 mm by an optical frequency synthesizer phase-locked to an optical frequency comb.

Dual-comb mid-infrared spectroscopy with free-running oscillators and complete optical calibration from a radio-frequency reference, OGUZHAN KARA1, Zhaohui Zhang1, Tom Gardiner1, Derryc T. Reid2, Henot-Watt Univ., UK; 1Emissions and Atmospheric Metrology Group, National Physical Lab, UK; 2School of Optical and Electrical Information, National University of Mexico, Mexico. We present a compact, high-resolution dual-comb infrared Fourier transform spectrometer that uses free-running mid-IR oscillators to generate highly stable comb replicas.

Comb offset frequency measurement using two-photon—three-photon quantum interference control, Kai Wang1, Rodrigo A. Munoz1, John Sipe1, Steven T. Cundiff2; 1Electrical and Computer Engineering, University of Michigan, USA; 2School of Electrical and Computer Engineering, Georgia Tech, USA. Two-photon—three-photon frequency measurements are performed using a UV laser in a single-mode optical fiber and a femtosecond laser in a short optical fiber cavity. The two-color frequency difference is measured by the beat frequency between the two-photon—three-photon signal light and the optical feedback light from the optical cavity.

Modulation-Free Frequency-Stabilized Laser at 1.5 µm Using a Narrow-Linewidth Diode Laser, Kazumichi Yoshihi1,2, Takuya Inamura1, Hirokiy Sagawa1, Yu Asahina1, Ken’ichi Nakagawa1, Feng-Lei Hong1,2, Yo-kohama National University, Japan; 3JST, ERATO MINOSHIMA Intelligent Optical Synthesizer Project, Japan; 4Institute of Laser Science, University of Electro-Communications, Japan. We present a modulation-free, frequency-stabilized laser at 1.5 µm. A 120-GHz optical carrier signal is generated by mixing a sub-THz signal with a diode laser at 1.5 µm. The beat frequency of the two signals is locked to the resonant frequency of a Fabry-Perot interferometer.

Nitrogen-Vacancy Ensemble Magnetometry Based on Pump Absorption, Sepehr Amidali1, Haitian A. R. El-Dilla2, Jann B. Hansen1, Alexander Huck1, Ulf L. Andersen1; 1Danmarks Tekniske Universitet, Denmark. By exploiting the magnetic field sensing by recording the pump light absorption with nitrogen-vacancy center ensembe. At a frequency of 10 kHz, we obtain a noise floor of about 10-17 Hz.

Nitrogen-Vacancy Ensemble Magnetometry Based on Pump Absorption, Sepehr Amidali1, Haitian A. R. El-Dilla2, Jann B. Hansen1, Alexander Huck1, Ulf L. Andersen1; 1Danmarks Tekniske Universitet, Denmark. We demonstrate magnetic field sensing by recording the pump light absorption with nitrogen-vacancy center ensemble. At a frequency of 10 kHz, we obtain a noise floor of about 10-17 Hz.

Optical Frequency Comb for Microresonator Frequency Combs, Jonathan M. Silver1, Changlei Guo2,2, Leonardo Del Bino1, Pascal Del Haye1, National Physical Lab, UK; 1Xiamen Univ., China. We present an intuitive frequency-domain model of microresonator-based frequency combs in which large numbers of comb modes act as a few superoscillators. Our model is linked to a recently-developed description of periodic pulse patterns (soltos crystals).

Kerr Superscillator Model for Microresonator Frequency Combs, Jonathan M. Silver1, Changlei Guo2,2, Leonardo Del Bino1, Pascal Del Haye1, National Physical Lab, UK; 1Xiamen Univ., China. We present an intuitive frequency-domain model of microresonator-based frequency combs in which large numbers of comb modes act as a few superoscillators. Our model is linked to a recently-developed description of periodic pulse patterns (soltos crystals).

Comb offset frequency measurement using two-photon—three-photon quantum interference control, Kai Wang1, Rodrigo A. Munoz1, John Sipe1, Steven T. Cundiff2; 1Electrical and Computer Engineering, University of Michigan, USA; 2School of Electrical and Computer Engineering, Georgia Tech, USA. Two-photon—three-photon frequency measurements are performed using a UV laser in a single-mode optical fiber and a femtosecond laser in a short optical fiber cavity. The two-color frequency difference is measured by the beat frequency between the two-photon—three-photon signal light and the optical feedback light from the optical cavity.

Comb offset frequency measurement using two-photon—three-photon quantum interference control, Kai Wang1, Rodrigo A. Munoz1, John Sipe1, Steven T. Cundiff2; 1Electrical and Computer Engineering, University of Michigan, USA; 2School of Electrical and Computer Engineering, Georgia Tech, USA. Two-photon—three-photon frequency measurements are performed using a UV laser in a single-mode optical fiber and a femtosecond laser in a short optical fiber cavity. The two-color frequency difference is measured by the beat frequency between the two-photon—three-photon signal light and the optical feedback light from the optical cavity.

Optical Frequency Comb for Microresonator Frequency Combs, Jonathan M. Silver1, Changlei Guo2,2, Leonardo Del Bino1, Pascal Del Haye1, National Physical Lab, UK; 1Xiamen Univ., China. We present an intuitive frequency-domain model of microresonator-based frequency combs in which large numbers of comb modes act as a few superoscillators. Our model is linked to a recently-developed description of periodic pulse patterns (soltos crystals).

10:00–12:00 JTh2A • Poster Session III

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
CROSSTALK MITIGATION IN POLARIZATION-SWITCHING FIBERS

Phase-Matched Second Harmonic Generation of Continuous-Wave Optical Vortices in Telecommunication Wavelengths

Stéphanie Rennisson, 2, Fabrice Semond, 2, Kresten Yvind, 2, Jan Westenkær Thomsen, 1; Bedrich Rus, 1, Jakub Novak, 1,2, Jonathan T. Green, 1, Roman Sekine, 1, Akifumi Kasamatsu, 1, Naokatsu Sako, 1

1Ecole Polytechnique, Palaiseau, France; 2CNRS-CRHEA, France; 3Univ. Paris Sud, France; 4Univ. Montpellier, France.

We report a simple and versatile scheme for tuning and locking on a time scale of continuous-wave optical vortices in telecommunication wavelengths is demonstrated via single-pass SHG in a PPLN. By measuring SHG-OVs output power, optical conversion efficiencies depending on OAMs are investigated.

Stable Supercontinuum Generation in YAG with Picosecond Pulses

Jinjun Yu, 1,2, Fabrizio Rossetti, 1, Benoit Wiblé, 1, Brent Little, 1, Sai Chou, 1, David J. Moss, 1, Michael Kues, 1, Roberto Morandotti, 1,2,3, EMT/INRS, Canada; 4Dept. of Physics and Astronomy, Univ. of Sussex, UK; 5State Key Lab of Transient Optical Phenomena and Ultrashort Laser, Academia Sinica, China; 6School of Physics and Astronomy, Univ. of Glasgow, UK; 7Inst. of Fundamental and Frontier Sciences, Univ. of Electronic Science and Technology of China, China; 8CuHK, Hong Kong.

We demonstrate on-chip multi-channel phase-sensitive amplification in a nonlinear waveguide, achieving 5 dB net gain and 15 dB extinction ratio. We show the manipulation of individual channels in a multi-channel scheme through controlling the initial phases.

Stable Supercontinuum Generation in a YAG Crystal

Junying Ru, 1, Chaoran Huang, 1, Chester Shu, 1; 2National Univ. of Singapore, Singapore; 3Oki Electric Industry Co., Ltd., Japan.

Stable supercontinuum generation in a YAG crystal driven by 3 ps pulses at 1030 nm. The supercontinuum is demonstrated to be coherent and compressible by Dazzler and prism compressor to below 15 fs.

Towards Actively Stabilized Micro Ring Resonator Based Frequency Comb

Iannis Roland, 1, Maksym Gromovyi, 2, yijia Lu, 2, Christian Reimer, 1, Jenny Wu, 1, Petar Rostocki, 1, Benjamin Wiblé, 1, Brent Little, 1, Sai Chou, 1, David J. Moss, 1, Michael Kues, 1, Roberto Morandotti, 1,2,3, EMT/INRS, Canada; 4Dept. of Physics and Astronomy, Univ. of Sussex, UK; 5State Key Lab of Transient Optical Phenomena and Ultrashort Laser, Academia Sinica, China; 6School of Physics and Astronomy, Univ. of Glasgow, UK; 7Inst. of Fundamental and Frontier Sciences, Univ. of Electronic Science and Technology of China, China; 8CuHK, Hong Kong.

We report a multi-channel femtosecond low-power tunable second-harmonic generation system is designed, fabricated and characterized based on metamaterial structure. The device experimentally displays low loss (<3 dB), low crosstalk (<16.4dB) and broad 1-dB bandwidth (>18nm) with compact size of 2.6μm×5μm.
Stephan Hofmann 1, Hark Hoe Tan 2, Chen - Catherine Groschner 1, Abhay Sagade 1, Min Qiu1, Qiang Li1; Cambridge, UK; 2Dept. of Electronic Materi-
Wavelength-tunable thermal sources with photodetector applications. Withdrawn.
through surface-state engineering, can nupati Jagadish 2, Hannah Joyce 1; Tunable Photoresponse in InAs Nanowire
The device shows a leakage current of 78.5nA of 0.1 mW/µm2. photoactive area for visible-light is presented.

SabriAlirezaei 1, Jörg Vierhaus 1, Edmund
A Butt-Coupled 3D-Bulk Si CMOS Photodetector Array Integrated with a Monolithic U-Groove Array on a Single Chip, Iman

Stephan Hofmann 1, Hark Hoe Tan 2, Chen - Catherine Groschner 1, Abhay Sagade 1, Min Qiu1, Qiang Li1; Cambridge, UK; 2Dept. of Electronic Materi-
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A Butt-Coupled 3D-Bulk Si CMOS Photodetector Array Integrated with a Monolithic U-Groove Array on a Single Chip, Iman
JTh2A.128  
Ultrafast Diode Laser with Self-Adapting Pulse-Shaping in Passive, Active and Hybrid Mode-Locking Operation, Rouven Pilny\textsuperscript{1}, Benjamin Döpke\textsuperscript{1}, Carsten Brenner\textsuperscript{1}, Andreas Kneiss\textsuperscript{2}, Gunther Trankle\textsuperscript{3}, Martin Hofmann\textsuperscript{3}; \textsuperscript{1}Ruhr Universität Bochum, Germany, \textsuperscript{2}Ferdinand-Braun-Institut für Höchstfrequenztechnik im Forschungsverbund Berlin e.V., Germany. We present an ultrafast edge-emitting diode laser system, which is able to self-adapt the resonator internal phase and amplitude. The best operating conditions for passive, active and hybrid mode-locking are analyzed.

JTh2A.129  
Coherently seeded optical parametric amplifier with 500 nJ short-wave infrared signal at 1 MHz, Scott Domingue\textsuperscript{2}, mathew kirchner\textsuperscript{2}, Sterling J. Backus\textsuperscript{2}; \textsuperscript{1}Colorado State Univ., USA; \textsuperscript{2}Kapteyn-Murnane Labs, USA. We introduce a near-infrared pumped, white-light seeded optical parametric amplifier driven by a 3.5 μJ, 130 fs pulse at 1040 nm from a KMLabs Y-Fi HP. The signal conversion efficiency is as high 14%.

JTh2A.130  
Single-walled carbon nanotube mode-locked Yb\textsuperscript{3+}-doped CaF\textsubscript{2} laser, Naoyuki Yokoshima\textsuperscript{1}, SHOTARO KITAJIMA\textsuperscript{1}, Akira Shirakawa\textsuperscript{1}, Sunyoung Choi\textsuperscript{2}, Fabian Retternmund\textsuperscript{2}; \textsuperscript{1}Inst. for Laser Science, UEC, Japan; \textsuperscript{2}Institut für Laser-Physik, Universität Hamburg, Germany. We demonstrated SWCNT-assisted Kerr-lens mode-locked Yb:CaF\textsubscript{2} laser. The pulse duration of 87 fs with a 260 mW output power and the shortest pulse duration of 77 fs with a 94 mW output power were obtained.

JTh2A.131  
SHG-FROG characterization of a novel multichannel synchronized AWG-based mode-locked Yb:GSO oscillator, Wenlong Tian\textsuperscript{1,2}, Yingnan Peng\textsuperscript{1,2}, Jiangfeng Zhu\textsuperscript{1}, Zhiyi Wei\textsuperscript{2}, Jun Xu\textsuperscript{3}; \textsuperscript{1}Xidian Univ., China; \textsuperscript{2}Inst. of Physics, Chinese Academy of, China; \textsuperscript{3}Tongji Univ., School of Physics & Engineering, Shanghai Engineer- ing Research Center for Sapphire, China. A fiber laser pumped Kerr-lens mode-locked Yb:GSO oscillator delivering 4-W, 249-fs pulses at the repetition rate of 92 MHz is demonstrated for the first time. The corresponding optical-to-optical efficiency is as high as 54%.

JTh2A.132  
Time Range Extension of Ultrafast Waveform Measurement by Using Optical Frequency Comb Synthesizer/Analyzer, Takashi Hasegawa\textsuperscript{1}, Takayuki Miyamoto\textsuperscript{1}, Tatsutoshi Shioda\textsuperscript{1}; \textsuperscript{1}Saitama Univ., Japan. Single-shot ultrafast waveform measurement system with time-resolution in femto-second and time-range of 40 pico-second has been developed using 200 GHz optical frequency comb synthesizer and analyzer by means of the proposed time window extension technology.

JTh2A.133  
High efficiency Kerr-lens mode-locked Yb:GSO oscillator, Guoqing Hu\textsuperscript{1}, Ting Li\textsuperscript{1}, Yingling Pan\textsuperscript{1}, Xin Zha\textsuperscript{1}, Meng Zhang\textsuperscript{1}, Zheng Zheng\textsuperscript{1,2}; \textsuperscript{1}School of Electronic and Information Engineering, Beihang Univ., China; \textsuperscript{2}Collaborative Innovation Center of Geospatial Technology, China. We show both asynchronous and synchronous, dual-wavelength femtosecond pulse generation from an SWNT-mode-locked fiber laser by tailoring the intracavity anomalous dispersion, suggesting the effect of the mode-locker on pulse synchronization in the presence of dispersion.

JTh2A.134  
Asynchronous and synchronous dual-wavelength pulse generation in a non-zero-dispersion fiber laser, Songtao Liu\textsuperscript{1,2}, Dan Lu\textsuperscript{1,2}, Lingjuan Zhao\textsuperscript{1,2}, Wei Wang\textsuperscript{1,2}, Ronald Broeke\textsuperscript{3}, Chen Ji\textsuperscript{1}; \textsuperscript{1}Key Lab of Semiconductor Materials Science, Inst. of Semiconductor, CAS, China; \textsuperscript{2}Univ. of Chinese Academy of Sciences, China; \textsuperscript{3}Bright Photonics, Netherlands. We report the second harmonic generation frequency-resolved optical gating (SHG-FROG) measurements on a monolithically integrated multichannel mode-locked semiconductor laser based on arrayed waveguide grating. Clear phase correlation between synchronized mode-locked channels was demonstrated.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
### Executive Ballroom 210A

**JTh3A • Symposium on Multimodal Imaging in Biophotonics I**

**Presider:** Wolfgang Drexler; Medizinische Universität Wien, Austria

#### JTh3A.1 • 14:00  Invited

**Multimodal Label-free Low Fluence Non-linear Imaging of Living Systems with High-Throughput,** Carlos Macias-Romero, Vitalij Žubkovs, Siyuan Wang, Sylvie Roke; Ecole Polytechnique Federale de Lausanne, Switzerland. Photo-damage thresholds in aqueous solutions and living cells are determined for wide field multimodal imaging. Possible dwell times are 10²-10³ times longer compared to scanning confocal imaging. High throughput time-resolved multimodal neuroimaging is performed.

#### JTh3A.2 • 14:30  Tutorial

**Chemical Microscopy: Seeing the Invisible Using Intrinsic Molecular Spectroscopic Signatures,** Ji-Xin Cheng; Purdue Univ., USA. This tutorial talk will describe various modalities recently developed for high-speed chemical imaging of cancer, neuron and infectious diseases, with a focus on stimulated Raman scattering microscopy, pump-probe microscopy, and mid-infrared photothermal microscopy.

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### Executive Ballroom 210B

**CLEO: Applications & Technology**

**Joint**

#### 14:00-16:00

**JTh3B • Optical Devices & Components**

**Presider:** Jana Jägerská; UiT Norges Arktiske Universitet, Norway

#### JTh3B.1 • 14:00  Invited

**Ultrasound extinction on-chip amplitude modulators with broadband operation,** Sheng Liu, Hong Cai, Christopher DeRose; Laboratory d’Optique Appliquée, France. We report here recent work on an optical-field ionized (OFI) high-order harmonic-seeded 32.8 nm laser. The gain duration monotonically decreased from 7 ps to an unprecedented shortness of 450 fs FWHM as the amplification peak rose from 150 to 1,200 with an increase of the plasma density from 3 × 10¹⁰ cm⁻³ up to 1.2 × 10¹⁵ cm⁻³. The integrated energy of the EUV laser pulse was also measured, and found to be up to 14 µJ.

#### JTh3B.2 • 14:15

**Broadside Beam Routing by Dielectric Micro-Prism,** Ambar Dewanjee, J. Stewart Atchison; Univ. of Toronto, Canada. We propose and demonstrate the design and fabrication of a broadside beam routing and also a stress induced broadside beam scanning mechanism using high index dielectric micro prism structures compatible to integrated photonics.

#### JTh3B.3 • 14:30

**Tunable Enhanced Mid-Infrared Light Absorption in Graphene,** Ruizhe Lu, Guo1; Univ. of Massachusetts Lowell, USA. We present an on-chip plasmonic graphene device for enhanced mid-infrared light absorption with tunability by gate voltage. Further, we show that the absorption bandwidth depends on the carrier mobility of graphene.

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### Executive Ballroom 210C

**CLEO: Applications & Technology Joint**

#### 14:00-16:00

**JTh3C • A&T Topical Review on Extreme Ultraviolet and Soft X-ray Sources and Application I**

**Presider:** Carmen Menoni; Colorado State Univ., USA

#### JTh3C.1 • 14:00  Invited

**Toward Compact and Ultra-Intense Laser Based Soft X-ray Lasers,** Stephanie Sebben; Université de Genève, Switzerland. We present our progress in the design and construction of an XUV frequency comb source with linewidths below 200 fs and tuning range exceeding 300 nm. This will be achieved by using a combination of intracavity synthesized soft X-ray radiation and mode-locked Ti:sapphire laser technology.

#### JTh3C.2 • 14:30  Invited

**Next Generation High-Order Harmonic Sources and Application,** Katsumi Morikawa; RIKEN Center for Advanced Photonics, Japan. High-order harmonics are established as a high-output coherent light source in the XUV region and the sole source of attosecond pulses. Recent efforts on high harmonic generation and application at RIKEN is reviewed.

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### Executive Ballroom 210D

**CLEO: QELS-Fundamental Science**

#### 14:00-16:00

**JTh3D • PT Symmetry and Beyond**

**Presider:** Demetrios Christodoulides; CREOL, Univ. of Central Florida, USA

#### JTh3D.1 • 14:00

**Polarization state conversion through exceptional point encirclement,** Aabsar U. Hassan, Bo Zen, Marin Soljacic, Mercedes Khajavikhan; Demetrios Christodoulides; 1Univ. of Central Florida, CREOL, USA; 2MIT, USA; 3Technion, Israel. We present an integrated optical configuration for converting any arbitrary polarization into a desired output state. This topologically robust chiral process relies on encircling the system’s exceptional point through parameter variations along the propagation direction.

#### JTh3D.2 • 14:15

**PT-symmetric Micro-resonators: High Sensitivity at Exceptional Points,** Hossein Hodaei, Absar U. Hassan, Demetrios Christodoulides, Mercedes Khajavikhan; 1Univ. of Central Florida, USA. Enhanced sensitivity is demonstrated in PT-symmetric coupled micro-resonator arrangements biased at an exceptional point. The spectral response of such a system is shown to follow a square root dependence on externally introduced perturbations.

#### JTh3D.3 • 14:30

**Electrically Pumped Coupled Waveguide Lasers by Parity-Time Symmetry,** Ruixhe Yao, Chi-Sen Lee, Viktor A. Podolsky, Wei Guo; Univ. of Massachusetts Lowell, USA. We demonstrate single transverse-mode operation of InAs quantum dot (QD) broad-area coupled waveguide lasers enabled by parity-time symmetry breaking. By tuning the loss, suppression and revival of higher order modes from fundamental mode is obtained.
Simulations indicate that $Q/V > 1.2 \times 10^4$ is possible in these structures with optimized dimensions. Efficient photonic interfacing is achieved when $N \approx 2 \times 10^6$ intracavity photons is reached, sufficient for coherent photon-phonon coupling. With a cooperativity of $C \approx 1.2$ for $N = 2 \times 10^6$ intracavity photons is reached, sufficient for coherent photon-phonon coupling.
19:40-21:00
STh3.1 • Quantum Confined Materials & Devices
Presider: Roberto Paiella; Boston Univ., USA

Flexible Light Emitting Diodes Based on Nitride Nanowires, Nan Guan1, Xing Dai, Agnès Messarini2, Heshi Zhang3, Jiantang Yan4, Eric Gautier5, Catherine Bougerol5, Martin Vallo3, François H. Julien3, Christophe Durand4, Joel Eymery4, Maria Tchernycheva1, Centre de Nanosciences et de Nanotechnologies, Université Paris-Saclay, France; 2Université Grenoble Alpes, France; 3CNRS, Institut Néel, France; 4INAC-SPINTEC, CEA, France; 5Femtolasers CE, France. Flexible blue/green/white light emitting diodes based on nitride nanowires embedded in polymer layers are demonstrated. The fabrication and physics of these novel hybrid light sources will be described.

STh3.2 • Strain-Engineered SiGe Nanomembrane Quantum-Well Infrared Photodetectors, Habibe Durmaz1,2, Pornsatit Sookchoo3, Yiyin Zhou2, Wei Du1,2, Seyed Ghetmiri2, Sattar H. Al-Kabi2, Boston, USA; 3Univ. of Wisconsin, USA.

We report the formation of SiGe quantum-well nanomembranes, where stress from lattice mismatch is relaxed via elastic strain sharing rather than defect formation, are used to develop intersubband photodetectors showing improved performance compared to identical devices grown on rigid substrates.

STh3.3 • Study of SiGeSn/GeSn/SiGeSn Quantum Well towards All Group-IV-Optoelectronics, Wei Du1,2, Seyyed Ghetmiri3, Sattar H. Al-Kabi4, Joe Margetis5, Yiying Zhou6, Wei Dou2, Aboozar Mosleh7, Jaime Cardenas8, Yoshitomo Okawachi9, Alexander L. Gaeta1, Michiel Lipson1, Columba Univ., USA; 2Cornell Univ., USA; 3Inst. of Sciences, China; 4INAC-SPINTEC, CEA, France; 5Paris-Saclay, France; 6Univ. of Rochester, USA; 7Arktonics, LLC, USA.

Temperature-dependent Evolution and Properties of Laser-induced Periodic Surface Structures on Fused Silica, Stephan Graf1, Clemens Kunz1, Sebastian Engel1, Frank A. Müller1, Friedrich-Schiller-Universität Jena, Germany. We report the formation of laser-induced periodic surface structures in fused silica by fs-laser irradiation at different substrate temperatures. Using scanning electron microscopy, we reveal the evolution process and properties of these structures.

STh3.4 • Characterization of Intermodal Group Index Matched Soliton Interactions leading to MW Peak Powers at 1300 nm, Lars Rishøj1, Boyin Tai1, Poul Kristensen2, Lars Christensen3,4, Hisashi Kato3,4, Tatsuo Miyai3,4, ‘Center for Free Electron Laser Science, Germany. We demonstrate an energy scalable method of implementing widely tunable femtosecond sources. Based on fiber-optic nonlinearities, ~100-fs pulses tunable in 825-1700 nm are achieved, well suited for driving multiphoton microscopy.

STh3.5 • Dead-band-free, real-time high-resolution microwave frequency measurement without the ‘dead-band’ limitation in previous dual-comb schemes. 1.5*10$^{-10}$ measurement accuracy is achieved at 20 GHz using a low-cost, compact fiber-optic setup.
**Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.**

<table>
<thead>
<tr>
<th>Marriott Salon III</th>
<th>Marriott Salon IV</th>
<th>Marriott Salon V &amp; VI</th>
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<td><strong>Joint</strong></td>
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<td>14:00–16:00</td>
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<td>JTh3M • Symposium on Optical Microcavities for Ultrasensitive Detection I Presider: Yun-Feng Xiao; Peking Univ., China</td>
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<td><strong>STh3N • Light Emitters and Lasers</strong> Presider: Zhihong Huang; Hewlett Packard Labs, USA</td>
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<td><strong>STh3O • Free-Space Optical Communications</strong> Presider: David Geisler; MIT Lincoln Lab, USA</td>
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| JTh3M.1 • 14:00 Invited Optical Microresonators as Single-Particle Absorption Spectrometers: Fano Resonances, Attometer Sensitivity, and Working Toward Single-Molecule Spectroscopic Identification, Randall H. Goldsmith; Univ. of Wisconsin Madison, USA. We present a single-particle optical microresonator spectrometer capable of extremely low limit of detection. Spectroscopy of gold nanorods shows signatures of photonic-plasmonic hybridization, including formation of Fano interferences. |
| JTh3M.2 • 14:15 Invited Trapping Nanoparticles with Plasmonic and Photonic Nanostructures, Kenneth B. Crozier; Univ. of Melbourne, Australia. We describe optical trapping with plasmonics and with silicon photonics. We furthermore describe recent work in which fluorescence microscopy is used to track the positions of nanoparticles trapped by structures such as double nanohole apertures. |
| JTh3M.2 • 14:30 Invited Fully-Integrated CMOS-Compatible Q-Switched Laser at 1.9µm Using Thulium-Doped Al₂O₃, Patrick T. Callahan; Katia Shtrykova; Nanxi Li; Emir S. Magden; Purnawirman Purnawirman; Christopher Baocco; Douglas Coolbaugh; Erich P. Ippen; Michael Watts; Franz Kaertner; MIT, USA; Harvey Univ., USA; College of Nanoscale Science and Engineering, State Univ of New York, USA; Center for Free-Electron Laser Science, Germany. A fully-integrated Q-switched laser is demonstrated at 1.9µm using thulium-doped aluminum oxide waveguides, with the potential for achieving an on-chip passively mode-locked laser. All components of the laser are fabricated in a CMOS-compatible silicon photonics process. |
| JTh3M.3 • 14:30 Invited Lasing of Site-Controlled InGaAs/InP Quantum Well Nanopillars Grown on Silicon, Fabian Schuster; Jonas Kapaun; Gilliard N. Malheiro-Silveira; Saniya Deshpande; Connie J. Chang-Hasnain; UC Berkeley, USA. Site-controlled InP nanopillars MOCVD grown on Silicon show 0.87 µm lasing at room temperature. Integrated InGaAs quantum wells enable the first realization of a silicon transparent III-V nanolaser (1.21 µm) monolithically integrated on Silicon. |

**Thursday, 14:00–16:00**

<table>
<thead>
<tr>
<th>CLEO: Science &amp; Innovations</th>
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<tr>
<td><strong>STh3N.1 • 14:00</strong></td>
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<tr>
<td>Wavelength Tuning in InGaN/GaN Light-emitting Diodes with Strain-induced Through Nanosphere Lithography, Sung-Wen Huang; Hao-chung Kuo; Sheng-Wen Wang; Kuo-Bin Hong; An-Jye Tsou; You-Chen Chu; Po-Tsung Lee; Chien Chung Lin; Dept. of Photonics &amp; Inst. of Electro-Optical Engineering, National Chiao Tung Univ., Taiwan; Inst. of Photonic System, National Chiao Tung Univ., Taiwan. Nanoring light emitting diodes with different wall width shows that the effective bandgap can be tuned by reducing the strain. This research successful to make the devices with four colors emission on the same wafer.</td>
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<tr>
<td><strong>STh3N.2 • 14:15</strong></td>
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<tr>
<td>Fully-Integrated CMOS-Compatible Q-Switched Laser at 1.9µm Using Thulium-Doped Al₂O₃, Patrick T. Callahan; Katia Shtrykova; Nanxi Li; Emir S. Magden; Purnawirman Purnawirman; Christopher Baocco; Douglas Coolbaugh; Erich P. Ippen; Michael Watts; Franz Kaertner; MIT, USA; Harvey Univ., USA; College of Nanoscale Science and Engineering, State Univ of New York, USA; Center for Free-Electron Laser Science, Germany. A fully-integrated Q-switched laser is demonstrated at 1.9µm using thulium-doped aluminum oxide waveguides, with the potential for achieving an on-chip passively mode-locked laser. All components of the laser are fabricated in a CMOS-compatible silicon photonics process.</td>
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<td>Lasing of Site-Controlled InGaAs/InP Quantum Well Nanopillars Grown on Silicon, Fabian Schuster; Jonas Kapaun; Gilliard N. Malheiro-Silveira; Saniya Deshpande; Connie J. Chang-Hasnain; UC Berkeley, USA. Site-controlled InP nanopillars MOCVD grown on Silicon show 0.87 µm lasing at room temperature. Integrated InGaAs quantum wells enable the first realization of a silicon transparent III-V nanolaser (1.21 µm) monolithically integrated on Silicon.</td>
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Hamid Hemmati, Ph.D., is a Director of Engineering at Facebook Inc. Prior to that, he was with the JPL/Caltech for 28 years working on the lasercom technology. He is the editor and author of two books: “Deep Space Optical Communications” and “Near-Earth Laser Communications” and author of five other book chapters.

**Thursday, 14:00–16:00**

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CLEO: Applications & Technology

Joint

JTh3A • Symposium on Multimodal Imaging in Biophotonics I—Continued

JTh3B • Optical Devices & Components—Continued

JTh3C • A&T Topical Review on Extreme Ultraviolet and Soft X-ray Sources and Application I—Continued

JTh3D • PT Symmetry and Beyond—Continued

CLEO: QELS-Fundamental Science

Executive Ballroom 210A

FTh3D.1 • 14:45
Demonstration of Compact Silicon Nitride Grating Coupler Arrays for Fan-out of Multicore Fibers, Sarvagya Dwivedi1, Bowen Song1, yuan liu1, Renan Moreira1, Li-Jing Cheng1, ‘Oregon State Univ., USA. We report an MAFIB technique that significantly improves the fidelity of nanofabrication that allows direct milling of nanостructures on various materials with fine edges and smooth surfaces. The technique supports precise fabrication of nanophotonic devices.

FTh3D.2 • 15:00
Metal Assisted Focused-Ion Beam Etching for High-Fidelity Fabrication of Nanophotonic Devices, Akash Kannegula1, Li-Jing Cheng1, ‘Oregon State Univ., USA. We report an MAFIB technique that significantly improves the fidelity of nanofabrication that allows direct milling of nanостructures on various materials with fine edges and smooth surfaces. The technique supports precise fabrication of nanophotonic devices.

FTh3D.3 • 15:00
Phase Matching of Noncollinear Sum and Difference Frequency High Harmonic Generation, Jennifer L. Elia1, Kevin M. Doneyn, Charles Durfey1, Carlos Hernandez-Garcia1, Franklin Dollar1, Christopher Mancuso1, Tingting Fan1, Dmitry Zuan1, Christian Gentry1, Patrick Grychtol1, Henry Kapteyn1, Margaret Murnane1, Daniel Hickstein1, JILA - NIST and Dept. of Physics, Univ. of Colorado Boulder, USA; 2Dept. of Physics, Colorado School of Mines, USA; 3Grupo Fotonica, Univ. of Salamanca, Spain. We experimentally investigate phase matching of high harmonic generation in a noncollinear geometry and demonstrate phase matching above critical ionization using noncollinear high-order-difference-frequency generation, which provides a route to maximize the generated photon energies.

FTh3D.4 • 15:00
Laser self-termination in complex photonic molecules, Mohammad Hasan Teimourpour1, Ramy El Ganainy1, ‘Michigan Technological Univ., USA. We demonstrate numerically and analytically that laser self-termination can occur in complex photonic molecules made of more than two cavities. We also confirm our results in the presence of gain saturation nonlinearities.

FTh3D.5 • 15:00
Single shot nano-holography with compact soft X-ray laser, Alex P. Rockwood2, Charles Durfey1, Kevin M. Doneyn, Charles Durfey1, Carlos Hernandez-Garcia1, Franklin Dollar1, Christopher Mancuso1, Tingting Fan1, Dmitry Zuan1, Christian Gentry1, Patrick Grychtol1, Henry Kapteyn1, Margaret Murnane1, Daniel Hickstein1, JILA - NIST and Dept. of Physics, Univ. of Colorado Boulder, USA; 2Dept. of Physics, Colorado School of Mines, USA; 3Grupo Fotonica, Univ. of Salamanca, Spain. We experimentally investigate phase matching of high harmonic generation in a noncollinear geometry and demonstrate phase matching above critical ionization using noncollinear high-order-difference-frequency generation, which provides a route to maximize the generated photon energies.

FTh3D.6 • 15:15
Spontaneous Symmetry Breaking of Counterpropagating Light in Microresonators, Leonardo Del Bino1,2, Jonathan Silver1, Sarah L. Stellings1, ‘National Physical Lab (NPL), UK; ‘Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK. We demonstrate spontaneous symmetry breaking of counter-propagating states of light in optical microresonators. The symmetry breaking is induced by nonlinear interaction of counterpropagating light and leads to a splitting of clockwise and counterclockwise resonance frequencies.

FTh3D.7 • 15:15
Observation of the Linear Response of a Laser to an Externally Incident Probe, Ali Kazemi Jahromi1, Alexander Cerjan1, Alfred D. Stone1, Ayman F. Abouraddy1, ‘Univ. of Central Florida, CREOL, USA; 2Stanford Univ., USA; 3Applied Physics, Yale Univ., USA. Investigating the optical response of a laser cavity to a probe signal not coinciding with the laser wavelength can give rise to paradoxes. We address this question experimentally along with steady-state ab-initio laser theory.
CLEO: QELS-Fundamental Science

**JTh3E.3 • 14:45**

**Heralded Quantum Interference of On-chip Micro-ring Resonator Sources in Si-photonics,** Imad I. Faruque1, Damien Bonneau1, Gary F. Sinclair1, Mark G. Thompson1, *Univ. of Bristol, UK.* We report a 4-photon measurement in silicon-on-isolator, demonstrating 67.31±10% indistinguishability among heralded photons generated from two separate micro-ring resonators, and interfered on-chip. The heralded single-photons purities from each source are estimated as 96.20±3.89% and 78.69±2.44%.

**JTh3E.4 • 15:00**

**Integrated Silicon Photonics for High-Speed Quantum Key Distribution,** Jake E. Kennard1, Philip Sibson1, Stasja Stanisic1, Chris Erven1, Jeremy L. O’Brien1, Mark Thompson1, *Univ. of Bristol, UK.* Integrated silicon photonics offers great potential for quantum communication devices in terms of robustness and scalability. Here we demonstrate high-speed low-error QKD using silicon photonic devices combining slow thermo-optic DC biases and fast carrier-depletion modulation.

**JTh3E.5 • 15:00**

**Tailored surface distortions of sub nanometer size excited by optical transient gratings,** Mathias Sander1, Marc Herzog1, Jan-Etienne Pudell1, Matthias Bangheer1, Peter Gaal2, *Inst. of Physics and Astronomy, Univ. of Potsdam, Germany;* 1Inst. of Solid-State and Nanostructure Physics, Univ. of Hamburg, Germany. The amplitude of surface distortions induced by transient grating excitation has been measured via time-resolved XRD. Results show 4 times higher amplitude of the thermal surface deformation compared to the propagating surface acoustic waves with a total amplitude of 4 Angstrom.

**FTh3F.4 • 14:45**

**Phonon Dephasing in Bulk and Monolayer MoS2,** Liuyang Sun1, Kha Tran1, Sebastian Roesch1, Junho Choi1, Eduardo Priega1, Galan Moody1, Yu-Ming Chang1, Kevin Silverman1, Richard Mirts1, Xiaoqin Li1, *Univ. of Texas at Austin, USA;* 1Dept. of Physics, Univ. of Tübingen, Germany; 1National Inst. of Standards and Technology, USA; 1National Taiwan Univ., Taiwan. We investigate phonon dephasing times in MoS2 using a two-pulse coherent Raman spectroscopy method. The phonon dephasing times are 3.9 and 4.9 ps in monolayer and bulk MoS2 at room temperature.

**FTh3F.5 • 15:00**

**Chirality Dependent Coherent Phonon Dynamics in Carbon Nanotube Solutions,** Iku-fumi Katayama1, Renjie Xu1, Yasuo Minami1, Kazuhiro Tanagi1, Masahiro Kitajma1, Jun Takeda1, *Yokohama National Univ., Japan;* 2Tokyo Metropolitan Univ., Japan; 2LxRay Co. Ltd., Japan. Using probe-wavelength-resolved coherent phonon spectroscopy, we investigated coherent phonon dynamics in chirality-mixed carbon nanotube solutions. The chirality dependent electron-phonon coupling is clearly visualized in phonon-frequency vs. probe-wavelength two-dimensional mapping.

**FTh3G.4 • 15:15**

**Optomechanical Quantum Correlations,** Thomas Purdy1, Karen Grutter1, Kartik Srinivasan1, Nikolai Klimov1,2, Zeeshan Ahmed1, Jacob Taylor1,2, *NIST, USA;* 1Joint Quantum Inst., USA. We present methods to measure optical quantum correlations arising from an optomechanical interaction even when large classical noise sources are present. We demonstrate quantum-backaction-noise-calibrated Brownian motion thermometry as a metrological application of quantum optomechanics.

**FTh3H.5 • 15:15**

**The Origin and Limit of Asymmetric Transmission in Chiral Resonators,** P. Nikhil1, F. Alpeggiani1,2, L. Kuijpers1,2, E. Verhagen1, *FOM Inst. AMOLF, Netherlands;* 1Kavli inst. of Nanoscience, Netherlands. We develop a theoretical formalism which explains asymmetric transmission (AT) in chiral resonators from their eigenmodes. We derive a fundamental limit for AT and propose the design of a chiral photonic crystal offering 84% AT.
Thursday, 14:00–16:00

STh3I.6 • 15:15
Cun-Zheng Ning 1,2; Praneeth Ranga 1, Dongying Li 1, fan fan 1, Fan Fan Cui 1
Force Research Lab, USA; 3Frederick Seitz

ZnGeN2 Quantum Wells Light-Emitting
Diodes, 1Case Western Reserve Univ., USA. 2Osaka Sangyo Univ., Japan; 3National Inst.
for Fusion Science, Japan; 4WRI Osaka Univ., Japan. We observe the self-organization of
light into its most spatiotemporally-unnatural state through propagation in graded-index
multimode fiber. We understand this effect in terms of mode-coupling caused by dissipa-
tion, disorder, and nonlinearity.

STh3J.4 • 15:00
Towards 2-4 μm supercontinuum with kW/
mm-level spectral density from large-core
tellurite glass fiber, Hongxing Shi 1, Xian
Wang 1, 2, Xuanyue Wang 2,1, Jonathan M. Silver 2, A. Crause 2, Derryck T. Reid 1;
2Osaka Univ., Japan; 2JST, ERATO MINOSHIMA
Intelligent Optical Synthesizer (IOS), Japan; 3Osaka Univ., Japan. Combination of the
dual comb spectroscopy with the single-pixel imaging is effectively applied for a scan-less
hyperspectral imaging of an object having spectral-dependent absorption.

STh3K.4 • 15:00
Fiber-Based SBS Pulse Compression Using
Bragg Grating Reflection Feedback of
Stokes Seed, Masayuki Matsumoto 1, Genya
Miyashita 1, Hitoshi Kiso 1, 2, Yukuki Sato 1, 2,
Wakayama Univ., Japan. Efficient pulse compression using SBS in fiber is reported where a
Stokes seed copropagating with a pump is reflected back by a fiber Bragg grating located at the end of
the fiber. 1.1 μs pulse is compressed to 12 ns with peak power ~30 W.

STh3L.5 • 15:15
Passively Stable Astrocomb from 550–890-
nm for High Resolution On-Sky Spectros-
copy, Richard A. McCracken 1, Eric Depagne 2, A. Crause 2, Derryck T. Reid 1;
2South African Astronomical Observatory, South Africa. A broadband visible
astrocomb was implemented on the 10-m Southern African Large Telescope, delivering
complete calibration of one channel of its high-resolution spectrograph. The passively
stable master comb removed the need for overnight CEO-frequency locking.
JTh3M • Symposium on Optical Microcavities for Ultrasensitive Detection I—Continued

JTh3M.3 • 15:00
Breaking the Limitation of Evanescent Wave Sensing with Subwavelength Grating Waveguides, Hai Yan1, Lijun Huang1, Xianchuan Xu1, Swapnaijit Chakravarty3, Naimi Tang2, Huiping Tian2, Ray T. Chen1,2; 1The Univ. of Texas at Austin, USA; 2Beijing Univ. of Posts and Telecommunications, China; 3Omega Optics Inc., USA. Microring resonator based on subwavelength grating waveguides was studied and demonstrated in biosensing experiment to show its thickness-independent high sensitivity, which breaks the limitation in conventional evanescent wave sensors.

JTh3M.4 • 15:15
Multiplexed Subcellular Lasing in Cancer Tissues for Molecular Diagnostics, Yu-Cheng Chen1, Xiaotian Tan1, Guishu Chen1, Xudong Fan1; 1Biomedical Engineering, Univ. of Michigan, Ann Arbor, USA. The first demonstration of multiplexed lasing in human cancerous tissues with subcellular resolution was achieved by using antibodies and nucleic acid probes. Our work represents a critical milestone to implement optical probes in clinical applications for cancer diagnosis and prognosis.

STh3N • Light Emitters and Lasers—Continued

STh3N.4 • 14:45
Coherence and Dynamics of a Metallo-dielectric Nanolaser, Si Hui Pan1,2, Gong Gu3,4, Abdelkrim El Amili2, Felipe Vallin2, Yeshaaihu Fainman2; 1Physics, University of California, San Diego, USA; 2Electrical and Computer Engineering, University of California, San Diego, USA; 3Electrical Engineering, Univ. of Texas at Dallas, USA. We conducted the second-order intensity-correlation measurement on a high-β metallo-dielectric nanolaser under nanosecond pulse pumping. Our results confirm fully coherent emission can be achieved and dynamical hysteresis can be observed via the width of the emission pulse.

STh3N.5 • 15:00
A Yellow Emitting InGaN/GaN Nanowires-based Light Emitting Diode Grown on Scalable Quartz Substrate, Aditya Prabaswara1, Tien Khee Ng1, Chao Zhao1, Bilal Janjua1, Ahmed Alyamani1, Munir El-desouki2, Boon S. Oo1,1; 1King Abdullah Univ. of Science and Technology, Saudi Arabia; 2King Abdulaziz City for Science and Technology, Saudi Arabia. The first InGaN/GaN nanowires-based yellow (λ = 590 nm) light-emitting diodes on scalable quartz substrates are demonstrated, by utilizing a thin Ti/TiN interlayer to achieve simultaneous substrate conductivity and transparency.

STh3N.6 • 15:15
Demonstration of Athermally Synchronized Distributed Feedback Laser with Microring Filter, Nannxi Li1,2, Zhan Su1,3, Purnawirman Purnawirman1, Emir S. Magden1, Alfonso Ruocco1, Neetesh K. Singh1, Matthew Byrd1, Christopher V. Poulton1,2, Jonathan Bradley1,2, Gerald Leake1,2, Douglas Coolbaugh1, Michael Watts1; 1Research Lab of Electronics, MIT, USA; 2John A. Paulson School of Engineering and Applied Science, Harvard Univ., USA; 3Analog Photonics, USA. We demonstrate an athermally synchronized distributed feedback laser cascaded with microring filters on a silica photonic platform, with >10dB extinction ratio and a synchronized wavelength shift of 0.02 nm °C from 20 to 50 °C.

STh3O • Free-Space Optical Communications—Continued

STh3O.2 • 15:00
Invited
Next-generation Free-space Optical Transceivers for High-capacity Space-based Communications, David O. Caplan1, J.P. Wang1, Mark L. Stevens1, Mark Burton1, J.C. Carney1, Barry Romkey1, N.W. Spellmeyer1, Hemanth G. Rao1, David J. Geisler1, A Horvath1, M Scheinbart1, Garvin Lund1, O Mikulin1, J.D. Moores1, Scott A. Hamilton1; 1MIT Lincoln Lab, USA. Building upon multi-rate optical transceivers developed for both near-Earth and deep-space communications, we present scalable next-generation designs for future systems requiring more compact implementation and both power- and photon-efficient performance.
JTh3A.3 • 15:30 Invited
Looking at Tissue with a New Light: Clinical Advances of Multispectral Optoacoustic Tomography, Vasilis Ntziachristos 1,2
1Inst. of Biological and Medical Imaging, Helmholtz Zentrum Munchen, Germany; 2Chair of Biological Imaging, Technical Univ. of Munich, Germany. The talk discusses progress in multi-spectral optoacoustic tomography (MSOT) that brings unprecedented imaging performance in visualizing anatomical, physiological and molecular imaging biomarkers. Clinical applications and complementarity with other imaging modalities will also be addressed.

JTh3B.7 • 15:30
The self-calibrating dual-mode Si detector - improved design based on Comsol Multiphysics simulations, Mani Ulset Nordvåen 1,2; Chi K. Tang 1, Jarle Gran 1; Juster-vesen, Norway; 1Dept. of Physics, Univ. of Oslo, Norway. Our dual-mode optical power detector combines the principles of electrical substitution with measuring photocurrent. We present a new detector design, which shows a considerable reduction in non-equivalence between optical and electrical heating during electrical substitution.

ATH3B.8 • 15:45
Microcavity-ECDL for super-cavity frequency stabilization, Jinkang Lim 1, Anatoly Savchenkov 2, Andrey Matsko 2, Shu-Wei Huang 1, Lute Maleki 2, Cheewei Wong 1; 1Univ. of California Los Angeles, USA; 2OEwaves Inc., USA. We report on the development of a tunable microresonator-based sub-kHz extended cavity diode laser (ECDL) for frequency stabilization to an ultrastable high finesse super-cavity. The relative spectral linewidth after the stabilization is ~ 1 Hz limited by the super-cavity.

ATH3C.5 • 15:30
Valley-dependent Carrier and Lattice Dynamics in Silicon measured by Transient XUV Spectroscopy, Scott Cushing 1, Lucas Carreño 1, Michael Zurch 1, Peter Krauss 1, Chris Kaplan 1, Hung-Tzu Chang 1, Stephen R. Leone 1,2; Chemistry, UC Berkeley, USA; 2Chemical Sciences Division, Lawrence Berkeley National Lab, USA. Transient XUV core level spectroscopy is used to resolve photoexcited electron and hole distributions, as well as carrier-phonon and phonon-phonon scattering times, in the Γ, L, and X valleys of silicon.

ATH3C.6 • 15:45
Extreme ultraviolet laser ablation mass spectrometry for sensitive materials studies and nanoscale chemical imaging, Ilya Kuznetsov 1, Tyler Green 1, Andrew Duffin 2; 1Physics, Univ. of California Berkeley, USA; 2Physics, MIT, USA. We demonstrate three dimensional nanoscale molecular composition imaging of inorganic samples by extreme ultraviolet laser ablation mass spectrometry. The method has applications in studies of surface and interface chemistry, diffusion and contamination at nanoscale dimensions.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

Executive Ballroom 210E

JTh3E • Quantum Photonics II—Continued

FTh3F • Ultrafast Lattice and Molecular Dynamics—Continued

JTh3G • Symposium on Optomechanics: Towards the Second Quantum Revolution I—Continued

FTh3H • Photonic Crystals for Light Manipulation and Concentration—Continued

Thursday, 14:00–16:00

16:00–16:30 Coffee Break, Concourse Level

Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.
STh3I • Quantum Confined Materials & Devices—Continued

STh3l.7 • 15:30
246 nm AlN-delta-GaN Quantum Well Ultraviolet Light-Emitting Diode, Cheng Liu1, Yu Kee Ooi1, SM Islam2, Huli (Grace) Xing3, Debdeep Jena4, Jing Zhang5; 1Rochester Inst. of Technology, USA; 2Cornell Univ., USA. The 246 nm AlN-delta-GaN quantum well ultraviolet light-emitting diode was proposed and realized experimentally, with the dominant transverse electric-polarized emission been verified by both the k·p simulation and the room-temperature polarization-dependent electroluminescence measurements.

STh3l.8 • 15:45
High-quality GaAs Grown on Aluminum Film, Chia-Chu Cheng1, Yen-Ting Fan1; 1NCTU, Taiwan. We have grown GaAs layers on an aluminum nanofilm by using molecular beam epitaxy. Defect-free GaAs and InAs quantum dots are investigated with X-ray diffraction, transmission electron microscopy, and room-temperature photoluminescence.

STh3J • Ultrafast Laser-Material Interactions—Continued

STh3J.6 • 15:30
Comparison of Filament-Generated Periodic Surface Features using Different Laser Wavelengths, Anthony Valenzuela1, Kristopher Behler2, Zachary Brunson2, Ali Rastegar3, Chengyong Feng4, Christopher Wollf5, Laura Vanderhoel6, Brian Kramer1, Ladan Arissian3, Aaron Schweinsberg1, Jean-Claude Diels4, Aaron Stebner5; 1US Army Research Lab, USA; 2TKC Global, USA; 3Mechanical Engineering, Colorado School of Mines, USA; 4The Center for High Technology Materials, Univ. of New Mexico, USA; 5Oak Ridge Inst. for Science and Education, USA. Filament-induced periodic surface structures are generated on a wide variety of materials with near-IR and UV lasers. The surface structure features demonstrate the relation to laser wavelength and polarization and energy distribution in a filament.

STh3K • Nonlinear Fiber Photonics II—Continued

STh3K.6 • 15:45
Efficient Polarization-Insensitive Four-Wave Mixing Assisted by Raman Amplification, Xiaojie Guo1, Chester Shu2; 1Inst. of Photonics Technology, Jinan Univ., China; 2Dept. of Electronic Engineering, The Chinese Univ. of Hong Kong, Hong Kong. We report efficient polarization-insensitive four-wave mixing in a two-orthogonal-pump configuration with the assistance of backward Raman amplification. Due to Raman enhancement, conversion efficiency of ~0dB is obtained in a nonlinear fiber without stimulated-Brillouin-scattering suppression.

STh3L • Dual Frequency Comb Techniques—Continued

STh3L.7 • 15:30
Hybrid Dual-comb Interferometer Using Electro-optic Comb and Free-running Femtosecond Laser, Shuai Wang1, Xinyu Fan2, Qiu Li3, Zuyuan He4, 1Shanghai Jiao Tong Univ., China. We demonstrate a rapid-scan-rate dual-comb interferometer employing an electro-optic comb generated from Fabry-Perot modulator and a free-running femtosecond laser. High dynamic range has been achieved without the necessity of complicated phase-locking and laser stabilization.

STh3L.8 • 15:45
Gas Spectroscopy with a Dual-Comb Semiconductor Disk Laser, Sandro M. Link1, De-ren J. Maas2, Dominik Waldburger3, Cesare G. Allen1, Matthias Golling1, Florian Emayr1, Ursula Keller1, 1ETH Zurich, Switzerland; 2ABB, Corporate Research, Switzerland; 3ABB, Corporate Research, Switzerland. For the first time, we use a stabilized dual-comb modelocked semiconductor disk laser to perform dual-comb spectroscopy. A water vapor absorption spectrum around 968 nm is measured with our very compact, simple and cost-efficient system.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

**JTh3M • Symposium on Optical Microcavities for Ultrasensitive Detection—Continued**

**JTh3M.5 • 15:30**
Ultrasound-Q/V single point-defect photonic crystal nanocavity with embedded sub-wavelength air-slot, Eiichi Kuramochi¹, Jun K. Kim¹, Hideaki Taniyama¹, Akiko Shinya¹, Shota Kita¹, Masaya Notomi¹, ¹NTT Corporation, Japan. H1 photonic crystal nanocavities with a short sub-wavelength air-slot that can concentrate an electric field to one antinode with V<0.025(λ/n)² experimentally exhibited a Q-factor over 2×10⁶ and a Q/V reaching 10⁷.

**JTh3M.6 • 15:45**
Size spectrometry of environmental particulate matter using optical evanescent fields from a nanofiber array, Xiao-Chong Yu¹, Yanyan Zhi¹, Bei-Bei Li¹, Qihuang Gong¹, Yun-Feng Xiao¹, ¹Peking Univ., China. We propose and build an optical evanescent field-based size spectrometer using a nanofiber array by measuring the distinction. This method is practically applied to monitor the particulate matters in atmosphere in Beijing.

**STh3N • Light Emitters and Lasers—Continued**

**STh3N.7 • 15:30**
Resonant Light Emission from Highly N-doped Germanium-on-Insulator Microdisks with Circular Bragg Grating, Xuejun Xu¹, Hideaki Hashimoto¹, Kentarou Sawano¹, Takuya Maruzumi¹, ¹Tokyo City Univ., Japan. Resonant light emission with high Q-factor and fringe contrast, corresponding to Fabry-Perot modes, have been observed over 250 nm wavelength range from highly n-doped Ge-on-Insulator microdisks by combining with highly reflective circular Bragg grating.

**STh3N.8 • 15:45**
Individually Addressable Micron-Sized LED Color Pixels with Integrated Condenser Lenses, Brandon Demory¹, Kunook Chung¹, Jingyang Sui¹, Pei-Cheng Ku¹, ¹Univ. of Michigan, USA. A multi-color LED chip with integrated parabolic lenses is shown. The emission collimates within a 0.5NA zone with percentages of 75% for red, 83% for green, and 95% for blue, of the total emission, respectively.

**STh3O • Free-Space Optical Communications—Continued**

**STh3O.3 • 15:30**
First Demonstration of 400Mb/s PAM4 Signal Transmission Over 10-meter Underwater Channel Using a Blue LED and a Digital Linear Pre-Equalizer, Boyuan Zhuang¹, Chao Li¹, Nan Wu¹, Zhengyuan Xu¹, ¹USTC, China. A 400Mb/s PAM4 signal is experimentally generated and transmitted over 10-meter underwater channel using a single blue LED and a simple digital linear pre-equalizer for the first time.

**STh3O.4 • 15:45**
Near-Infrared Wireless Optical Communication with Particulates In-Suspension over the Underwater Channel, Yujian Guo², Tien Khee Ng², Ki-Hong Park², Mohamed-Slim Alouini², Boon S. Ooi², ²Faculty of Engineering (FOE), Multimedia Univ. (MMU), Malaysia; ²Computer, Electrical and Mathematical Sciences and Engineering (CEMSE) Division, King Abdullah Univ. of Science and Technology (KAUST), Saudi Arabia. We demonstrate a gigabit near-infrared-based underwater wireless optical communication link using an 808-nm laser diode to mitigate the particle scattering effect in turbid medium. An improvement in the error performance is observed with increasing concentrations.

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**16:00–16:30 Coffee Break, Concourse Level**
JTh4A.1 • 16:30
Assessing Airway Smooth Muscle Microstructure and Contractile Force in Vivo Using Birefringence Microscopy, Melissa Suter1, 2, Massachusetts General Hospital, Harvard Medical School, USA. Excessive contraction of airway smooth muscle (ASM) is responsible for the majority of the symptoms of asthma. We have developed a birefringence microscopy platform to volumetrically assess ASM in patients and to quantify and predict ASM contractile force as a function of optical retardation.

JTh4A.2 • 17:00
Complete Cutaneous Vasculature Imaging and its Clinical Translation Using Multimodal Photoacoustic and Optical Coherence Tomography Angiography, Mengyang Liu1, Zhe Chen1, Behrooz Zabihian1, Christoph Sinz1, Edward Zhang2, Paul Beard3, Eric Hoover3, Michael Meinmeme4, Jason Enscher4, Liu1, Zhe Chen1, Behrooz Zabihian1, Christoph Sinz1, Edward Zhang2, Paul Beard3, Eric Hoover3, Michael Meinmeme4, Jason Enscher4,

ATH4B.1 • 16:30
Chemical Segregation and Microstructural Evolution of Fiber Laser Beam Welded Low Carbon Sheet Steel, Ann Chiaramonti Debay1, Paul T. Blanchard1, Stephanie M. Kaster1, Jeffrey W. Sowards1, James R. Fekete1, NIST, USA. This study provides fundamental data for phase transformation prediction during the rapid solidification of laser beam welded low carbon sheet steel. Findings can strengthen modeling efforts by providing kinetic and thermodynamic data based on real-world observations.

ATH4B.2 • 17:00
High Speed Hyperspectral Thermal Imaging of the Melt Pool Dynamics During Metal Additive Manufacturing, Nicholas P. Calta1, Gabe Guiss2, Sheldon S. Wu2, Sonny Li3, Dave Deane1, Michael F. Cumb1, Manyalibo Mattheus1, Lawrence Livermore National Lab, USA. We use high speed multiswavelength thermal imaging to quantify cooling rates and temperature gradients generated by the laser – powder interaction during a metal powder bed fusion process to understand rapidly solidified material properties.

ATH4B.3 • 17:15
Dependence of THz Signals on Carbon Black Compounding Amount in Vulcanized Rubber, Yasuyuki Hirakawa1, Tatsumi Yamauchi1, Takuya Kami4, Koyokio Gondo1, Seichii Hirano1, Toshiyuki Noguchi2, NIT, Kurume College, Japan; “Technical Service Dept., DAIKIN INDUSTRIES, LTD, Japan. Dependence of the THz absorbance and reflectance on carbon black (CB) compound amount in vulcanized rubber was investigated. It was found that the THz absorbance was not proportional to the CB concentration at higher amount.

ATH4C.1 • 16:30
Nuclear Photonics Enabled by MeV Laser-Compton Sources, Christopher P. Barty1, Lawrence Livermore National Lab, USA. This paper reviews the design and optimization of MeV laser-Compton sources and the development of the unique nuclear science and applications enabled by them, i.e. nuclear photonics.

ATH4C.2 • 17:00
Coherent extreme ultraviolet pulse generation using metal-sapphire nanostructures, Seungwoo Han1, Hyunwoong Kim1, Yong Woo Kim1, Seung-Woo Kim1, Korea Advanc Inst. of Science & Tech, Korea (the Republic of) Coherent extreme ultraviolet (EUV) light pulses are produced from metal-sapphire nanostructures by irradiation of infrared femtosecond pulses. Single-crystal sapphire emitters subject to plasmonic field enhancement enable high-order harmonics generation up to the 13th order.

FTh4D.1 • 16:30
Stokes Solitons in Optical Microcavities, Qifan Yang1, Xu Yi1, Xi Y. Yang1, Kerry Vahala2, California Inst. of Technology, USA. A soliton is reported that regenerates by optimizing its Raman interaction with another soliton within a shared optical potential well. The soliton is observed in a high-Q silica optical microcavity.

FTh4D.2 • 16:45
Counter-Propagating Solitons in Microresonators, Chaithanya S. Joshi1, Yoshitomo Okawachi1, Mengjie Yu2, Alexander Klein1, Xingchen Ji2, Kevin Luke1, Michael Lipson1, Alexander Gaeta1, Dept. of Applied Physics and Applied Mathematics, Columbia Univ, USA, School of Applied and Engineering Physics, Cornell Univ, USA; School of Electrical and Computer Engineering, Cornell Univ, USA, Dept. of Electrical Engineering, Columbia Univ, USA. Using a single pump laser, we demonstrate simultaneous soliton modelocked frequency combs in a silicon-nitride microresonator in the clockwise and counter-clockwise directions with slightly different repetition comb spacings.

FTh4D.3 • 17:00
Breathing Dissipative Solitons in Microresonators, Erwan Lucas1, Maxim Karpov2, HaRun Guo3, Michael L. Gorodetsky4, Tobias J. Kippenberg4, Ecole Polytechnique Federale de Lausanne, Switzerland, Faculty of Physics, Lomonosov Moscow State Univ, Russia. We present a comprehensive analysis of breathing dissipative solitons in two microresonator platforms. Numerical simulations and theoretical analyses are in good agreement with experimental observations, providing insights into the dynamical instabilities in these systems.
**FTh4E.1 • 16:30**
Quantum Communication with Temporal Modes of Pulsed Light, Christine Silberhorn1, Vahid Ansari1, Markus Allgaier1, Benjamin Brecht1, Christof Eigner1, Viktor Modes of Pulsed Light, Quantum Communication with Temporal Loop, Temporal Multiplexing of Heralded Single Photons, Christine Silberhorn1, Vahid Ansari1, Markus Allgaier1, Benjamin Brecht1, Christof Eigner1, Viktor Modes of Pulsed Light, Quantum Communication with Temporal Loop, Temporal Multiplexing of Heralded Single Photons. We investigate the properties of temporal modes of pulsed light and their application in quantum communication. We present a framework for quantum communication using temporal modes of quantum light with orthogonal spectral-temporal shapes. These span a high-dimensional Hilbert space and are ideally suited for efficient quantum information coding for network applications.

**FTh4E.2 • 17:00**
Temporal Multiplexing of Heralded Single Photons with a Resource-Efficient Fiber Loop, Rowan A. Hoggarth1, Robert J. Francis-Jones1, Peter Mosley1. We have implemented resource-efficient active multiplexing that synchronizes single photons generated by several consecutive pump pulses with a single optical switch. We demonstrate an increase in delivery probability per mode of heralded single photons.

**FTh4E.3 • 17:15**
Relative time multiplexing of heralded single photons for efficient quantum communication, Fumihiro Kaneda1, Alexander Hill2, Paul G. Kwiat3, Univ. of Illinois at Urbana-Champaign, USA. We demonstrate relative time multiplexing of heralded single-photon sources, using a low-loss photon storage technique. Our scheme can realize efficient two-photon quantum communication protocols, e.g., measurement-device-independent quantum key distribution.

**JTh4G.1 • 16:30**
High-fidelity ground state cooling of a mechanical resonator via squeezed light driving, David Vitali1,2, Muhammad Asjad1, Stefano Zippilli1, Universita di Camerino, Italy, ‘Sezione di Perugia, INFN, Italy. We show that preparation of nonclassical states of a mechanical resonator with close-to-one fidelity is possible by driving a cavity optomechanical system with squeezed vacuum light.

**JTh4G.2 • 16:45**
Topology of Light and Sound, Florian Marquardt1,2, Max Planck Inst. Science of Light, Germany, ‘Dept. of Physics, Univ. of Erlangen-Nuremberg, Germany. I will show how the interaction of light and sound can be used to engineer topologically robust chiral transport of phonons and photons on the nanoscale. This connects the fields of optomechanics and topological transport.

**JTh4G.3 • 17:15**
Exceptional Points in an Optomechanical System, David Mason1, Haitian Xu2, Luyao Jiang1, Jack Harris1,2, Universita di Camerino, Italy, ‘Sezione di Perugia, INFN, Italy. We demonstrate experimentally that spurious effects caused by interference can be eliminated in passive near-field imaging by implementing a random illumination.
STh4I.1 • 16:30
Broadband planar multilayer absorber tuned by VO$_2$ phase transition, Hao Peng$^1$, Yi Luo$^1$, Xiangkao Ying$^1$, Yang Pu$^1$, Zeyi Li$^1$, Yadiang Jiang$^1$, Zhijun Liu$^1$; 'Univ of Electronic Sci & Tech of China, China. A dynamically tunable planar multilayer absorber is demonstrated using the VO$_2$ phase-change material. As the VO$_2$ phase transition is thermally triggered, a modulation depth of 72.6% is achieved over a broad wavelength range from 4-8.2µm.

STh4I.2 • 16:45
Nano-structured Wild Moth Cocoon Fibers as Radiative Cooling and Waveguiding Optical Materials, Norman N. Shi$^1$, Cheng-Chia Tsai$^1$, Catherine Craig$^2$, Nanfang Yu$^1$; 'Columbia Univ., USA; 2Harvard Univ., USA. The study shows that comet moth cocoon fibers exhibit radiative cooling properties with enhanced solar reflectivity and thermal emissivity. Optical waveguiding due to transverse Anderson localization of light is also observed in these natural fibers.

STh4I.3 • 17:00
Control over Emissivity of Zero-Static-Power Thermal Emitters Based on Phase Changing Material GST, Kakai Du$^1$, Qiang Li$^1$, Dong Dong$^1$, Yue Liu$^1$, Zhiyuan Cheng$^1$, Min Gu$^2$; 'State Key Lab of Modern Optical Instrumentation, College of Optical Science and Engineering, Zhejiang Univ., China; 'Inst. of Microelectronics and Nanoelectronics, College of Information Science & Electronic Engineering, Zhejiang Univ., China. A switchable, tunable and defect layer. Dynamic tunability and hysteresis properties of the Bragg filter promise more applications by combining phase transition materials and optical cavities.

STh4J • 16:30
First-Principles Description for Initial Stage of Femtosecond Laser Processing, Kazuhiro Yabana$^1$; 'Univ of Tsukuba, Japan. Interactions of intense laser pulse and dielectrics in femtosecond time scale are described using time-dependent density functional theory coupled with Maxwell’s equations. Threshold and depth of the laser damage are estimated from the calculation.

STh4K.1 • 16:30
Broadband Coherent Raman Imaging - Method Development and Application to Tissue Imaging, Marcus T. Cicerone$^1$, Charles H. Camp$^1$; 'NIST, USA. I will discuss efforts to render spectroscopic coherent Raman imaging sufficiently simple and robust for general users. I will discuss progress in signal generation, data reduction, and extraction of information from rich spectroscopic images.

STh4K.2 • 17:00
Real-Time Observation of Microsecond-Order Periodic Velocity Change of Fiber Fuse using Heterodyne Detection, Shoulin Jiang$^1$, Lin Mai$^1$, Shuai Wang$^1$, Zuyuan He$^1$; 'Shanghai Jiao Tong Univ., China. We studied the propagation speed of fiber fuse using heterodyne detection method by analyzing the Doppler shift based on short-time Fourier transform. We observed periodic velocity changes about 160 µs with a constant launched power.

STh4K.3 • 17:15
Spectral dynamics of polarization-rotating vector solitons, Bowen Li$^1$, Xiaoming Wei$^1$, Ying Wu$^1$, Kenneth Kin-Yip Wong$^1$; 'Univ of Hong Kong, China. Vector soliton is obtained by using a fiber stretcher inside a dispersion-engineered nonlinear-polarization-rotation (NPR) mode-locked fiber laser. Fascinating real-time spectral dynamics of vector soliton is observed for the first time using dispersive Fourier transform (DFT).
JTh4M.1 • 16:30
Monolithically Integrated Ring Resonator Systems On-chip, Hongky Chandrabhal1, Xudong Fan1, 1Univ of Michigan, USA. We review the recent development in robust, monolithically integrated optical ring resonator systems fabricated on-chip using photolithographic and femtosecond laser writing technologies, which potentially has broad applications in passive/active photonic devices and bio/chemical sensing.

JTh4M.2 • 16:45
High quality LiNbO3, photonic crystal nanobeams, Hanxiao Liang1, Rui Luo1, Jian Lin1, 1Univ of Rochester, USA. We report, for the first time, high-quality LiNbO3 one-dimensional photonic crystal nanobeams, with optical Q up to 1.09 x 106, which allows us to observe strong reversible photorefractive effect.

JTh4M.3 • 17:00
Thresholdless lasing with quantum dot gain, Yasutomo Ota1, Daishu Takanaka2, Tsukiyuki Watanabe2, Satoshi Iwamoto1, 1NTT Basic Research Labs, Japan; 2IIS, The Univ of Tokyo, Japan. We demonstrate thresholdless lasing with quantum dot gain, operated under cavity resonant excitation. The lasing behavior is systematically compared with that under conventional above bandgap excitation, providing a firm verification of the thresholdless operation.

JTh4M.4 • 17:15
Guiding of laser light from a nanocavity in a three-dimensional photonic crystal, Takeyoshi Tajiri1, Shun Takahashi1, Yasutomo Ota2, Tsukiyuki Watanabe2, Satoshi Iwamoto1, 1NTT Basic Research Labs, Japan; 2IIS, The Univ of Tokyo, Japan. A nanocavity laser and two orthogonal waveguides are integrated in a three-dimensional photonic crystal, allowing us to observe strong reversible photorefractive effect.

STh4N.1 • 16:30
Forward-biased photonic crystal photodetector towards amplifier-free bias-free receiver, Kengo Nozaki1, Shinji Matsuo1, Takuro Fujii1, Koji Takeda1, Eiichi Kunamoto1, 1NTT Basic Research Labs, Japan; 2Nanolight Photonics Center, Japan; 3NTT Device Technology Labs, Japan. We demonstrate a photonic-crystal photodetector under a forward bias voltage maintaining a 0.88-A/W responsivity and a 40-Gbit/s bitrate. This will allow an ultralow-energy receiver with high-impedance termination that requires neither amplifiers nor a bias circuit.

STh4N.2 • 16:45
Self-Heating in Photonic Thermometers, Impact of Varying Vacuum Levels on the temperature-wavelength calibration, Beibei Li1,2, James Fedchak1, Hands1,1PML, NIST, USA. We report, for the first time, high-quality LiNbO3 one-dimensional photonic crystal nanobeams, with optical Q up to 1.09 x 106, which allows us to observe strong reversible photorefractive effect.

STh4N.3 • 17:00
Thresholdless lasing with quantum dot gain, Yasutomo Ota1, Daishu Takanaka2, Tsukiyuki Watanabe2, Satoshi Iwamoto1, 1NTT Basic Research Labs, Japan; 2IIS, The Univ of Tokyo, Japan. We demonstrate thresholdless lasing with quantum dot gain, operated under cavity resonant excitation. The lasing behavior is systematically compared with that under conventional above bandgap excitation, providing a firm verification of the thresholdless operation.

STh4N.4 • 17:15
Guiding of laser light from a nanocavity in a three-dimensional photonic crystal, Takeyoshi Tajiri1, Shun Takahashi1, Yasutomo Ota2, Tsukiyuki Watanabe2, Satoshi Iwamoto1, 1NTT Basic Research Labs, Japan; 2IIS, The Univ of Tokyo, Japan. A nanocavity laser and two orthogonal waveguides are integrated in a three-dimensional photonic crystal. Guiding of the laser light from the nanocavity through the waveguides is demonstrated experimentally.

Manijeh Razeghi started at Thomson-CSF as the Head of the Exploratory Materials Laboratory. In 1991, she joined Northwestern University, as a Walter P. Murphy Professor and Director of the Center for Quantum Devices. She is one of the leading scientists in the field of semiconductor science and technology.
JTh4A • Symposium on Multimodal Imaging in Biophotonics II—Continued

JTh4A.3 • 17:30 Invited
New Directions in Multimodal Imaging and Light Sheet Microscopy, Kishan Dholakia1; 1Univ. of St Andrews, UK. I will describe new work combining Raman imaging with morphological imaging (e.g. digital holographic microscopy and OCT). Additionally, I will describe new directions using light sheet microscopy with studies in neuroscience and developmental biology.

JTh4B • Process Evaluation & Microscopy—Continued

JTh4B.4 • 17:30 Lensfree On-chip Microscopy Achieves Accurate Measurement of Yeast Cell Viability and Concentration Using Machine Learning, Alborz Feizi1, Yibo Zhang1, Alon Greerbaum1,2, Alex Guzik1, Michelle Luong1, Raymond Chan1, Brandon Berg1,2, Haydar Oztan1, Wei Lu1, Michael Wu1, Yichen Wu2, Aydogan Ozcan1; 1Univ. of California Los Angeles, USA; 2California Institute of Technology, USA. Automatic measurement of yeast viability and concentration is achieved by coupling a lensfree on-chip holographic microscope with a machine learning based classification algorithm that counts the number of live/dead cells stained with methylene blue.

JTh4B.5 • 17:45 Time-Domain Measurements Reveal Spatial Aberrations in a Sub-Surface Two-Photon Microscope, Marius Rutkauskas1, Derynck T. Reid2, Jesus Gardutia-Mejia1, Martha Rosete2; 1Heriot-Watt Univ., UK; 2Centro de Ciencias Aplicadas y Desarrollo Tecnológico, Universidad Nacional Autónoma de Mexico, Mexico. We experimentally demonstrate that in a sub-surface microscope the effects of chromatic and spherical aberrations are revealed by a difference in the focal positions corresponding to the shortest pulse duration and the maximum autocorrelation amplitude.

JTh4C • A&T Topical Review on Extreme Ultraviolet and Soft X-ray Sources and Application II—Continued

JTh4C.4 • 17:45 Quasi-phase-matched high harmonic generation in gas-filled photonic crystal fibers, Patrick Anderson1, Florian Wiegandt1, Fei Yu1, Daniel Treacher1, David Lloyd1, Peter Mosley1, Simon Hooker1, Ian A. Walmsley1; 1Clarendon Lab, Univ. of Oxford, UK; 2Centre for Photonics and Photonic Materials, Dept. of Physics, Univ. of Bath, UK. We review HHG in gas-filled PCFs with micropore driving lasers. QPM is implemented for the first time, enhancing the flux at 30 eV by a factor of 60.

JTh4C.5 • 17:45 Characterization and Scaling of Laser Produced Plasma EUV Light Source for Lithography, Jayson Stewart1; 1AMSL, USA. We discuss ASML’s enabling technologies for producing clean and stable high power EUV LPP sources, including new tools to characterize ions from the Sn plasma, droplet generators, and dose control methods to deliver in-spec stability.

JTh4D • Solitons and Temporal Wave Guiding—Continued

JTh4D.4 • 17:30 Soliton Breathing Induced by Avoided Mode Crossing in Optical Microresonators, Huirun Guo1, Martin Pfeiffer1, Erwan Lucas1, Maxim Karpov1, Miles Anderson1, Junqiu Liu1, Michael Geiselmann1, John Jost1, Tobias J. Kippenberg1; 1Ecole Polytechnique Federale De Lausanne, Switzerland. We observed soliton breathing induced by avoided mode crossing, in soliton-based Kerr frequency combs in two microresonator platforms. We present an understanding of avoided mode crossing as a Lorentzian response that reveals the breathing dynamics.

JTh4D.5 • 17:45 Temporal Dissipative Solitons in a Microresonator Driven by Optical Pulses, Evelina Obrzud1,2, Steve Leomete1, Tobias Herr1; 1CSEM, Switzerland; 2Observatoire de Geneve, Switzerland. A nonlinear optical microresonator is driven by picosecond laser pulses resulting in formation of temporal dissipative solitons. These femtosecond solitons are stable and generated at a fraction of the power required in continuous-wave driven system.
Chih-Sung Chuu1, Tsung-Yao Wu1, Yung-Chin Liu1, Po-Hui Liu1, Chin-Hsuan Chang1, Chiao-Yeh1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Eric Huang1, Zhaowei Liu1, Athanasios Margiolakis1, Keshav Dani1, Markos Ramdhan1, Wing Yung S. Lau1, Markus Rambach1, Vajtai2, Pulickel M. Ajayan2, Keshav Dani1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Weinhold1, Andrew Winchester1, Michael K. 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Man1, Vivek Pareek1, Julien Madéo1, Keshav Dani1, Till Wei...
**STh4J • Imaging and Nonlinear Fiber Effects—Continued**

**STh4K.4 • 17:30** Characterization of Chirped Pump Four-Wave Mixing in Nonlinear Fibers using only Continuous-Wave-Lasers, Mads Lillieholm1, Mads Lillieholm1; Oxenløwe1; 1Technical Univ. of Denmark, Denmark; 2OFS, Denmark. We propose a novel fiber characterization method that reveals the four-wave mixing bandwidth for chirped pump operation, using two tunable continuous-wave lasers. The method accurately predicts the bandwidth for optical time lenses with broadband multi-carrier input.

**STh4K.5 • 17:45** Sensitivity Enhancement of Brillouin Frequency Shift Measurement Based on Multispectral Pump and Probe, Yousuke Tanaka 1, Yuta Ozaki1, Takashi Kurokawa1,2; 1Univ. of Tokyo, Japan; 2School of Mechanical and Aerospace Engineering, Nanyang Technological Univ., Singapore. We propose and demonstrate a novel approach to monolithically fabricate photonic transfer processes. We developed an approach to monolithically fabricate photonic devices on 2-D materials conventionally relied on transfer processes. We developed an approach on the use of single-crystal silicon, enabling high-speed phase and frequency control.

**STh4J.4 • 17:30** Stealh dicing with ultrafast Bessel beams with engineered transverse profiles, Remi Meyer1, Jassem Safiou1, Remo Giust1, Pierre-Ambroise Lacourt1, Luca Furfaro1, John Michael Dudley1, Francois courvoisier1; 1FEMTO-ST, France. We investigate high-speed glass cleaving with ultrafast laser beams with engineered transverse intensity profiles. We achieve accuracy of ~ 1 µm at 25 mm/s and drastically enhance cleavability compared to standard Bessel beams.

**STh4K.6 • 18:00** Phase and Combining Efficiency in Divided Pulse Amplification, Koji Ikawa1, Ei Jo1, Henk Tunnermann1, Akira Shirakawa1; 1Inst. for Laser Science, UEC, Japan. We show amplitude and phase retrieval of both pulses on the combined and the rejected port and amplitude and phase retrieval of both pulses on type-II Weyl semimetal WTe2. We report measurements of very small refractive index changes in crystalline silicon by fs laser irradiation below melting threshold. We measured threshold for permanent optical change is up to five times lower than previously reported.

**STh4J.5 • 17:45** Very Fine Refractive Index Tuning of Silicon by Single Femtosecond Laser Pulses Below Melting Threshold, Daniel Bachman1, Zhijun Chen1, Robert Fedosejevs1, Ying Tsui1, Vien Van1; 1Univ. of Alberta, Canada. We report measurements of very small refractive index changes in crystalline silicon by fs laser irradiation below melting threshold. We measured threshold for permanent optical change is up to five times lower than previously reported.

**STh4I.5 • 17:45** Growth, Spectroscopy and Laser Operation of Tm-doped Monoclinic Magnesium Tungstate, Xavier Malato1, L Zhang1, Z Linh1, H Lin2, G Zhang1, Pavel Liko1, Josep M. Serres1, Magdalena Aguiló1, Francesc Diaz1, Yicheng Wang1, Uwe Griebner1, Valentín Petrov1, Elena Vlasishkina1, Konstantin Yumashev1, Weidong Chen3; 1Materials Science and Engineering, MIT, USA; 2The College of Optics & Photonics, Univ. of Central Florida, USA; 3The College of Optics & Photonics, Univ. of Central Florida, USA; 3The College of Optics & Photonics, Univ. of Central Florida, USA. A novel monoclinic magnesium tungstate crystal, Tm_MgWO4, was grown with engineered transverse profiles, for high-performance photonic integration.

**STh4I.6 • 17:45** Continuous-Wave-Lasers, Michael Galili1, Lars Grüner-Nielsen2, Leif K. Oxenløwe1; 1Technical Univ. of Denmark, Denmark; 2OFS, Denmark. We propose and demonstrate a novel approach to monolithically fabricate photonic transfer processes. We developed an approach on the multi-band Keldysh formula and Drude model to describe semiconductor interactions are frequently used to model optical properties of semiconductors and semimetals. However, the multi-band Keldysh formula and Drude model to describe semiconductor interactions are frequently used to model optical properties of semiconductors and semimetals. We report measurements of very small refractive index changes in crystalline silicon by fs laser irradiation below melting threshold. We measured threshold for permanent optical change is up to five times lower than previously reported.

**STh4I.6 • 18:00** Beyond the Drude Approach: a Keldysh-Vinogradov Model of Dynamics of Ultrafast Laser-Induced Electron Excitation, Vitaly Grudzev1, Drake R. Austin2, Olga N. Seregaeva1, Eman Chowdhury1; 1Univ. of Missouri-Columbia, USA; 2Dept. of Physics, The Ohio State Univ, USA. High-power laser-semiconductor interactions are frequently simulated with the Keldysh photoionization-rate formula and Drude model to describe generation and dynamics of conduction-band electrons. We report a novel approach utilizing the multi-band Keldysh formula and Vinogradov equation.

**STh4I.7 • 18:00** Photograph carrier dynamics in Weyl semimetal WTe2 thin films, Chunhui Zhu1, Ming Gao1, Hongtao Lin1, Yi Song2, Yizhong Huang1, Chunhui Zhu1, Ming Gao1, Yi Song2, Yizhong Huang1; 1Materials Science and Engineering, MIT, USA; 2Electrical Engineering and Computer Science, MIT, USA; 3The College of Optics & Photonics, Univ. of Central Florida, USA; 3The College of Optics & Photonics, Univ. of Central Florida, USA. We report measurements of very small refractive index changes in crystalline silicon by fs laser irradiation below melting threshold. We measured threshold for permanent optical change is up to five times lower than previously reported.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

Marriott Salon III

JTh4M • Symposium on Optical Microcavities for Ultrasensitive Detection II—Continued

JTh4M.4 • 17:30
Cavity Optomechanics for Sensing Applications, Wenyin Yu, Wei Jiang, Qiang Lin1, Tao Lu,1 Electrical and computer engineering, Univ. of Victoria, Canada; 1Inst. of Optics, Univ. of Rochester, USA; 1Electrical
and Computer Engineering, Univ. of Rochester, USA. This talk reviews the progresses on cavity optomechanical sensing. A comparison of mass induced and optical spring based sensing approaches are presented. Future improvements that may enable the detection of single atoms are discussed.

Marriott Salon IV

CLEO: Science & Innovations

STh4N • Photonic Crystals & Their Applications—Continued

STh4N.5 • 17:30
Cavity-enhanced light emission from an electrically-driven van der Waals heterostructures, Chang-Hua Liu1, Genevieve Clark1, Taylor Fryett1, Sanfang Wu1, Jiajui Zheng1, Xiaodong Xu1, Arka Majumdar1; 1Dept. of Physics, Univ. of Washington, USA; 2Dept. of Electrical Engineering, Univ. of Washington, USA; 3Dept. of Materials Science and Engineering, Univ. of Washington, USA. We demonstrate a novel light source, based on a photonic crystal cavity integrated van der Waals light emitting diode, which can be operated at room temperature with fast modulation speed.

STh4N.6 • 17:45
Enhanced and Preferential Optical Trapping in a Slot-Graphite Photonic Crystal, Aravind Krishnan1, Michelle Povinelli1, Ningfeng Huang1, Luis J. Martinez1, Shao-Hua Wu1; 1USC, USA. High-stiffness optical traps are developed for dielectric and metallic particles by exploiting the strong confinement of light in slot-graphite photonic crystal. An optical sieve is realized using the difference in growth kinetics of different nanoparticles.

STh4N.7 • 18:00
Photonic Crystal Enhanced Photothermal Lens, Yunfei Zhao1, Gufan Yin2, Juejun Hu2, Qing Hu1; 1Iowa State Univ., USA; 2MIT, USA. We optimized the dispersion compensating method that is capable of enhancing the photothermal lens effect generated by light absorbing materials. The method was used to analyze gold nanoparticles and exhibited stronger photothermal lens signals.

Marriott Salon V & VI

STh4O • Quantum Cascade Lasers—Continued

STh4O.2 • 17:30
Broadband Continuous Tuning of a THz Quantum-Cascade VECSEL, Christopher A. Curwen1, Lu Yao Xu1, John Reno2, Tatsuo Itoh1, Benjamin Williams1; 1UCLA, USA; 2Sandia Labs, USA. We report tuning of a terahertz quantum-cascade vertical-external-cavity surface-emitting-laser (VECSEL) using piezoelectric actuators and an intra-cryostat cavity. Continuous tuning over 260 GHz at a center frequency of 3.3 THz is demonstrated.

STh4O.3 • 17:45
Narrow-Beam, 4.7 micron-Emitting Near-Resonant Leaky-Wave-Coupled Quantum Cascade Laser Phase-Locked Array, Chris Sigler1, Colin Boyle1, Jeremy Kirch1, Don Lindberg-III1, Thomas Earles1, Joshua Myers2, Robert Bedford3, Dan Botez1, Luke J. Mawst1; 1Univ. of Wisconsin-Madison, USA; 2Intraband, LLC, USA; 3Air Force Research Lab, Sensors Directorate, USA. Narrow beam (3.2xD.L.) is demonstrated up to ~5.85 W pulsed output power from a five-element phase-locked array of 4.7 μm-emitting quantum cascade lasers. Devices are fabricated by a MOCVD process and operate predominately in an in-phase array mode, in agreement with design simulation studies.

STh4O.4 • 18:00
Full Dispersion Compensation of Terahertz Quantum Cascade Laser Frequency Combs, Yang Yang1, David P. Burghoff1, John Reno2, Qings Hu1, 1MIT, USA; 2Sandia National Labs, USA. Using a genetic algorithm, we optimized the dispersion compensation of terahertz quantum cascade laser frequency combs up to fourth-order. The fully dispersion-compensated device shows a larger dynamic range and a broader spectral coverage, exhibiting comb formation over 800 GHz.
JTh4A • Symposium on Multimodal Imaging in Biophotonics II—Continued

ATH4B • Process Evaluation & Microscopy—Continued

ATH4C • A&T Topical Review on Extreme Ultraviolet and Soft X-ray Sources and Application II—Continued

ATH4B.7 • 18:15
CMOS-Compatible Wavelength-Selective Infrared Sensors, Tsung-Ting Wu, Chia-Chien Hsieh, Ming-Chang Lee, Yu-Ting Wang, Photonics Technologies, National Tsing Hua Univ., Taiwan. We propose wavelength-selective infrared sensors made by multiple metallic resonant waveguide gratings integrated on a germanium photodetector array. The detective spectrum can cover from 1.25μm to 1.55μm with the FWHM less than 25nm.

18:30–20:00 Dinner Break (on your own)

20:00–22:00 Postdeadline Paper Sessions
### Executive Ballroom 210E
**CLEO: QELS-Fundamental Science**

**FTh4E • Single-Photon Sources and Quantum Communications—Continued**

**FTh4F • Imaging Electron Dynamics on the Nano-, Femto-Scale—Continued**

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### Executive Ballroom 210F
**Joint**

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### Executive Ballroom 210G
**CLEO: QELS-Fundamental Science**

**JTh4G • Symposium on Optomechanics: Towards the Second Quantum Revolution II—Continued**

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### Executive Ballroom 210H
**CLEO: QELS-Fundamental Science**

**FTh4H • Optical and Thermal Superresolution Imaging and Nanofocusing—Continued**

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<th>Description</th>
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<tr>
<td>FTh4E.7</td>
<td>18:15</td>
<td>Distribution of four-dimensional time-bin entangled state over 100 km of fiber, Takuya Ikuta, Hiroki Takesue; NTT Basic Research Labs, Japan. We distributed four-dimensional time-bin entangled photons over 100-km optical fiber. We reconstructed the quantum density operator by utilizing cascaded Mach-Zehnder interferometers, and obtained an average fidelity of 0.935±0.015.</td>
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<tr>
<td>FTh4H.7</td>
<td>18:15</td>
<td>Efficient Waveguide-to-Plasmon Coupling and Adiabatic Nanofocusing for HAMR Applications, Patrick W. Flanagan, Chuan Zhong, Brian Jennings, Gwenael Atcheson, Frank Bello, David McCloskey, John Donegan, Trinity College Dublin, Ireland. We present several specific and actionable steps to improve the quality of HAMR devices. Recommendations include using a cladding layer to improve coupling efficiency and designing the near-field transducer to achieve adiabatic (low loss) nanofocusing.</td>
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18:30–20:00 Dinner Break (on your own)

20:00–22:00 Postdeadline Paper Sessions
CALL FOR CLEO 2018 SYMPOSIUM PROPOSALS

The 2018 CLEO CLEO Program Committee is seeking special symposium proposals for consideration from members of the optics and photonics community. Submissions should consist of timely, cutting-edge topics and/or new material in rapidly advancing areas.

Submissions need to address the following questions.
1. Why is this symposium topic important now and needed in contrast to other years?
2. Which existing topic subcommittees if any, would this topic be most aligned with?
3. Proposed invited speaker list and talk titles.

Submission Deadline: 10 July 2017 at 12:00 EDT (16:00 GMT)

For more information, visit www.cleoconference.org/symposiaproposals
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<th>Joint</th>
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<td><strong>JTh4M</strong> • Symposium on Optical Microcavities for Ultrasensitive Detection II—Continued</td>
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<td><strong>STh4N</strong> • Photonic Crystals &amp; Their Applications—Continued</td>
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<td><strong>STh4O</strong> • Quantum Cascade Lasers—Continued</td>
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### JTh4M.8 • 18:15
2D Photonic Crystal Structures in Silicon Rich Nitride Platform, Kapil Debnath1, Thalia Dominguez Bucio1, Matteo Galli2, Daniele Baioni2, Abdelrahman Al-Attishi1, Ali Z. Khokhar1, Swee Z. Oo1, Shinchi Saito1, Frederic Gardes1; 1Univ. of Southampton, UK; 2Univ. of Pavia, Italy. Here we report experimental demonstration of 2D Photonic Crystal waveguide (PhC) and cavity in suspended silicon rich nitride platform. We demonstrate W0.7 PhC waveguide with 70 nm transmission bandwidth and PhC cavity ultra-high Q-factor of over 100,000.

### STh4N.8 • 18:15
Efficient THz Generation in Long-Wavelength Infrared Quantum Cascade Lasers, Yifan Jiang1, Jae Hyun Kim1, Seungyong Jung1, Frederic Demmerle2, Gerhard Boehm2, M.-C. Amann1, Mikhail A. Belkin1; 1Univ. of Texas at Austin, USA; 2Walter Schottky Institut, Technische Universität München, Germany. We report more than an order of magnitude improvement in the mid-IR-to-THz conversion efficiency in 1-3 THz sources based on intra-cavity difference-frequency generation in quantum cascade lasers designed to provide mid-infrared gain in 14-15mm range.

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**18:30–20:00 Dinner Break (on your own)**

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**20:00–22:00 Postdeadline Paper Sessions**
Executive Ballroom 210A

CLEO: Applications & Technology

08:00–10:00

AF1A • A&T Topical Review on Supercontinuum and Applications

President: Robert Alfano; CUNY City College, USA

AF1A.1 • 08:00

Invited

Structured Light using OAM and Wavelength Domains for Terabit/sec Communications, Alan E. Willner 1,2; 1Dept. of Electrical Engineering, Univ. of Southern California, USA. Light can be tailored in different domains, including space (e.g., orbital angular momentum) and wavelength. Each domain can also be encoded with information, and multiplexing of multiple beams can increase system capacity. This presentation will discuss recent advances and technical challenges in applying the tailoring of light to communication systems.

AF1B • Application & Advances of Frequency Combs

President: Dirk Mueller; Coherent Inc., USA

AF1B.1 • 08:00

Invited

Mid-Infrared Spectrometer Featuring µ-second Time Resolution Based on Dual-comb Quantum Cascade Laser Frequency Combs, Andreas Hugi 1, Anne-Mazarine Lyon 1, Markus Mangold 2, Markus Gessner 3, Wolf Wüster 2, Filippos Kapsalis 2, Jossy Pierre 1, Jérôme Faist 1, I. Rooswe AG, Switzerland; 2ETH Zurich, Switzerland. We present a dual-comb spectrometer based on QCL frequency combs. It features a large optical bandwidth and high-resolution. One key benefit of this instrument is the ability to measure broadband µs time-resolved mid-IR spectra.

AF1B.2 • 08:30

Absorption spectroscopy based on polarization-multiplexed dual-frequency femtosecond fiber laser combs, Rongqiang Hui 1,2; 1Univ. of Kansas, USA. Coherent dual-frequency optical combs are generated using common-cavity approach based on polarization-multiplexing in an all-PM fiber laser configuration. We demonstrate the application of these optical combs in spectroscopy without the need of active phase synchronization.

Executive Ballroom 210B

CLEO: Science & Innovations

08:00–10:00

SF1C • Frequency Comb Technology

President: Guanhao Wu; Tsinghua Univ., China

SF1C.1 • 08:00

Fully-Stabilized Optical Frequency Comb from a Diode-Pumped Solid-State Laser with GHz Repetition Rate, Sargis Hakobyan 1, Valentin J. Wittwer 2, Pierre Broochard 1, Kutan Guerel 1, Stephanie Schilt 1, Aline Sophie Mayer 1, Ursula Keller 2, Thomas Sudmeyer 2; 1Université de Neuchâtel, Switzerland; 2Inst. of Quantum Electronics, ETH, Switzerland. We show full frequency-stabilization of a GHz diode-pumped solid-state laser frequency comb. The CEO is stabilized via pump-current modulation. We present a thorough characterization of the comb in terms of noise and frequency stability.

SF1C.2 • 08:15

Optimizing the Power Efficiency of a SESAM Fiber Comb Laser, Shaokang Wang 1, Curtis R. Menyuk 2, Laura Sinclair 2, Ian R. Coddington 1, Nate Newbury 2; 1E.L. Ginzton Lab, Stanford Univ., USA; 2Computer Science and Electrical Engineering, Univ. of Maryland, Baltimore County, USA. The power efficiency of femtosecond fiber lasers with semiconductor saturable absorbers is limited by the wake instability. We computationally optimize the output power and efficiency by increasing the output coupling ratio and gain fiber length.

SF1C.3 • 08:30

Coherent Supercontinuum Generation with Picosecond Pulses, Adrea R. Johnson 1,2, Xingshen Ji 3,4, Michael R. Lamont 2, Yoshitomo Wang 1, Curtis R. Menyuk 1, Stefan Droste 2, Ian R. Coddington 2, Nate Newbury 2; 1Univ. of Kansas, USA. Coherent, octave-spanning supercontinuum with >1-ps pulses. Our proof-of-principle experiments demonstrate the feasibility of utilizing long waveguides and multiple cross sections for supercontinuum generation at ultralow pulse energies.

Executive Ballroom 210C

08:00–10:00

JF1D • Symposium on Thermal Noise in Precision Interferometry

President: Gregory Harry; American Univ., USA

JF1D.1 • 08:00

Introduction to the Special Symposium On Thermal Noise: Fostering Collaboration Between the Gravitational Wave and Cavity-Stabilized Laser Communities, Garrett D. Cole 1,2; 1Crystalline Mirror Solutions LLC, USA. Precision optical interferometers have now enabled the direct detection of gravitational waves as well as the construction of lasers with linewidths below 10 mHz. It is becoming increasingly clear that thermal noise now stands as a significant impediment to continued progress in the development of such advanced optical systems. This symposium will serve to educate interested parties on the fundamental scientific aspects as well as implications for advanced applications in precision metrology, bringing together researchers from the fields of gravitational-wave astronomy and laser-based precision metrology. Our aim is to foster collaboration between materials scientists, physicists, and optical engineers interested in developing components and systems with reduced levels of thermal noise.

JF1D.2 • 08:15

Thermal Noise in Mirror Coatings for Gravitational Wave Detection, Martin M. Fejer 1,2; 1E.L. Ginzton Lab, Stanford Univ., USA; 2Georgia Tech, USA. Mid-band sensitivity of gravitational-wave detectors is limited by Brownian noise in interferometer mirrors. We discuss connections between thermal noise and elastic dissipation in mirrors, and between that dissipation and the structure of amorphous films.
**FF1E • Single-Photon Detectors**

Presider: Christine Silberhorn; Universität Paderborn, Germany

**FF1E.1 • 08:00**

Single-photon detection with near unity efficiency, ultra-high detection-rates, and ultra-high time resolution, Val Zwiller1, Iman Esmaeili Zadeh2, Johannes Los1, Ronan Gourgue1, Violette Steinmetz2, Sergiy Dobrovolsky2, Sander N. Dorenbos2; 1Single Quantum B. V., Netherlands; 2KTH Royal Inst. of Technology, Sweden. In this work we demonstrate a broadband single-photon detector with efficiency higher than 92%, over 150 MHz photon detection-rate, dark counts below 130 Hz and a record low jitter of 14.80 ps.

**FF1F • Optical & THZ Spectroscopy of Quantum Matter**

Presider: Robert Kaindl; Lawrence Berkeley National Lab., USA

**FF1F.1 • 08:00**

Photodetected dynamics of terahertz plasmonics response in Bi$_2$Se$_3$, topological insulator, Flavio Giorgianni1, Mostafa Shababy1, C. Vicario1, Christoph P. Haust1, Stefano Lupi1; 1SwissFEL, Paul Scherrer Institut, Switzerland; 2Dept. of Physics, Sapienza Univ. Of Rome, Italy. We present time-resolved photo-induced plasmonic response in Bi$_2$Se$_3$, topological insulator investigated by means of optical-pump/THz-probe spectroscopy. We have found that topological insulators offer a non-trivial relaxation dynamics due to their complex bulk-surface interactions.

**FF1F.2 • 08:15**

Terahertz investigation of Dirac plasmons and phonon interaction in the topological insulator Bi$_2$Se$_3$, metamaterials, Chihun Im1,4, Sangwan Sim1, Sungjoon Park1, Hyemin Bae1, Niekesh Koirala1, Jisoo Moon1, Maryam Salehi1, Seangshik Oh1, Dohyun Kim1, Hyunyoung Choi1, Yongsoo Univ., Korea (the Republic of), 4Rutgers Univ., USA, 1Seoul National Univ., Korea (the Republic of); 2Korea Atomic Energy Research Inst., Korea (the Republic of). We have measured the terahertz responses of plasmon-phonon interaction in the topological insulator Bi$_2$Se$_3$, metamaterials. Upon photoexcitation, we observed transient phonon stiffening of ~0.1 THz when the plasmon frequency is above the phonon energy.

**FF1F.3 • 08:30**

Terahertz Pump-Probe Study of the Weyl Semimetal TaAs, Mohammad Mehdiljadidi1, Martin Mitterndorfer1, Stephan Winnerl2, Jing Chen1, Andrei B. Sushkov2, Greg S. Jenkins2, H. Dennis Drew2, Thomas E. Murphy1; 1Inst. for Research in Electronics and Applied Physics, Univ. of Maryland, College Park, MD 20742, USA, 2Dept. of Physics and Astronomy, Univ. of California at Los Angeles, Los Angeles, CA 90095, USA. We use terahertz reflection pump-probe measurements to study carrier dynamics in the newly discovered Weyl semimetal tantalum arsenide (TaAs). Our measurements reveal the relaxation dynamics of intra- and inter-band excited carriers near the Weyl points.

**FF1G • Nanoparticle Enhanced Emission and Field Enhancement**

Presider: Berardi Sensale-Rodriguez; Univ. of Utah, USA

**FF1G.1 • 08:00**

Magnetic vs Electric Second-Harmonic Generation from AlGaAs Nanowannas, Sergey S. Knut1, Lei Xu1, Rocio Camacho-Morales1, Moshehn Rahman1, Lei Wang1, Daria Smirnova1, Guoquan Zhang1, Hoe Tan1, Chennupati Jagadish1, Yuri Kivshar1, Dragomir Neshev1; 1Australian National Univ., Australia; 2Nankai Univ., China; 3Electronic Materials Engineering, Australian National Univ., Australia. We suggest and demonstrate experimentally AlGaAs nanoantennas for efficient second-harmonic generation (SHG). We show that the SHG directionality and efficiency are defined by either electric or magnetic multipoles and controlled by incident polarization and design.

**FF1G.2 • 08:15**

Mid-Infrared Third-Harmonic Emission from Heavily-Doped Germanium Plasmonic Nanowannas, Marco Patrick Fischer1, Aaron Rieder1, Alexander Grupp2, Kevin Gallacher2, Jacopo Frigerio2, Giovanni Pellegrini3, Michele Vitiello1, Alfred Leitenstorfer1, Paolo Brigioni1, Daniele Brida1, Dept. of Physics and Center for Applied Photonics, Univ. of Konstanz, Germany; 2School of Engineering, Univ. of Glasgow, UK; 3-NESS, Dipartimento di Fisica, Politecnico di Milano, Italy; 4Dipartimento di Fisica, Politecnico di Milano, Italy. We investigate the nonlinear optical properties of single resonant plasmonic antennas fabricated from heavily-doped Germanium films. Excitation with intense and ultrashort mid-infrared pulses at 10.8 µm wavelength produces emission at 3.7 µm via third-harmonic generation.

**FF1G.3 • 08:30**

Do Low-Loss Doped Semiconductor Nanoparticles Yield Stronger Field Enhancement?, Jacob Khurgin1, Pin C. Wu1, Din P. Tsai2, Ning Liu4, Wen T. Hsieh1, Gregory Sun1; 1Univ. of Massachusetts Boston, USA; 2Physics, National Taiwan Univ., Taiwan; 3ECE, Johns Hopkins Univ., USA; 4Physics and Energy, Univ. of Limerick, Ireland. We show that using nanoparticles made of low-loss doped semiconductor in place of noble metals with higher losses does not lead to the anticipated superior enhancement of the electric field.
Executive Ballroom 210H

Meeting Room 211 B/D

Meeting Room 212 A/C

**CLEO: Science & Innovations**

**Friday, 08:00–10:00**

**SF1H • Waveguides and Ring Resonators**

*President: Jian Wang; Huazhong Univ of Science and Tech, China*

- **Coherent Beam Combining On Silicon Chip Through Hybrid Integration**, Yeyu Zhu, Yunsong Zhao, Lin Zhu; *Clemson Univ., USA.* We demonstrate hybrid integration of passive coherent beam combining cavity integrated with a diode laser array on silicon photonics platform. Silicon nitride adiabatic coupler is used to obtain a broadband power splitting ratio of 50:50.

**SF1J • Micro- and Nanophotonic Devices**

*President: Kenneth Crozier; Univ. of Melbourne, Australia*

- **A Black Phosphorus Optoelectronic Mixer**, Ryan J. Suess, Lei Chen, Joseph D. Hart, Edward Leong, Thomas E. Murphy, Martin Mittleman; *Inst. for Research in Electronics and Applied Physics, Univ. of Maryland, USA.* An optoelectronic mixer based on the non-linear photoconductivity of black phosphorus is presented. We demonstrate mixing with a maximum conversion loss of 31 dB at local oscillator frequencies up to 640 MHz.

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**SF1H.1 • 08:00**

Coherent Beam Combining On Silicon Chip Through Hybrid Integration, Yeyu Zhu, Yunsong Zhao, Lin Zhu; *Clemson Univ., USA.* We demonstrate hybrid integration of passive coherent beam combining cavity integrated with a diode laser array on silicon photonics platform. Silicon nitride adiabatic coupler is used to obtain a broadband power splitting ratio of 50:50.

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**SF1I • Integrated Photonic Devices**

*President: Jian Wang; Huazhong Univ of Science and Tech., China*

- **Tutorial** From Concept to a Working Silicon Photonic Chip, Lukas Chrostowski; *Univ. of British Columbia, Canada.* This presentation describes approaches to designing silicon photonic circuits while taking manufacturing variability into account to ensure a functioning chip. Our method is an enhanced Monte Carlo technique that includes layout-specific correlated manufacturing variations.

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**SF1J.1 • 08:00**

A Black Phosphorus Optoelectronic Mixer, Ryan J. Suess, Lei Chen, Joseph D. Hart, Edward Leong, Thomas E. Murphy, Martin Mittleman; *Inst. for Research in Electronics and Applied Physics, Univ. of Maryland, USA.* An optoelectronic mixer based on the non-linear photoconductivity of black phosphorus is presented. We demonstrate mixing with a maximum conversion loss of 31 dB at local oscillator frequencies up to 640 MHz.

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**SF1J.2 • 08:15**

Passive and Active Light Control using Computational Metamaterials, Apratim Majumder, Bing Shen, Randy Polson, Rajesh Menon; *Univ. of Utah, USA.* We report on our latest developments in computational metamaterials based nanophotonics devices to design and implement ultra-compact on-chip polarization rotator, waveguide cloaks and all-optical modulators.

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**SF1H.2 • 08:15**

A Compact Silicon Photonic Add-Drop Multiplexer with Misaligned Sidewall Bragg Gratings in a MZI, Md. Ghulam Saber, Zhenping Xing, David Patel, Eslam El-Fiky, Nicolas Abadía, Yun Wang, David V. Plant; *Dept. of Electrical and Computer Engineering, McGill Univ., Canada.* We experimentally demonstrate a compact optical add-drop multiplexer based on misaligned sidewall Bragg gratings in a MZI. We achieved 51dB transmission isolation and 5nm 3-dB bandwidth with a footprint of 400 µm x 125 µm.

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**SF1H.3 • 08:30**

Automatic Monitor-Based Tuning of Reconfigurable Silicon Photonic 2nd-Order APF-Based Pole/Zero Filters, Gilhoon Choo, Shengchang Cai, Bin Hao Wang; *Inst. for Research in Electronics and Applied Physics, Univ. of California, Berkeley.* We report on our latest developments in computational metamaterials based nanophotonics devices to design and implement ultra-compact on-chip polarization rotator, waveguide cloaks and all-optical modulators.

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**SF1J.3 • 08:30**

Optical trapping using all-dielectric silicon nanoantennas with ultra-low heat generation, Zhe Xu, Wuzhou Song, Kenneth B. Crozier; *School of Physics, Univ. of Melbourne, Australia.* Silicon nanoantennas are used to trap polystyrene nanospheres (20 nm diameter). Fluorescence microscopy is used to monitor trapped particle position as a function of time. The nanoantennas produce subwavelength field enhancement with negligible heat generation.
SF1K.1 • 08:00
Overview of the 1.15 PW PETAL Laser in the LMJ Facility, Nathalie Blanchot1, Christelle Damiens-Dupont1, Herve Coic1, Claude Rouyer1, Fabrice Laniesse1, Jerome Neauport1, Gilles Behar1, Laurent Hila1, Eric Lavastre1, Didier Raffestin1, Martin Sozeti1, Laurent Lamaignere1, Steve Chardavoine1, Jean-Paul Goossens1, Melanie Mangeant1, Laurent Lamaignere1, Steeve Chardavoine1, Christelle Damiens-Dupont1, Herve Coic1, W/cm2 by focusing a 0.3 PW laser beam with a 0.1 Hz KAREN-P laser facility. PETAL is an additional PW beamline to the LMJ. The KJ shots in the amplifier section, the compressor alignment and the 1.15 PW @ 850 J operations are detailed. Damage issues encountered are also addressed.

SF1K.2 • 08:30
10^{19}W/cm^2, 0.1 Hz J-KAREN-P laser facility at QST, Hironao Hayashi1, Nicholas Dover1, Akito Saga1, Kenta Nishihara1, Yuji Fukuda1, Koichi Oghara1, Michiaki Mor1, James Koga1, Keita Nishitani1, Yuji Fukuda1, Jean-Paul Goossens1, Melanie Mangeant1, Laurent Lamaignere1, Steeve Chardavoine1, Christelle Damiens-Dupont1, Herve Coic1, W/cm2 by focusing a 0.3 PW laser beam with an f/1.4 off-axis parabolic mirror is achievable on target.

SF1L.1 • 08:00
An Efficient Hybrid Equalizer for 50 Gb/s PAM-4 Signal Transmission Over 50 km SSMF in a 10-GHz DML-Based IM/DD system, Jing Zhang1, Taejong Ye1, Xingwen Yi1, Changyuan Yu1, Kun Qiu1, Uestc, China; The Hong Kong Polytechnic Univ., China. We experimentally demonstrate an effective hybrid equalizer with FFE and truncated Volterra filter for a 50-Gb/s PAM-4 over 50-km SSMF in a DML-based IM/DD system. The results show significant computational complexity savings without performance degradation.

SF1L.2 • 08:15
Simplified Demultiplexing Scheme for Two PDM-IM/DD Links Utilizing a Single Stokes Analyzer, Yan Pan1, Lianshan Yan1, Anlin Yi1, Lin Jiang1, Wei Pan1, Bin Luo1, Xihua Zou1, Southwest Jiaotong Univ., China. A simplified demultiplexing scheme for two PDM-IM/DD links utilizing a single Stokes analyzer is experimentally demonstrated. Results of 4×10-Gbit/s transmission over 2-km SSMF show <2-dB power penalty compared to the single PDM-IM/DD system.

SF1L.3 • 08:30
Chip Control in Directly Modulated 25G PAM4 Transmitters for Optical Access Networks, Marco Dalla Santa1, Cleitus Antony1, Giuseppe Talli1, Paul Townsend1, 1Tyndall National Inst., Ireland. Narrowband filtering chip control is demonstrated for a 25Gb/s PAM4 signal in directly modulated transmitters for next generation optical access systems, allowing 50km transmission without chromatic dispersion compensation with blue-shift filtering offering the best performance.

SF1M.1 • 08:00
Rapid switching between spectral windows for NO isotope sensing using an external cavity quantum cascade laser, Brian Brumfield1, Mark C. Phillips1, Pacific Northwest National Lab, USA. We present high-resolution spectroscopy and sensing of NO isotopes using a new external cavity quantum cascade laser rapidly switched between two spectral windows separated by 13 cm-1.

SF1M.2 • 08:15
Towards the Robust Trace Detection of Radiocarbon via Linear Absorption Spectroscopy, Adam J. Flesher1, David A. Long1, Qingnan Lu1, Joseph T. Hodges1, 1NIST, USA. Reported here is the optical detection of radiocarbon below contemporary levels using cavity ring-down spectroscopy in the linear absorption regime. Petrogenic and biogenic samples of CO2 are readily distinguished by repeated optical measurements.
The Early Days of Self-Phase Modulation and Supercontinuum Generation

Robert W. Boyd

Robert W. Boyd, UC Santa Barbara, USA

The 1980s witnessed the early days of the physics of self-phase modulation (SPM) and supercontinuum generation (SCG) in optical fibers, and their applications in nonlinear optical effects and devices. The slow progress of these early days is told, with special attention to the physical principles involved. Here we will find that the human participants tended to work on different aspects of SPM and SCG. The Kerr effect in a nonlinear medium was identified, and the fact that a single light pulse would start propagating at a higher and higher frequency (nearly) independent of the fiber material, but the pulse would also broaden greatly in time. Experiments were performed in Yb:glass fibers and glass waveguides.

John D. Harvey

John D. Harvey, University of California, USA

The interference of SPM-generated spectral components leading to a bright optical source, which is a key point of self-compression via soliton self-frequency shift, was observed in a fiber. The properties of the self-compressed pulse were studied in detail, and it was found that the pulse would acquire a large frequency chirp. This led to the realization that the pulse could be compressed and used as a coherent light source in a range of new applications.

Michael W. Mahoney

Michael W. Mahoney, University of California, USA

The role of the Kerr effect in the generation of solitons and supercontinua was discussed, and the importance of SPM in the generation of solitons was highlighted. The Kerr effect is a nonlinear optical effect that results in a change in the refractive index of a material, which can lead to the formation of solitons and supercontinua. Solitons are light pulses that maintain their shape during propagation in a nonlinear medium, while supercontinua are broadband light sources with a bandwidth that can be several octave spans.

Hans-Peter Stoll

Hans-Peter Stoll, Technical University of Munich, Germany

The importance of SPM and SCG in the development of ultrashort optical pulses and high-power laser systems was discussed, and the potential applications of these phenomena were highlighted. The Kerr effect is a key factor in the generation of ultrashort optical pulses, and it also plays a crucial role in the generation of high-power laser systems. The Kerr effect has been successfully exploited in a range of applications, including the generation of ultrashort pulses for optical communications, optical metrology, and optical metrology.
FF1E • Single-Photon Detectors—Continued

Reduced Effect of Single-Photon-Detector Deadtime Using a Switchable Detector Array in an Orbital-Angular-Momentum (OAM) Encoded Quantum System, Cong Liu, Yongxiong Ren, Jiapeng Zhao, Seyed M. Rafaanjani, Guodong Xie, Kai Pang, Haoqian Song, Zhe Zhao, Zhe Wang, Long Li, Joshua Bienfang, Alain Migdall, Moshe Tur, Robert Boyd, Alan E. Willner.

FF1E.6 • 09:30

We have demonstrated ~80% detection efficiency of 370 nm photons using superconducting nanowire single-photon detectors (SNPDs) operating at 4.2 K, with system dark count rates below 1 count/s. Prospects for detecting shorter wavelengths are discussed.

FF1E.6 • 09:45
Few-Cycle, Few-Femtosecond Pulses, Mina Bionta, 1 Vincent Wanle, 1 Philippe Lasonne, 1 Vincent Gruson, 2 Jerome Chaillou, 1 Mohamed Chaker, 2 Francois Leclerc, 2 INRS-Energie Materiaux et Telecom, Canada; 1 Dept. of Physics, The Ohio State Univ., USA.

We demonstrate in VO2, a nearly instantaneous band gap collapse which initiates a phase transition using few-cycle, femtosecond laser pulses to measure the change in the optical transmission of the sample in a pump-probe configuration.

FF1F • Optical & THZ Spectroscopy of Quantum Matter—Continued

Polarization-dependent surface-bulk scattering in the Weyl semimetal NbAs, Voosmin Dai, Bing Shen, Lingxiao Zhao, Bing Xu, Yongkang Luo, Aiping Chen, Run Yang, Xianggang Qiu, Gentu Chen, Ni Ni, Stuart Trugman, Jian-xin Zhu, Antinteret Taylor, Dmitry Yarotski, Rohit P. Prasankumar, Los Alamos National Lab, USA; 2Univ. of California, Los Angeles, USA Minor Outlying Islands, 1OP CAS, China.

Ultrafast optical spectroscopy reveals surface-bulk scattering in the Weyl semimetal NbAs within 50 femtoseconds. The direction of this scattering can be controlled by the pump and probe polarizations, suggesting potential ultrafast device applications.

FF1F.4 • 08:45
Correlation of Optic Effects in Hybrid Ni/Si Metasurfaces, Janine National Univ., Australia.

We study optic effects in hybrid Ni/Si metasurfaces and demonstrate a multifold enhancement of optoelectronic effects in hybrid Ni/Si metasurfaces, the total number of resonances and their spectral peaks can be tuned continuously.

FF1F.5 • 09:00
Pressure-Induced Metalization in VO2 Studied by Optical Pump – THz Probe Spectroscopy, Johannes M. Braun, Harald Schneider, Manfred Helm, Rafal Mirek, Lynn A. Boastner, Robert E. Manvel, Richard F. Haglund, Alexey Pushkin, Inst. of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany; 2Technische Universität Dresden, Germany; 3Univ. of Warsaw, Poland; 4Materi- als Science and Technology Division, Oak Ridge National Lab, USA; 5Dept. of Physics and Astronomy, Vanderbilt Univ., USA.

We have investigated pressurized VO2 using optical pump – THz probe spectroscopy. Distinct pump-probe signals and an excitation threshold are observed even in the metallic state. Our results are consistent with a pressure-driven Mott-Hubbard transition.

FF1G • Nanoparticle Mediated Emission and Field Enhancement—Continued

Invited Strangely Shaped Plasmonic Nanoparticles and Luminescence, Thomas A. Klar, Johannes Kepler Univ. Linz, Austria.

The fundamentals how pyramidal-, star- and sponge-shaped gold nanoparticles influence extrinsic and intrinsic luminescence, are discussed. Applications comprise random lasers and organic light emitting diodes.
Integrated polarization beam-splitter with 116 THz bandwidth via topographically anisotropic photonics, Jeff Chiles, Tracy Spajerma, Ashutosho Rao, Sasau Fathpour, Univ. of Central Florida, USA. Topographically anisotropic integrated photonics is proposed for extremely broadband polarization-selective devices. Polarization beam-splitting with an unprecedented 116 THz of bandwidth (0.52 octaves), insertion losses <1.2 dB and extinction ratio >16 dB is experimentally demonstrated.

An integrated high-extinction-ratio low-loss polarization rotator for silicon photonics across C+L bands, Andrew P. U., Xuan Cui, Yongnan Li, Mingbin Yu, Dim-Lea Kwong, Cheewei Wong, Mesoscopic Optics and Quantum Electronics Lab, Univ. of California, Los Angeles, USA; Inst. of Microelectronics, Singapore. We report a integrated silicon polarization rotator, with dual-level aligned fabrication. The rotator has record high 25-dB extinction, low 2-dB coupling loss with a single-mode fiber is -2.62 dB at the peak wavelength.

Observation of Synchronization in Air-slot Photonic Crystal Optomechanical Oscillator, Yongjun Huang, Jiagui Wu, Jaime G. Flores, Mingbin Yu, Dim-Lea Kwong, Guanggun Wen, Chee Wei Wong; School of Communication and Information Engineering, Univ. of Electronic Science and Technology of China, China; Univ. of California, Los Angeles, USA; College of Electronic and Information Engineering, Southwest Univ., China; Inst. of Microelectronics, Singapore. Synchronization between two very close mechanical modes in air-slot PhC optomechanical oscillators is observed with drive powers above threshold. Improvement in phase noise (70 dBc/Hz at 10 kHz offset) for the synchronized OMO is reported.

A 2/3-Octave-Spanning Three Spectral Band Splitter on a Si3N4 Photonic Integrated Circuit Platform, Tiehui Su, Siwei Li, Shaoq Feng, WeiCheng Lei, Guangyao Liu, S. J. Ben Yoo; Univ. of California Davis, USA. We show a three spectral band splitter that separates the wavelength bands of 1292nm, 1550nm and 1937nm. The device is fabricated using silicon nitride photonics integrated circuit platform. Optical characterization shows <3 dB loss for the three channels, and 11 ~ 30 dB inter-channel crosstalk.

Silicon Photonic Polarization Insensitive Filter with Low Polarization Dependent Extinction Radio, Tingge Dai, Gencheng Wang, Yuchao Wang, You Li, Hui Yu, Xiaoping Jiang, Jianyi Yang, Zhejiang Univ., China. We proposed and experimentally demonstrated a novel polarization-insensitive bandstop filter with a low polarization dependent extinction ratio (<1.6 dB) and low polarization dependent loss (<1.5 dB) on a SOI chip. The insertion loss is about 2.6 dB.

Silicon Nitride Spot-Size Converter for Efficient Supercontinuum Coupling to Chalcogenide Waveguide, Jean-Etienne Tremblay, Yung-Hsiang Lin, Po-Kai Hsu, You-Chia Chang, You-Chia Chang, Samantha P. Roberts, Brian Sterni, Iphatha Datta, Michal Lipson; Columbia Univ., USA. We demonstrate an approach based on mode conversion to recycle light within a waveguide without relying on resonance. The broadband approach enables a seven fold increase in the optical path of compact integrated interferometers.
SF1K • Laser Facilities and Applications—Continued

SF1K.4 • 09:00
Development of High Power Glass Laser systems in NLHPLP, Jianqiang Zhu1, Jian Zhu2, Kuechun Li3, Baoshan Chai1, Weixin Ma1, Dean Liu4, Chen Gou5, Guowen Zhang1, Zunqi Lin1; 1Shanghai Inst of Optics and Fine Mech, China. A new laser facility with 30kJ/ ms/3µm beams) output energy has begun operation with good performance. Another single laser prototype pushes 1µj output energy to 17.5kJ/21ns in 350mm×350mm aperture with four-pass main amplifier architecture.

SF1K.5 • 09:15
The CERN/ISOLDE Laser Ion Source, Bruce Marshall1, Valentin Fedoseev1, Katerina Chrysalidou2, Thomas Day Goodacre1, Pierre B. Larmonier1, Ralf E. Rossel1, Sebastian Rothe1, Christoph Seiffert1, Klaus Wendt2; 1CERN, Switzerland; 2Institut für Physik, Johannes Gutenberg-Universität, Germany. Laser resonance photo-ionization is an essential aspect of radioactive ion beam production and fundamental and applied physics research. The CERN/ISOLDE laser ion source, described here, is the most versatile of its type worldwide.

SF1K.6 • 09:30
Scaling of X-ray Flux from High-Intensity Laser-Solid Interactions as a Function of Energy, Dean R. Rusby1, Ceri Brenner2, Chris Armstrong1, Lucy Wilson2, Rob Clarke1, Aaron Alejo3, Robert Deas4, Paul McKenna1, Satya Kar5, David Neely2; 1Strathclyde Univ., UK; 2Central Laser Facility, UK; 3Queens Univ. Belfast, UK; 4Security Sciences Dept., DSTL, UK. The bremsstrahlung x-rays from a laser-solid interaction have been investigated for the use of radiography. The scaling of the x-rays as a function of energy has been characterized and modelled and agrees with previous measurements.

SF1L • Data Center Communications—Continued

SF1L.4 • 08:45
DSP Equalization-free Data Center Communication with High Dispersion Tolerant Optical Dual-binary PAM4 Signal, Jih-Heng Yen1, Tzu-Yu Yeh1, Yen-Hsiang Chang2, Yi-Chen Wu3, Kai-Ming Feng4; 1National Tsing Hua Univ., Taiwan. We propose and experimentally evaluate the dispersion tolerance of a data center communication system with DSP equalization free optical dual-binary-PAM4. Without dispersion compensation, its dispersion tolerance is three times higher than DFE equalized PAM4.

SF1L.5 • 09:00
Interplay of Bit Rate, Linewidth, and Reach on DMT vs. PAM Performance, Amrneza Yekani Khoei1, Leslie A. Rusch1,2; 1Université Laval, Canada. We theoretically study the effect of system bandwidth, bit rate, laser linewidth and fiber length on DMT and PAM. DMT is optimized in terms of signal-to-carrier-power ratio and the performance of the optimal DMT configuration is compared to that of PAM.

SF1L.6 • 09:15
Multiheterodyne Spectroscopy with In terband Cascade Lasers, Jonas Westberg1, Lukasz A. Sterczewski1,4, Link Patrick1, Chul Soo Kim3, Mijin Kim3, Chadwick L. Cady2, William W. Bewley2, Charles Merritt1, Igor Vurgaftman1, Jerry R. Meyer2, Gerard Wysocki1; 1Princeton Univ., USA; 2U.S. Naval Research Lab, USA; 3Sotera Defense Solutions, Inc., USA; 4Faculty of Electronics, Wroclaw Univ. of Science and Technology, Poland. A multiheterodyne spectroscopy system based on Fabry-Perot interband cascade lasers is demonstrated for broadband spectroscopic assessments of gaseous methane. The spectrometer is capable of ~240 GHz of spectral coverage around 3.21 µm.

SF1M • Aerosol and Gas Sensing—Continued

SF1M.4 • 09:00
Quartz Enhanced Photoacoustic Spectroscopy for Human Breath Analysis, Mikael Lassen1, Laureat Lamer1, Poul Feng2, Andre Peremans1, Jan C. Petersen2; 1Danish Fundamental Metrology, Denmark; 2Laserspec BVBA, Belgium. A combined quartz-enhanced photoacoustic sensor is demonstrated. The sensor targets exhaled human breath analysis.

SF1M.5 • 09:15
Online Gas Monitoring with Mid-Infrared Optical Parametric Oscillator Based Dual-Comb Spectrometer, Julien Mandon1, Simona M. Cristescu1, Frans J. Harren1, Daniel H. Le Blanc1, Ji-Ping Zou1, Antoine Freneaux1, Yekani Khoei1, Leslie A. Rusch1; 1Université Laval, Canada. A dual-comb spectrometer in the 3-5 µm spectral region is used for online gas monitoring. The spectrometer is combined with a 37-m absorption cell to reach a minimal absorption coefficient of 1.1x10⁻⁴ cm⁻¹.
AF1A • A&T Topical Review on Supercontinuum and Applications I—Continued
AF1B • Application & Advances of Frequency Combs—Continued
AF1B.7 • 09:45
Comparative study of the reflectometry and cut-back techniques for the distributed measurement of supercontinuum generation along optical fibers, Régis D. Hontin-finde1, Saliya Coulibaly2, Patrice Megret1, Majid Taki1, Marc Wuilpart1; 1Univ. of Mons, Belgium; 2PhLAM, Université de Lille, France. We propose a non-destructive measurement technique for the distributed measurement of supercontinuum generation in fibers. For validation purposes, we compare our results with those obtained thanks to the cut-back technique. A good agreement was observed.

SF1C • Frequency Comb Technology—Continued
SF1C.8 • 09:45
Modal Approach Towards Complete Characterization of Frequency Comb Noise, Syamsundar De1, Valérian Thiel1,2, Jonathan Roslund1, Nicolas Treps1; 1Laboratoire Kastler Brossel, UPMC-Sorbonne Université, France; 2Clarendon Lab, Dept. of Physics, Univ. of Oxford, UK. The fluctuations of the global parameters of an ultrafast frequency comb are analyzed using a novel measurement scheme and a modal representation. The propagation of excess noise added to the pump is also investigated.

10:00–10:30 Coffee Break, Concourse Level
FF1E • Single-Photon Detectors—Continued

FF1E.7 • 09:45
High-Operating-Temperature Superconducting Nanowire Single Photon Detectors Based on Magnesium Diboride, Angel Velasco1, Daniel P. Cunnane1, Simone Frasca2, Thomas Melbourne1, Narendra Acharya1, Ryan Briggs1, Andrew Bayer1, Matthew Shaw1, Boris Karasik1, Matthias Wolak1, Varun Verma1, Adriana Lita1, Hiroyuki Shibata1,2, Masataka Ohkubo1,2, Masahiro Ukube1,2, Xiaoqing Xi1, Francesco Marsili1; 1Jet Propulsion Lab, USA; 2Univ. of Pisa, Italy; 3Temple Univ., USA; 4National Inst. of Standards and Technology, USA; 5Kitami Inst. of Technology, Japan; 6National Inst. of Advanced Industrial Science and Technology, Japan. We report on optically sensitive 15 nm thick, 100 nm wide MgB2 nanowires in the operating-temperature range 4 - 11 K.

FF1F • Optical & THZ Spectroscopy of Quantum Matter—Continued

FF1F.8 • 09:45
Nonlinear polaron dynamics in colossal magnetoresistance manganites driven by intense THz pulses, Pamela R. Bowlan1, Mostafa Shalaby2, Stuart Trugman2, Aiping Chen1, Q.X. Jia1, C. Vicario2, Antionette Taylor2, Dmitry Yarotski1, Christoph P. Haurs5, Rohit P. Prasankumar1; 1Los Alamos National Lab, USA; 2Univ. of Pisa, Italy; 3Paul Scherrer Inst., Switzerland; 4Ecole Polytechnique Federale de Lausanne, Switzerland. Using intense, few-cycle THz pulses we investigate the strong-field interaction with polarons in La0.7Ca0.3MnO3. By probing the optical reflectivity, we observe a THz-induced detrapping of electrons from polarons, followed by thermalization of phonons with spins.

FF1G • Nanoparticle Mediated Emission and Field Enhancement—Continued

FF1G.7 • 09:45
Low-loss plasmonics via dielectric nanoparticles on metallic films, Yi Yang1, Owen Miller2, Thomas Christensen1, John Joan-nopoulos1, Marin Soljacic2,1, MIT, USA; 2Yale Univ., USA. We theoretically propose a pathway to low-loss plasmonics. We show that dielectric-on-metal nanoresonators scatter more strongly than is possible in all-metal or all-dielectric approaches, offer near-unity-efficiency spontaneous-emission enhancements, and are robust to quantum corrections.

10:00–10:30 Coffee Break, Concourse Level
SF1H • Waveguides and Ring Resonators—Continued

SF1H.8 • 09:45
Monolithic integration of vertical SiN, microrings on a ridge waveguide to achieve multi-channel photonic coupling, Xin Yu1, Lynford Goddard1, Xiuling Li1, Xiaogang Chen1; Univ of Illinois at Urbana-Champaign, USA. Multi-channel vertical photonic coupling was observed, by integrating two different SiN, vertical microring couplers (VμRC) monolithically on a single ridge waveguide. This work represents a critical step to 3D photonic integration using VμRCs.

SF1I • Integrated Photonic Devices—Continued

SF1I.5 • 09:45
Polarization Independent Adiabatic 3-dB Coupler for Silicon-on-Insulator, Luhua Xu1, Yun Wang1, David Patel1, Eslam El-Fiky1, Zhenping Xing1, Rui Li1; McGill Univ., Canada. We demonstrate a polarization independent adiabatic 3-dB coupler for the silicon-on-insulator platform, with a measured bandwidth of 100nm and power splitting ratios of 3±0.7dB for both the transverse electric and transverse magnetic modes.

SF1J • Micro- and Nanophotonic Devices—Continued

SF1J.8 • 09:45
Inverse Design of an Ultra-Compact Mode (De)multiplexer Based on Subwavelength Structure, Weijie Chang1, Minming Zhang1, Luluzi Lu1, Feiya Zhou1, Dongyu Li1, Zepeng Pan1, Deming Liu1; School of Optical and Electrical Information, Huazhong Univ. of Science and Technology, China. A novel ultra-compact mode (de)multiplexer using inverse design method is proposed and experimentally demonstrated with low crosstalk < 25 dB and a footprint of only 2.4 × 2.4 µm², fabricated by only one-step etching.

10:00–10:30 Coffee Break, Concourse Level
Velocity Map Imaging for Photocathode Characterization, Hong Ye1,2, Sebastian H. Trippel3, Michele Di Fraia1, Arya Fallahi1, Oliver D. Mücke1,2, Jochen Küpper1, Franz X. Kärtner1,2; 1Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron, Germany; 2Dept. of Physics, Univ. of Hamburg, Germany; 3The Hamburg Center for Ultrafast Imaging, Univ. of Hamburg, Germany. A velocity map imaging spectrometer (VMI) to characterize the transverse phase space of electron emission from solid surfaces is described. A first instrument test is presented using multi-photon emission from a planar Au surface.

Evanescent-Wave Gas Sensing with Dual-Comb Spectroscopy, Zaijun Chen1,2, Ming Yan1,2, Theodor W. Hänsch1,2, Nathalie Picqué1; 1Max-Planck Inst. of quantum optics, Germany; 2Physics Dept., Ludwig Maximilian Univ. of Munich, Germany. Attenuated total reflection spectroscopy with tapered fibers is combined to coherent multi-heterodyne spectroscopy in the near-infrared region. Evanescent sensing is extended to broadband high-resolution spectroscopy in the gas phase at high signal-to-noise ratio.

10:00-10:30 Coffee Break, Concourse Level
**AF2A.1 • 10:30 • Invited**
Supercontinuum Sources – Past, Present – Any Future?, J R Taylor1,2; Physics, Imperial College London, UK. For nearly fifty years the supercontinuum source, a result of the understanding and control of the underlying physical processes, has evolved as a scientific and commercial success, providing spectral versatility well beyond the limitations of the transmission window of silica and pumped versatile well beyond the limitations of the transmission window of silica and pumped high-quality, geo-registered imagery of terrestrial scenes for precise localization and quantification of gas plumes.

**AF2B.1 • 10:30 • Invited**
Gas Mapping LiDAR for Large-area Leak Detection and Emissions Monitoring Applications, Michael Thorpe1,2; Bridge Photonics, Inc, USA. We present gas mapping LiDAR that combines coherent ranging and path-integrated gas concentration measurements. Spatial scanning of the LiDAR beam produces high-quality, geo-registered imagery of terrestrial scenes for precise localization and quantification of gas plumes.

**AF2B.2 • 11:00 • Invited**
Ultrahigh Resolution Optical Coherence Tomography Using Supercontinuum and Their Wavelength Dependence, Norihiko Nishizawa1, Hiroyuki Kawagoe1, Masahito Yamanaka1; 1Nagoya Univ., Japan. Supercontinuum is useful light source for ultrahigh resolution optical coherence tomography (OCT) imaging. In this talk, the recent investigations about ultrahigh resolution OCT imaging using supercontinuum and their wavelength dependence are reviewed.

**AF2B.3 • 11:15**
Using a Sagnac Fourier Spectrometer for Laser-Induced Breakdown Spectroscopy, Matthias Leinzen1, Ali Rastegar2, Jean-Claude Diels1; 1Lenzen Research LLC, USA; 2CHTM, Univ. of New Mexico, USA. A new type of interferometric spectograph is realized by placing a transmission grating into a Sagnac interferometer. Two diffracted orders propagate in opposite directions; the Fizeau interferogram at the output yields a heterodyned spectrum.

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**SF2C.1 • 10:30 • Tutorial**
Optical Frequency Comb Applications Beyond Frequency Metrology, Kaoru Minoshima1,2; 1Univ. of Electro-Communications, Japan; 2JST, ERATO MINOSHIMA Intelligent Optical Synthesizer, Japan. Optical frequency comb provides powerful tools in broad area not only in frequency metrology as “ultrace -
cise frequency ruler”. In this tutorial, various new metrology applications by full use of the properties of combs are presented.

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**AF2D.1 • 10:30 • Invited**
Laser Frequency Stabilization for Ion Optical Clocks at NIST, David B. Hume1, David R. Leibrandt1,2; NIST, USA. The Ion Storage Laser Group at NIST develops stable optical cavities, which enable our trapped-ion optical clocks. I will give an overview of these efforts and describe a new cryogenic cavity with significantly reduced thermal noise.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

Executive Ballroom 210E
10:30–12:30
**FF2E • Quantum Technologies**

**Presider: Todd Pittman; Univ. of Maryland Baltimore County, USA**

**FF2E.1 • 10:30**
Directionally Unbiased Linear-Optical Multiports for Quantum Information Processing, Alexander V. Sergienko1, David Simon1, Casey Fitzgerald1, Boston Univ., USA; 2Stonehill College, USA. The concept of directionally unbiased optical multipor is introduced, in which photons may reflect back out the input direction. It acts as universal qubit and Bell-state processor to implement probabilistic quantum gates.

**FF2E.2 • 10:45**
Single-Photon-Level Spatial-Mode-Selective Frequency Up-Conversion in a Multimode X̂© Waveguide, Young Bong Kwon1, Mohan Giribabu1,3, Carsten Langrock2, Martin M. Fejer1, Michael Vasilev1, Univ. of Texas at Arlington, USA; 2Stanford Univ., USA; 3Corn-ing Inc., USA. We experimentally demonstrate selective up-conversion of either TM00 or TM01 mode of a 1540 nm single-photon signal into TM01 mode, at 775 nm with >70% efficiency, better than -10 dB crosstalk, and >106 signal-to-noise-photon ratio.

**FF2E.3 • 11:00**
Hong-Ou-Mandel Interference in the Frequency Domain, Chaitali Joshi1,2, Alessandra Farsi2, Alexander Gaeta1, Applied and Engineering Physics, Cornell Univ., USA; 2Applied Physics and Applied Mathematics, Columbia Univ., USA. We demonstrate the first observation of Hong-Ou-Mandel interference between two energy correlated single photons of different frequencies with a visibility of 0.68 ± 0.03, using Bragg-scattering four wave mixing as the active frequency-domain beamsplitter.

**FF2E.4 • 11:15**
Quantum Frequency Conversion: Into the Strong Coupling Regime, Zachary Vernon1, Marco Lucchini1,3, John Spee1, Univ. of Toronto, Canada; 3Univ. of Pavia, Italy. We show that Rabi-like coherent oscillations should be observable in integrated microresonators used for quantum frequency conversion, revealing a new regime of strongly coupled photonic modes.

Executive Ballroom 210F
10:30–12:30
**FF2F • Valley Coherence and Polaron Dynamics in 2D Materials**

**Presider: Chih-Wei Lai; US Army Research Lab, USA**

**FF2F.1 • 10:30**
**Invited**
Exciton-Polaritons in Atomically Thin Semiconductors and Their Heterostructures, Alexander Tartakovskii1,1, Physics and Astronomy, Univ. of Sheffield, UK. Exciton-polaritons are observed in monolayer MoSe2 and WSe2 in optical microcavities. Relaxation of the valley pseudospin and valley coherence is inhibited by the exciton-photon coupling, the effect controlled by the exciton-cavity-mode detuning.

**FF2F.2 • 11:00**
Room temperature Tamm-Plasmon Exciton-Polaritons in atomic monolayer, Nils Lundt1, Sebastian Klemm1, Sebastian Stoll1, Evgenia Cherchetkina1, Oliver Il1, Anton V. Nalitov2, Martin Klaas1, Alexey Kavokin1, Sven Höfling1, Christan Schneider1, Univ. of Wuerzburg, Germany; 2Univ. of Southampton, UK; 3Univ. of St. Andrews, UK. We integrated WSe2 and W5 monolayers into photonic Tamm-structures in order to observe Tamm-plasmon exciton-polaritons under ambient conditions. The characteristic dispersion observed by in-plane momentum-resolved micro-photoluminescence spectroscopy confirms their existence at room temperature.

**FF2F.3 • 11:15**
Ultrafast Photo-activation of Surface Polaritons in Black Phosphorus Heterostructures, Markus A. Huber1, Fabian Mooshammer1, Markus Planck1, Leonardo Vitr1, Fabian Sandner1, Lukas Z. Kastner1, Tobias Frank1, Jaroslav Fabian1, Miriam S. Vitello1, Tyler L. Cocker1, Rupert Huber1, Dept. of Physics, Univ. of Regensburg, Germany; 2NEST, CNR - Istituto Nanoscienze and Scuola Normale Superiore, Italy. Photo-activated surface plasmon polaritons in black phosphorus couple with surface phonon polaritons of SiO2, to form switchable hybrid modes. We resolve these modes in time, energy, and space with scattering-type scanning near-field multi-THz microscopy.

Executive Ballroom 210G
10:30–12:30
**FF2G • Nanoscale Control of Quantum Emission**

**Presider: Sergey Kruk; Australian National Univ, Australia**

**FF2G.1 • 10:30**
Shaping UV Emission through Graphene Plasmons, Jamison M. Sloan1, Nicholas Rivera1, Ido Kaminer1, Marin Soljacic1, MIT, USA. We demonstrate that combining Purcell-enhancement engineering, graphene plasmonics, and radiative cascade can result in a new type of UV emitter whose properties can be tuned by electrically doping graphene.

**FF2G.2 • 10:45**
Enhanced light matter interactions in plasmonic-molecular gas hybrid system, Roy T. Zektzer1,1, Leon Stern1, Noa Mazuslo1, Uriel Levy1, The Hebrew Univ. of Jerusalem, Israel. We demonstrate enhanced light matter interactions between surface plasmon and acetylene. Dispersion and absorption are controlled by the interplay between the molecular line and plasmonic resonance. Fano line shapes are observed, and applications are discussed.

**FF2G.3 • 11:00**
**Invited**
Chiral Nanophotonics and Quantum Optics, Arno Rauschenbeutel1,1, Atomistitut, Tu Wien, Austria. Tightly confined light fields exhibit an inherent link between their local polarization and their propagation direction. Their interaction with emitters therefore features chiral, i.e., propagation-direction-dependent, effects which are interesting both conceptually and for quantum-photonic applications.
10:30–12:30
**SF2I • Detectors and Other Novel Devices**
Presider: Jian Wang; Huazhong Univ of Science and Tech, China

**SF2I.1 • 10:30**
10-GHz 32-pixel 2-D photodetector array for advanced optical fiber communications,
Toshimasa Umezawa1, Takahide Sakamoto1, Kouichi Akahane1, Atsushi Matsumoto1, Atsushi Kanno1, Naokatsu Yamamoto1, Tetsuya Kawanishi1,2, 1National Inst of Information & Comm Tech, Japan; 2Waseda Univ., Japan.
We studied a 10-GHz 32-pixel two-dimensional photodetector array for advanced optical fiber communications and LiDAR applications. Electromagnetic field simulation revealed the RF crosstalk problem between pixels. A fabricated high-speed photodetector array will be discussed.

**SF2I.2 • 10:45**
Electrically Tunable Photoresponse in a Graphene Heterostructure Photodetector,
Dehui Zhang1, Gong Cheng1, Zhen Xu2, Che-Hung Liu1, Thomas E. Beechem1, Michael Goldflam1, David Peters1, Minmin Zhou1, Theodore Norris1,2, Zhaohui Zhong1, 1Electrical Engineering and Computer Science, Univ. of Michigan, USA; 2Center for Photonics and Multiscale Nanomaterials, Univ. of Michigan, USA; 3Sandia National Labs, USA; 4School of Electronic Science and Engineering, Nanjing Univ., China.
We report an electrically tunable photodetector design based on photogating effect in graphene heterostructures. We demonstrate electrically tunable photoresponse up to 60 A/W with a sub-millisecond speed. The detector’s spectra tunability will also be investigated.

**SF2I.3 • 11:00**
Invited
Low-voltage three-terminal avalanche photodiodes, Xiaoge Zeng1, Zhihong Huang1, Di Liang1, Marco Fiorentino1, Ray Beausoleil1, 1Hewlett Packard Labs, USA. We demonstrate a novel three-terminal avalanche photodiode detector with a measured breakdown voltage of only -6V, a 3dB bandwidth of 18.6GHz, a DC gain of 15.6 and an open eye diagram at 10Gbps.

**SF2J • Surface Emitting Lasers**
Presider: Hongping Zhao, Case Western Reserve Univ., USA

**SF2J.1 • 10:30**
Invited
Coherent Vertical Cavity Phased Micro lasers Arrays, Kent D. Choquette1, Stewart T. Fryxell1, Zhe Gao1, Bradley J. Thompson1, Harshil Dave1, Katherine Lakomy1, P. S. Carney1, 1Univ. of Illinois, USA. The characteristics and performance of implanted photonic crystal coherent vertical cavity laser arrays are reported. We discuss control of the coherence, phase, brightness, and beam steering, as well as achieving record small signal bandwidth for digital modulation.

**SF2J.2 • 11:00**
Investigation of Air-Hole Shapes for Direct Emission of Circularly-Polarized Beam from Photonic-Crystal Surface-Emitting Lasers, Masaya Nishimoto2,1, Kyohei Maekawa2, Susumu Noda1, 1School of Engineering, The Univ of Tokyo, Japan; 2Dept. of Electronic Science and Engineering, Kyoto Univ., Japan.
We propose photonic-crystal surface- emitting lasers with oblique-triangular-prism-shaped air holes for direct emission of circularly polarized beam. High degree of circular polarization ($S_S/S_P>0.9$) can be obtained by appropriate height and tilt angle of air holes.

**SF2J.3 • 11:15**
Lateral Size Scaling of Photonic Crystal Surface-Emitting Lasers on Si, Shih-Chia Liu1, Deyin Zhao1, Hongjun Yang1, Carl Reuterskiöld-Hedlund2, Mattias Hammar2, Shanhu Fan1, Zhenghao Ma1, Weidong Zhou1, 1Univ. of Texas at Arlington, USA; 2KTH-Royal Inst. of Technology, Sweden; 3Univ. of Wisconsin, USA; 4Stanford Univ., USA. We report here the lateral size scaling effect of the photonic crystal surface- emitting lasers (PCSELs) on silicon. Lateral and vertical confinement schemes were also investigated towards low threshold lasing of PCSELs with small lateral cavity sizes.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.

**SF2K • Infrared Laser Sources**
*Presider: Thomas Metzger, TRUMPF Scientific Lasers GmbH, Germany*

**SF2K.1 • 10:30**

Our talk reviews fundamentals as well as recent advances in fiber-based ultrafast mid-IR lasers and frequency combs, providing a flexible and robust fiber based technology platform to address demanding requirements set by the most advanced scientific and industrial applications, such as optogenetics, ultrasensitive molecular detection, nonlinear confocal microscopy, 3D-IR and multiphoton nonlinear spectroscopy, astrometry, as well as line material processing.

*In this tutorial the software platform will be demonstrated and the user will learn to generate and control the laser for applications.*

**SF2K.2 • 10:45**
*Extended time cloak based on inverse temporal Talbot effect, Bowen Li1, Xie Wang2, Jiqiang Kang1, Yuan Wei1, Kenneth Kin-Yip Wong2; University of Hong Kong, China; Huawei Technologies Co., LTD, China.*

Inverse temporal Talbot effect is used to enhance the performance of time cloak, achieving a continuous cloaking window of 196 ps, which is 5.4 time larger than previous record. Pseudo-random temporal event is successfully concealed.

**SF2K.3 • 11:00**
*Agile photonic generation of arbitrary RF chirped waveforms, Hugues Guillet de Chatellus1,2; Luis Romero Cortes1, Maurizio Burla1, Come Schébelin1, Jose Azana1; LPhy, France; INRS-EMT, Canada; 2ETH, Switzerland.*

We demonstrate a simple platform for reconfigurable generation of arbitrary RF chirped waveforms from a single CW laser. Our scheme is capable of generating >100 GHz bandwidth chirps with a time-bandwidth product up to ~1300.

**SF2K.4 • 11:15**
*Surface Nanoscale Axial Optomechanics, Misha Sumetsky1; Aston University, UK.*

It is shown that slow acoustic modes similar to optical modes can be fully controlled by nanoscale variation of the optical fiber radius. Acoustic anticontrol microresonators are discovered. Optical frequency combs generated mechanically are investigated.

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**SF2L • Advanced Fiber Devices and Concepts**
*Presider: Sze Set; Univ. of Tokyo, Japan*

**SF2L.1 • 10:30**
*Programmable passive waveform amplifier based on temporal self-imaging effects, Jinwoo Joon1, Reza Maram1, James van Howe2, Jose Azana1; Energie, Matériaux et Télécommunications, Institut National de la Recherche Scientifique, Canada; 2Dept. of Physics and Astronomy, Augsburg College, USA.*

We introduce a new design for Talbot-based passive amplifiers, involving temporal phase modulation and dispersion, in which the gain factor can be electrically reconfigurable. In particular, we show gain factors from m^2 to 30 using a fixed dispersive line.

**SF2L.2 • 10:45**
*Extended time cloak based on inverse temporal Talbot effect, Bowen Li1, Xie Wang2, Jiqiang Kang1, Yuan Wei1, Kenneth Kin-Yip Wong2; University of Hong Kong, China; Huawei Technologies Co., LTD, China.*

Inverse temporal Talbot effect is used to enhance the performance of time cloak, achieving a continuous cloaking window of 196 ps, which is 5.4 time larger than previous record. Pseudo-random temporal event is successfully concealed.

**SF2L.3 • 11:00**
*Agile photonic generation of arbitrary RF chirped waveforms, Hugues Guillet de Chatellus1,2; Luis Romero Cortes1, Maurizio Burla1, Come Schébelin1, Jose Azana1; LPhy, France; INRS-EMT, Canada; 2ETH, Switzerland.*

We demonstrate a simple platform for reconfigurable generation of arbitrary RF chirped waveforms from a single CW laser. Our scheme is capable of generating >100 GHz bandwidth chirps with a time-bandwidth product up to ~1300.

**SF2L.4 • 11:15**
*Surface Nanoscale Axial Optomechanics, Misha Sumetsky1; Aston University, UK.*

It is shown that slow acoustic modes similar to optical modes can be fully controlled by nanoscale variation of the optical fiber radius. Acoustic anticontrol microresonators are discovered. Optical frequency combs generated mechanically are investigated.

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**SF2M • Combustion Diagnostics and Imaging**
*Presider: Scott Howard; Univ. of Notre Dame, USA*

**SF2M.1 • 10:30**
*Tracking objects surrounded by scattering media, Milad Akhlaghi Bouzani1, Aristide Dogariu1; CCREOL, College of Optics and Photonics, Univ. of Central Florida, USA.*

Statistical properties of integrated scattered intensity from an object, under illumination with dynamic diffused light thorough a scattering wall, are exploited for tracking objects in real time. Experimental demonstrations are presented.

**SF2M.2 • 10:45**
*Underwater Three-Dimensional Imaging Using Single-Photon Detection, Aurora Maccarone1, Abderrahim Halimi1, Angus McCarthy1, Rachael Tobin1, Stephen McLaughlin1, Yvan Petitot1, Gerald S. Buller1; Heriot-Watt Univ, UK.*

Depth profile measurements are performed in highly scattering underwater environments at stand-off distances equivalent to nine attenuation lengths. The optical system used a scanning transceiver and single-photon detection to produce high-resolution images with milli-watt average powers.

**SF2M.3 • 11:00**
*Coherent Noise Reduction Using Heterodyne Detection, Milad Akhlaghi Bouzani1, Aristide Dogariu1; CCREOL, College of Optics and Photonics, Univ. of Central Florida, USA.*

We demonstrate the noise reduction using the intrinsic coherence properties of the field with single-shot heterodyne detection and we quantify the efficiency in low-SNR conditions.

**SF2M.4 • 11:15**
*Coherent Near-IR Spectroscopic Imaging with a Low-Cost Microbolometer Array, David Benirschke1, Scott S. Howard2; Electrical Engineering, Univ. of Notre Dame, USA.*

A low-cost, commercially available vanadium oxide microbolometer array is characterized in terms of its noise equivalent differential temperature and responsivity spectra. The same array is used in an FTIR spectroscopic imaging demonstration.
AF2A • A&T Topical Review on Supercontinuum and Applications II—Continued

AF2A.3 • 11:30
Label-free Techniques for the Assessment of Cancer and other Diseases using the Supercontinuum Light Source at the Four NIR Optical Windows, Laura Sordillo1,2, Peter P. Sordillo1, Lingyan Shi1, Robert R. Alfano1,2, 1Inst. for Ultrastar Spectroscopy and Lasers, The City College of New York, USA; 2The Grove School of Engineering, The City College of New York, USA.
A supercontinuum can generate wavelengths at all four near-infrared windows simultaneously. Additionally, using the supercontinuum can avoid the disadvantages of methods that require contrast agents as it utilizes intrinsic optical properties of the studied material.

AF2A.4 • 12:00
Future Supercontinuum Microscope for Medical and Biological Applications, Lingyan Shi1, Robert R. Alfano1,2, 1Inst. for Ultrastar Spectroscopy and Lasers, The City College of New York, USA; 2The Grove School of Engineering, The City College of New York, USA.
A supercontinuum (SC) light microscope is proposed for linear and nonlinear optical resonance and nonresonance processes in medical and biological applications.

AF2B • Applied Spectroscopy—Continued

AF2B.4 • 11:30
Isotope-Selective Breath Analysis, Albert Manninen1, Teemu Kaarjainen1, Markus Metsälä1, Markku Lehto1,2, Eero Hietala1, Rami Akio1, Hannu Vasama1, Paloma Ruiz Y Kärkkäinen1, Craig Richmond2, Pekka Suopajärvi3,4, VTT Technical Research Centre of Finland, Finland; 3Dept. of Chemistry, Univ. of Helsinki, Finland; 4Folkhåلسan Inst. of Genetics, Folkhålsan Research Center, Finland.
Isotope-selective breath analysis offers a non-invasive, fast and reliable alternative to traditional methods in numerous clinical applications. Especially stable isotopologues of carbon dioxide have been applied to tens of different studies.

AF2B.6 • 12:15
Spectroscopic Characterization of Si/Mo Thin-film Stack at Extreme Ultraviolet Range, Yen-Yin Li1,2, Yin-Wen Lee1,1, I-Chou Wu1, Sheng-Lung Huang1,2, 1Dept. of Electrical Engineering, National Taiwan Univ., Taiwan; 2Dept. of Electrical Engineering, National Taiwan Univ., Taiwan.
A common-path interferometry based extreme ultraviolet (EUV) spectrometer was used to characterize a Si/Mo thin-film beamsplitter. The complex transfer function of the Si/Mo stack was successfully obtained and verified near the pristine 13.5-nm wavelength range.

AF2C • Frequency Comb Applications—Continued

AF2C.2 • 11:30
Frequency comb transferred by plasmonic EOT, Young-Jin Kim1, Byung Jae Chun1, Seungchul Kim2,1, 1Nanyang Technological Univ., Singapore; 2Pusan National Univ., Korea (the Republic of).
We demonstrate that frequency comb can be transferred by plasmonic nanostructures without noticeable degradation in absolute position and linewidth, which implies frequency comb’s potential applications in nanoplasmonic spectroscopy.

AF2C.3 • 11:45
Development of confocal laser scanning microscopy by use of optical frequency comb, Takeo Minamikawa1,2, Eiji Hase1,2, Shuji Yajis1,2, Hirotugu Yamamoto1,2, Takeshi Yasui1,2, 1JST, PRESTO, Japan; 2JST, ERATO MINOSHIMA Intelligent Optical Synthesizer, Japan.
We proposed a confocal laser scanning microscopy based on dual-comb spectroscopy, which enables the three-dimensional quantitative amplitude and phase imaging.

AF2C.5 • 12:00
Long-Short of-Focus Imaging by a Non-Diffracting Optical Needle under Strong Aberration, Yuichi Kozawa1,2, Shunichi Sato1, Inst. of Multidisciplinary Research for Advanced Materials, Tohoku Univ., Japan; 2JST, PRESTO, Japan.
We experimentally investigated the focusing property of an annular-shaped beam. Apparent robustness against optical aberration was revealed when an annular-shaped beam is tightly focused in the presence of strong spherical aberration.

AF2C.6 • 12:15
Non-scanning three-dimensional tomographic imaging using chirped-frequency comb, Takashi Kato1,2, Megumi Uchida2,3, Yuina Tanaka1, Kaoru Minoshima2,3, 1The Univ. of Electro-Communications (UEC), Japan; 2JST, ERATO MINOSHIMA Intelligent Optical Synthesizer (IOS), Japan.
One-shot 3D tomographic imaging with a chirped-frequency comb is demonstrated using 2D pulse-to-pulse spectral interferometry. The profile of the glasses’ layered structure is measured, and the thickness of each layer is deduced with 100-nm-level uncertainty.
FF2E • Quantum Technologies—Continued

FF2E.5 • 11:30
Practically Noiseless Parametric Frequency Upconverter, Ivan A. Burenkov1, Thomas Gerritsa1, Adriana Lita1, Sae Woo Nam2, Lynden K. Shalm3, Sergei V. Polyakov2,
1Joint Quantum Inst., NIST and UMD, USA; 2Institute for Quantum Computing, University of Waterloo, Canada; 3National Institute of Standards and Technology, USA.
We demonstrate a practical and efficient unconstrained frequency upconversion scheme for single photon sources, resulting in an upconversion efficiency of 20% and a frequency conversion efficiency of 5%.

FF2E.6 • 11:45
Quantum Frequency Down-Conversion of Ca resonant Polarization-Entangled Photons to the Telecom O-band, Matthias Bock1, Stephan Kucera1, Jan Arenskötter1, Benjamin Kambs1, Sebastian Rühle1, Andreas Lenhard1, Jürgen Escher1, Christoph Becker1, Universität des Saarlandes, Germany.
We demonstrate a quantum frequency down-conversion scheme for entangled photons from a transition wavelength of 854 nm to the telecom O-band at 1312 nm, enabling compact and efficient optical communication systems.

FF2E.7 • 12:00
Telecom-Wavelength Quantum Relay Using a Semiconductor Quantum Dot, Jan Huwer1, Martin Felle1,2, R. Mark Stevenson3, Joanna Skiba-Szymanska1, Martin B. Ward1, Ian Farrer1, Richard V. Penty1,2,4, Martin Felle1,2, R. Mark Stevenson1,5, Inst. of Microelectronics, Singapore.
We demonstrate a novel quantum relay scheme using a semiconductor quantum dot to transfer quantum information from a remote source to a telecom wavelength receiver, enabling long-distance quantum communication.

FF2E.8 • 12:15
A chip-scale single-photon SWAP gate as integrated interface between polarization and spatial-momentum qubits, Zhendong Li1,2,3, Tingting Li1,2,3, Xianjun Li1,2,3, Xin Ma1,2,3, Christian Schüller2, Tobias Korn2, Joe Seifert2, Yiping Wang2, Kai Hao1,2,3,4, Dennis Pleskot5, Natalie Noginova6, 1Yonsei Univ., Korea; 2Dept. of Physics, Univ. of Regensburg, Germany; 3National Inst. of Standards & Technology, USA; 4Joint Quantum Inst., NIST and UMD, USA; 5National Inst. of Standards & Technology, USA.
We report the development of a chip-scale single-photon SWAP gate using a semiconductor quantum dot, enabling the integration of quantum information processing into miniature devices.

FF2F • Valley Coherence and Polariton Dynamics in 2D Materials—Continued

FF2F.4 • 11:30
Valley Polarized Exciton Polaritons From Two-dimensional Semiconductor In Microcavity, Zheng Sun1,2, Jie Gu1,2, Areg Ghazaryan1, Zav Shohaj1, Christopher R. Considine1, Michael Dollar1, Payam Ghamemi2,4, Vinod M. Menon2,3,1, Physics, City College of New York, USA; 2City Univ. of New York, USA.
We report the observation of valley-polarized exciton polaritons in a two-dimensional semiconductor microcavity, demonstrating valley coherence with unprecedentedly low count rate, corresponding to a Purcell factor of 540.

FF2F.5 • 11:45
Valley Polarization Dynamics of Inter- and Intra-valley Trions in Monolayer WS2, Akshay Singh1, Kha Tran1, Mirco Kolarzik1, Joe Seifert2, Yiping Wang2, Kai Hao1,2,3,4, Dennis Pleskot5, Nathaniel Gabor1, Sophia Helmrich1, Nina Oweischitikov1, Unike Waggoner1, Xiaoqin Li2, Technical Univ. Berlin, Germany; 1University of Texas at Austin, USA; 3Dept. of Physics and Astronomy, Univ. of California, USA; 4National Inst. of Standards & Technology, USA.
We investigate valley polarization dynamics of trions in WS2, demonstrating a dark count reduction algorithm for unprecedentedly low count rate, and show the observation of room temperature strongly coupled microcavity polaritons that are valley polarized due to the coupling of the photons with specific helicity to excitons in the distinct valleys of the 2D material.

FF2F.6 • 12:00
Trion Valley Coherence in Transition Metal Dichalcogenides, Kha Hao1,2, Lixiang Xu1,2,3,4,5, Tao Sun1,2, Jie Gu1,2, Areg Ghazaryan1, Zav Shohaj1, Christopher R. Considine1, Michael Dollar1, Payam Ghamemi2,4, Vinod M. Menon2,3,1, Physics, City College of New York, USA; 2City Univ. of New York, USA.
We report the observation of room temperature strongly coupled microcavity polaritons that are valley polarized due to the coupling of the photons with specific helicity to excitons in the distinct valleys of the 2D material.

FF2F.7 • 12:15
Generation, transport, and detection of valley-coupled spin-polarized electrons in WS2-graphene-topological insulator heterostructure devices, Soonyoung Cha1, Deon Lee1, Jee-Hyun Kim1, Minji Noh1, Hyunmin Bae1, Seongjun Kim1, Wookyung Shim1, Jun Sung Kim1, Dohun Kim1, Hyunyoung Choi1, Yongnan Li1,3, Xinan Xu2, Abhinav K. Chong3, Tae Hyun Hong3,4,5, Hyunseung Kim1,2,3,6, 1Univ. of Maryland, College Park, USA; 2ETH Zürich – Swiss Federal Inst. of Technol. Zürich, Switzerland.
We experimentally study enhanced coherence between valley-coupled spin-polarized electrons and optical excitons in WS2-graphene-topological insulator heterostructure devices, demonstrating valley coherence time of 230fs.

FF2F.8 • 12:15
Probing and Mapping Optical Fields in Si Disk Arrays with Eu+, Natalia Noginova1, Soheila Mashhadi2, Mikhail Noginov1, Katie Chong3, Yuri Kivshar2, David Keene1, Aleksandr Vaskin3, Evgenia Rusak4, Carsten Rockstuhl5, Thomas Pertsch6, Dragomir N. Neshev7, Isabelle Stauder8, Norfolk State Univ., USA; 2The Australian National Univ., Australia; 3Friedrich Schiller Univ. Jena, Germany; 4Karlsruhe Inst. of Technology, Germany; 5Bielefeld University, Germany; 6ETH Zürich – Swiss Federal Inst. of Technol. Zürich, Switzerland.
We demonstrate the mapping of optical fields in Si disk arrays using Eu+ ions as a single-photon source, allowing the probing of local optical fields with unprecedented spatial resolution.

FF2G • Nanoscale Control of Quantum Emission—Continued

FF2G.4 • 11:30
Ultrafast room-temperature single photon source with plasmonic nanocavities, Mikalen H. Mikkelsen1,2, Duke Univ., USA.
We report the demonstration of a single-photon source with a plasmonic nanocavity, emitting at room temperature with an ultrafast response time of 13 ps.

FF2G.5 • 11:45
Multiphoton Emission Enhancements in Quantum Dot-Plasmon Coupling, Akash Kannegulla1,2, Yu Li1, Bo Wu1, Li-Jing Cheng1, Oregon State Univ., USA.
We report the enhancement of multiphoton emission in quantum dot-plasmon coupling systems, demonstrating a factor of 3 enhancement.

FF2G.6 • 12:00
Purcell enhanced Spontaneous Emission of Colloidal Perovskite Nanocrystals, Zhiyi Fang1, Maryna Bodnarchuk2, Edil Waks2, 1Univ. of Maryland, College Park, USA; 2ETH Zürich – Swiss Federal Inst. of Technol. Zürich, Switzerland.
We report the demonstration of Purcell enhanced spontaneous emission in colloidal perovskite nanocrystals, coupled to a nanobeam photonic crystal cavity, at room temperature.

FF2G.7 • 12:15
Quantum Emission—Continued

FF2G.8 • 12:15
Quantum Emission—Continued
SF2I • Detectors and Other Novel Devices—Continued

SF2I.4 • 11:30
Two-dimensional Quantum Walk using 3D Silicon Photonic Fabrication, Libin Yan1, Jianguo Huang1, Gong Zhang1, Leong Chuang Kwek1,2, Jangbin Gong1, Weibo Gao1, Yidong Chong1, Wee Ser1, Ai Qun Liu1; 1Nanyang Technological Univ., Singapore; 2National Univ. of Singapore, Singapore. A 2D quantum walk on an integrated quantum photonic circuit is demonstrated by using a multilayer low-loss Si3N4 waveguide lattice, which has promising applications in quantum computing and quantum communication, etc.

SF2J • Surface Emitting Lasers—Continued

SF2J.4 • 11:30
Uniform Operation of Coherent Photonic Crystal VCSEL Arrays, Harshil Dave1, Stewart Frysie1, Zhe Gao1, Bradley Thompson1, Katherine Lakomy1, Kent D. Choquette1; 1Univ. of Illinois, USA. Coherent 1x2 VCSEL arrays with improved electrical isolation have enhanced output power, visibility, and uniformity for injection locked operation. The current range for locked operation is as large as 6.5mA, which decreases with increasing bias.

SF2I.5 • 11:45
Multivariable Phase Tuning Control and its Application to Wavelength Tracking in High-Order Multi-Ring Filters, Jason Msk1, Wesley D. Sacher1,2, Jared C. Mikkelsen1, Joyce Poon1; 1Univ. of Toronto, Canada; 2California Inst. of Technology, USA. We propose a multivariable controller based on a state-space approach and estimation that only requires a single monitor. The procedure is demonstrated on a tunable silicon 5-ring filter to track the passband to a reference wavelength.

SF2J.5 • 11:45
Uniform, High Modulation Bandwidth VCSEL Arrays, Stewart Frysie1, Zhe Gao1, Harshil Dave1, Bradley Thompson1, Katherine Lakomy1, Kent D. Choquette1; 1Univ. of Illinois Urbana-Champaign, USA. We show improved performance from high-speed 1x2 photonic crystal VCSEL arrays. A modulation bandwidth of 37 GHz is obtained under highly single mode coherently coupled operation in the in-phase coupled mode. Modulation bandwidth > 30 GHz are found for all photonic crystal designs on the sample.

SF2I.6 • 12:00
Power-dependence of high-Q optomechanical oscillators: from pre-oscillation, to oscillation, to Drude-plasma, Jaime Flor Flores1, Yongjun Huang1, Linghai Li1, Vito Iaia1, Chee Wei Wong1; 1UCLA, USA. We demonstrate the power dependence of high-Q OMOs, which permits pre-oscillation, oscillation, and chaos like performance. Power dependence on mechanical frequency is also modeled and simulations are compared to the measured data.

SF2J.6 • 12:00
GaSb-based Electrically-Pumped Vertical Cavity Surface Emitting Lasers for the 3-4 μm Wavelength Range, Ganpath Kumar Veerabathran1, Stephan Sprengel1, Alexander Andrejew1, Markus-Christian Amann1; 1Walter Schottky Inst., Technische Universität München, Germany. We present GaSb-based single-mode electrically-pumped VCSELs emitting at 3 and 3.9 μm. Continuous wave operation at thermo-electrically cooled temperatures and over 19 nm of electro-thermal tuning range are achieved.

SF2I.7 • 12:15
Organic Membrane Photonic Waveguide with Metal Grating Couplers, Tomo Amemiya1, Toru Kanazawa1, Taku Hiratani1, Daisuke Inoue1, Zhichen Gu1, Satoshi Yamasaki1, Tatsuhito Urakami1, Shigeishi Arai1; 1Tokyo Inst. of Technology, Japan; 2Mitsui Chemicals, Inc., Japan. We made an organic-membrane waveguide with input/output metal grating couplers, a basic element of organic membrane photonic integrated circuits. The propagation loss and coupling loss were 1.4 dB/cm and 27 dB/coupler, respectively.

SF2J.7 • 12:15
Projection of freely designed images by integrable phase-modulating surface-emitting lasers, Yoshitaka Kurosaka1, Kazuyoshi Hirose1, Takahiro Sugiyama1, Yu Takiguchi1, Yoshio Nomoto1; 1Hamamatsu Photonics, Japan. We demonstrate semiconductor lasers which emit freely designed images directly without any optical elements or scanners. We introduce holographic modulation in a square lattice photonic crystal. The fabricated devices are on-chip-sized and suitable for integration.
Concurrent sessions are grouped across four pages. Please review all four pages for complete session information.