Welcome to CLEO: 2015!

We welcome you to CLEO:2015. CLEO continues to be the world's premier scientific and engineering forum for quantum electronics, laser science, and the broad range of applications for laser and EO science and technology. Within the scope of a single conference, CLEO provides a forum where attendees can explore new scientific ideas, engineering concepts, and emerging applications in fields such as biophotonics, optical communications, and novel light sources. While the quality of work presented remains assured by CLEO's world-renowned technical program, the conference continues to evolve with new features to enhance your experience.

CLEO: 2015 offers high quality content in five core event elements:

CLEO QELS–Fundamental Science: the premier venue for discussion of basic research in optical and laser physics and related fields. Topics include optics, modern spectroscopy, optical materials, quantum information science, nanophotonics, plasmonics, and metamaterials.

CLEO Science & Innovations: world-leading scientific research and innovation in lasers, optical materials, and photonic devices. Topics include laser processing of materials, terahertz technologies, ultrafast optics, biophotonics, nanophotonics, metrology, sensing, and energy-efficient "green" photonics.

CLEO Applications & Technology: explores the development of photonic technologies for use in emerging applications and products. The scope spans advanced photonic componentry as well as its use in systems and applications. This includes: biomedical devices for diagnostics and therapeutics, laser systems for industry, energy and defense, industrial applications of optics, photonic instrumentation for various applications, environmental sensing, and energy conservation, etc.

CLEO Market Focus and Technology Transfer: Market Focus sessions emphasize commercial developments and market forecasts for the optics, photonics, and laser industry. The sessions will discuss how photonic technologies are leveraged by systems and sub-systems level companies within multiple commercial vertical markets like biomed and industrial manufacturing, to accelerate new product development. A Technology Transfer showcase will feature the latest research ready to be transitioned for commercial implementation and will feature case studies and a tutorial focused on how to take commercial-ready IP to market.

CLEO Expo: exhibition of businesses who provide leading-edge products and services to CLEO attendees. The Expo will host more than 200 participating companies featuring a wide range of photonics innovations, products and services; it is expected to attract more than 5,000 visitors including researchers, engineers, and leaders from top research institutions and emerging businesses who represent the fastest growing markets in optics and photonics.

Through its rigorous peer review system, CLEO ensures high technical quality in all presentations. This system comprises the combined efforts of over 300 scientists serving on 25 technical committees. This year the conference features an outstanding collection of invited and contributed papers, tutorials, and poster presentations. We are excited to offer more than 1,220 oral, and 300 poster presentations, as well as 140 invited talks by some of the leading researchers in our international community representing 39 countries. The program also includes 22 tutorials — hour-long in-depth presentations by experts — along with a comprehensive program of 15 short courses; which provide half day immersion in selected topic areas.

This year the technical Program Chairs selected 8 special symposia that were submitted during an open call for submissions that consisted of timely, cutting-edge topics and/or new material in rapidly advancing areas. In addition, Applications and Technology Topical Reviews were added as they are designed to emphasize significant recent advances in the application of photonic technologies to address current real world problems.

This year CLEO features eight exceptional plenary speakers, including six Nobel laureates. On Monday we will hear from Eric Betzig, Stefan Hell and W.E. Moerner on their achievements that have broken the diffraction limit in confocal microscopy, along with Tony Heinz on the optical properties of two-dimensional materials. Tuesday afternoon will feature Steven Chu and Hiroshi Amano. Chu will describe how new imaging technologies will give us the ability to have a detailed molecular understanding of what happens in genes and proteins while Amano will discuss LED lighting applications and current issues. On Wednesday evening we will celebrate the International Year of Light and hear from Miles Padgett on structured light and Shuji Nakamura will update us on the latest news concerning GaN-based optoelectronic devices, their technology and scientific foundations.

We thank technical Program Co-chairs Siddharth Ramachandran and Jon Zuegel in Science and Innovations; Nicusor Iftimia and Christian Wetzel in Applications and Technology; and Junichiro Kono and Yurii Vlasov in Fundamental Science, for coordinating the work of our subcommittees and pulling together this excellent, diverse program. We also thank Sasan Fathpour and Ben Eggleton, Short Course Co-chairs, and all of the program committee members whose leadership, dedication, and hard work are critical to maintaining the high quality of the meeting. Additionally, we would like to thank the APS Division of Laser Science, the IEEE Photonics Society, The Optical Society (OSA), and the exhibitors for their support and contributions to the meeting. Finally, we thank the OSA staff for their professional assistance and dedication in organizing this event.

We welcome you to the conference and thank you for your participation.

General Co-Chairs

Yu Chen
Univ. of Maryland at College Park, USA

Alfred Leitenstorfer
Univ. of Konstanz, Germany

Eric Mottay
Amplitude Systemes, France

Mikhail A. Noginov
Norfolk State Univ., USA

Thomas R. Schibli
Univ. of Colorado at Boulder, USA

Peter M. Smowton
Cardiff Univ., UK

Plenary Sessions and Award Ceremony

Plenary Session I

Monday, 11 May, 16:00–18:00
Grand Ballroom, San Jose Convention Center

The first plenary session features the 2014 Chemistry Nobel Laureates and their achievements that have broken the diffraction limit in confocal microscopy. In addition, Tony Heinz will discuss the optical properties of two-dimensional materials.

Electrons in Atomically Thin Two-Dimensional Crystals
Tony Heinz, *Columbia Univ., USA*

Tony F. Heinz is the David Rickey Professor in the Departments of Physics and Electrical Engineering at Columbia Univ. He received his BS degree in physics from Stanford Univ. in 1978 and a PhD degree, also in physics, from the Univ. of California at Berkeley in 1982. After 12 years at IBM Research in Yorktown Heights, he joined Columbia Univ. as a professor of physics and electrical engineering. He was appointed to the David Rickey Chair in 2001 and has served as a director of several large-scale research centers. His research has been recognized by a von Humboldt Research Award, the Springer Prize for Applied Physics, and the APS Isakson Prize. He served as the President of the OSA in 2012.

Nanoscopy with Focused Light
Stefan W. Hell, *Max Planck Inst. for Biophysical Chemistry, Germany*
Nobel Prize Winner in Chemistry 2014

Stefan W. Hell is a director at the Max Planck Inst. for Biophysical Chemistry in Göttingen and also leads a research division at DKFZ in Heidelberg. He is credited with having conceived, validated and applied the first viable concept for breaking Abbe's diffraction-limited resolution barrier in a light-focusing microscope. He has received several awards, including the "Innovation Award of the German Federal President" (2006), the Leibniz Prize (2008), the Otto-Hahn-Prize in Physics (2009), the Hansen Family Award (2011), the Körber European Science Prize (2011), the Meyenburg Prize (2011) and in 2014 the Kavli Prize in Nanoscience and the Nobel Prize in Chemistry.

Light Paves the Way to Single-Molecule Detection and Photocontrol, Foundations of Super-Resolution Microscopy
W. E. Moerner, *Stanford Univ., USA*
Nobel Prize Winner in Chemistry 2014

W. E. Moerner, the Harry S. Mosher Professor of Chemistry and Professor, by courtesy, of Applied Physics at Stanford Univ., conducts research in physical chemistry and chemical physics of single molecules, single-molecule biophysics, super-resolution imaging and tracking in cells, and trapping of single molecules in solution. His interests span methods of precise quantitation of single-molecule properties, to strategies for three-dimensional imaging and tracking of single molecules, to applications of single-molecule measurements to understand biological processes in cells, to observations of the photodynamics of single photosynthetic proteins and enzymes. He has been elected Fellow/Member of the NAS, American Academy of Arts and Sciences, AAAS, ACS, APS, and The Optical Society. Major awards include the Earle K. Plyler Prize for Molecular Spectroscopy, the Irving Langmuir Prize in Chemical Physics, the Pittsburgh Spectroscopy Award, the Peter Debye Award in Physical Chemistry, the Wolf Prize in Chemistry, and the 2014 Nobel Prize in Chemistry.

Imaging Life at High Spatiotemporal Resolution
Eric Betzig, *Howard Hughes Medical Inst., USA*
Nobel Prize Winner in Chemistry 2014

After obtaining a BS in Physics from Caltech, Eric Betzig moved to Cornell, where his thesis involved the development of near-field optics, the first method to break the diffraction barrier in light microscopy. Betzig became a PI at AT&T Bell Labs in Murray Hill, NJ, where he further refined the technology and explored many applications, including high density data storage, semiconductor spectroscopy, and superresolution fluorescence imaging of cells. In 1993, Betzig was the first to image single fluorescent molecules under ambient conditions, and determine their positions to better than 1/40 of the wavelength of light. Tiring of academia, he served as Vice President of R&D at his father's machine tool company, developing a high speed motion control technology based on an electrohydraulic hybrid drive with adaptive control algorithms. The commercial failure of the technology left him unemployed and his search for new directions culminated in the invention and demonstration of the superresolution technique PALM by himself and fellow Bell Labs expatriate, Harald Hess. Since 2005, Betzig has been a Group Leader at Janelia, developing new optical imaging technologies for biology. Betzig won the 2014 Nobel Prize in Chemistry.

Plenary Session II

Tuesday, 12 May, 13:30–14:30
Grand Ballroom, San Jose Convention Center

Microscopy 2.0
Steven Chu, *Stanford Univ., USA*
Nobel Prize Winner in Physics 1997

Steven Chu is the William R. Kenan, Jr., Professor of Humanities and Sciences and Professor of Physics and Molecular & Cellular Physiology at Stanford Univ. His research program encompasses atomic physics, quantum electronics, energy and energy economics, and biophysics and biomedicine that tests fundamental theories in physics, the development of methods to laser cool and trap atoms, atom interferometry, and the study of polymers and biological systems at the single molecule level. For his work developing the theory of laser cooling of atoms, he was co-recipient of the Nobel Prize in Physics in 1997. Before serving as the U.S. Secretary of Energy, he was a professor of physics and molecular and cellular biology at the Univ. of California Berkeley and director of the Lawrence

Berkeley National Lab. In addition to the Nobel Prize, he has won dozens of awards, including the Science for Art Prize, the Herbert Broida Prize for Spectroscopy, the King Faisal International Prize for Science, the Arthur Schawlow Prize for Laser Science, and the William Meggers Award for Laser Spectroscopy, and holds 23 honorary degrees.

Current and Future of Solid State Lighting
Hiroshi Amano, *Nagoya Univ., Japan*
Nobel Prize Winner in Physics 2014

Hioshi Amano received his BE, ME and DE degrees from Nagoya Univ. in 1983, 1985 and 1989. He was a research associate of Nagoya Univ. from 1988–1992. He moved to Meijo Univ. in 1992 and back to Nagoya Univ. in 2010, where is a Professor in the Department of Electrical Engineering and Computer Science, Graduate School of Engineering. He joined Professor Isamu Akasaki's group in 1983 as an undergraduate course student at Nagoya Univ. Since then, he has been doing research on the growth and device application of group III semiconductors. In 1985, he developed low-temperature deposited buffer layers, which provided the technology vendors to the development of high-quality group III semiconductor based LEDs and LDs. In 1989, he succeeded in growing p-type GaN and fabricating a p-n junction light emitting diode for the first time in the world. He has authored and co-authored more than 500 technical papers and contributed to 25 books. His work has brought several awards. In 2014 he received the Nobel Prize in Physics.

Plenary Session III: International Year of Light Celebration and Awards Ceremony

Wednesday, 13 May, 18:30–20:30
Grand Ballroom, San Jose Convention Center

To continue the year-long celebration theme this year, this plenary session will feature luminaries Shuji Nakamura, 2014 Nobel Laureate, and Miles Padgett. In addition, we will be celebrating outstanding achievements of your colleagues through awards and fellowships bestowed by the sponosoring societies.

Light's Twist
Miles Padgett, *Univ. of Glasgow, Scotland, UK*

Miles Padgett holds the Kelvin Chair of Natural Philosophy at the Univ. of Glasgow, Scotland. He leads the Quantum Imaging Hub, one of four Quantum Technology hubs in a UK network. In 2001 he was elected a Fellow of the Royal Society of Edinburgh (RSE) and in 2014 a Fellow of the Royal Society, the UK's National Academy. In 2009, with Les Allen, he won the Inst. of Physics Young Medal and in 2014 the RSE Kelvin Medal. In 2015 he was awarded the Science of Light Prize from the European Physical Society. He is best known for his Group's work in Optical Angular Momentum: Light's Twist.

Energy Savings by LED Lighting
Shuji Nakamura, *Univ. of California Santa Barbara, USA*
Nobel Prize Winner in Physics 2014

Shuji Nakamura was born on May 22, 1954, in Ehime, Japan. He obtained his B.E., M.S., and Ph.D. degrees in Electrical Engineering from the Univ. of Tokushima, Japan. He joined Nichia Chemical Industries Ltd. in 1979. He spent a year at the Univ. of Florida as a visiting research associate in 1988, and started the research of blue LEDs using group-III nitride materials the following year. In 1993 and 1995, he developed the first group-III nitride-based blue/green LEDs. He also developed the first group-III nitride-based violet laser diodes (LDs) in 1995. He has received a number of awards, including the MRS Medal Award (1997), the IEEE Jack A. Morton Award, the British Rank Prize (1998) and the Benjamin Franklin Medal Award (2002). He was elected as a member of the US National Academy of Engineering (NAE) in 2003, received the Finnish Millennium Technology Prize in 2006, the Prince of Asturias Award from Spain in 2008, the Harvey Prize of Israel Inst. of Technology in 2010, and the Noble Prize in Physics in 2014. Since 2000, he is a professor in the Materials Department of the Univ. of California Santa Barbara. He holds more than 200 patents and has published more than 400 papers in this field.

IEEE Photonics Society Young Investigator Award

The IEEE Photonics Society Young Investigator Award honors an individual who has made outstanding technical contributions to photonics (broadly defined) prior to his or her 35th birthday.

The 2015 award is presented to Jeremy N. Munday of the Institute for Research in Electronics and Applied Physics at the University of Maryland at College Park, USA, for pioneering contributions to plasmonic and photonic light-trapping in solar cells.

OSA Charles Hard Townes Award

OSA established this award in 1980 to honor Charles H. Townes, whose pioneering contributions to masers and lasers led to the development of the field of quantum electronics. It is given to an individual or a group of individuals for outstanding experimental or theoretical work, discovery or invention in the field of quantum electronics. Bell Laboratories originally endowed the award. Hewlett-Packard, The Perkin Fund, and students and colleagues of Charles Townes contributed generously to the Townes Award Endowment Campaign.

The 2015 recipient is Ursula Keller, ETH Zürich, Switzerland, for seminal contributions in the fields of octave-spanning lasers, frequency comb technology, and high repetition-rate ultrafast semiconductor disk lasers.

IEEE Photonics Society 2015 Fellows

Hao-chung Kuo, *National Chiao Tung Univ., Taiwan*
For contributions to light emitting diodes and vertical cavity surface emitting lasers

Marek Osinski, *Univ. of New Mexico, Center for High Technology Materials, USA*
For contributions to analysis of optoelectronic materials and devices

Yong-Hang Zhang, *Arizona State Univ., USA*
For contributions to molecular beam epitaxy growth technology, infrared lasers and photodetectors

The Optical Society 2015 Fellows

Alexandra Boltasseva, *Purdue Univ., USA*
For seminal contributions to the fields of nanophotonics and new plasmonic materials.

Giulio Cerullo, *Politecnica di Milano, Italy*
For pioneering work on few-optical-cycle laser sources, for seminal achievements in ultrafast spectroscopy of organics, and for service to the optics community.

Christophe Dorrer, *Univ. of Rochester, USA*
For the invention of methods and devices for the control and characterization of ultrafast optical pulses, with significant impact across a wide range of applications, from telecommunications to high-energy lasers.

Jason Matthew Eichenholz, *Open Photonics, USA*
For achievements and leadership across a broad spectrum of projects in supporting open innovation, entrepreneurship, commercialization, technology and strategic developments for multiple corporations and for excellence in leadership at the OSA.

Clemens F. Kaminski, *Univ. of Cambridge, UK*
For pioneering work in the development of optical methods for quantifying the kinetics of reactions in chemical and biological systems.

Junichiro Kono, *Rice Univ., USA*
For pioneering contributions to fundamental optical studies of nanostructures, including carbon nanotubes and semiconductor heterostructures, and their optoelectronic device applications.

Qingming Luo, *Huazhong Univ. of Science and Technology, China*
For pioneering contribution in optical neuroimaging and applications, including functional imaging of human brain activity, laser speckle imaging of cerebral blood flow and blood vessels, and mapping brain-wide neuronal networks.

Kaoru Minoshima, *The Univ. of Electro-Communications, Japan*
For seminal contributions to advanced research on fundamental science and applied technology in precision metrology using ultrafast optics and optical frequency combs.

William J. Munro, *NTT Basic Research Labs., Japan*
For achievements in optics and photonics, as a key bridge in the optical quantum information field between academia and industry.

Malini Olivo, *Singapore Bio-imaging Consortium, A*STAR, Singapore, and NUI Galway, Ireland*
For pioneering contribution in clinical photodiagnostics in the area of clinical spectroscopy and imaging in early cancer detection and phototherapeutics of cancer.

Viktor A. Podolskiy, *Univ. of Massachusetts Lowell, USA*
For pioneering scientific contributions to the fields of strongly anisotropic metamaterials, plasmonics and the development of fundamental understanding of nonlocal effects in optical nanostructures.

Michael Vasilyev, *University of Texas at Arlington, USA*
For pioneering experimental and theoretical contributions to multimode phase-sensitive optical parametric amplifiers, in fibers for noise-free amplification of communication signals and in crystals for noise-free amplification of images.

Michael Withford, *Macquarie Univ., Australia*
For pioneering work on developing novel 3-D optical chips, and on translating scientific research to end-users in the industry and university sectors.

Michalis N. Zervas, *Univ. of Southampton, UK*
For seminal contributions to the development of advanced optical fiber amplifier configurations, fiber distributed-feedback lasers, Bragg grating theory and devices, high-power fiber lasers and nonlinear fiber optics.

Weili Zhang, Oklahoma State Univ., USA
For outstanding contributions to terahertz subwavelength photonics, including plasmonics, metamaterials and invisibility cloaking, and their advancement in China.

Incubic/Milton Chang Travel Grant

OSA Foundation

The OSA Foundation is pleased to award 10 recipients this year's Incubic/Milton Chang Student Travel Grants, endowed by Milton and Rosalind Chang. The list of recipients can viewed at www.osa.org/foundation

James P. Gordon Memorial Speakership

OSA Foundation

Established in 2014 with the support of the Gordon family, The James P. Gordon Memorial Endowment funds a speakership on Quantum Information and Quantum Optics to a CLEO invited speaker. This speakership pays tribute to Dr. Gordon for his numerous high-impact contributions to quantum electronics and photonics, including the demonstration of the maser.

One recipient will receive a $1,500 honorarium and their presentation will be recorded and archived in OSA's media library. The contents will serve as an educational resource for the next generation of optics and photonics leaders.

Congratulations to:

Jean Michel Raimond, *Université Pierre et Marie Curie, France*

Raimond will present his talk, **Quantum State Control with Atoms and Cavities (FW1A.1**) at 08:00 on Wednesday.

Tingye Li Innovation Prize

The Tingye Li Innovation Prize, established in 2013, honors the global impact Dr. Li made to the field of Optics and Photonics. This prize is presented to a young professional with an accepted paper that has demonstrated innovative and significant ideas and/or contributions to the field of optics. The recipient of this prize receives a $3,000 stipend, a special invitation to the Chairs' Reception, and special recognition at the conference.

Congratulations to:

Antonietta De Sio, *Universität Oldenburg, Germany*

Maiman Student Paper Competition

The Maiman Student Paper Competition honors American physicist Theodore Maiman for his demonstration of the first working laser and his other outstanding contributions to optics and photonics. It recognizes student innovation and research excellence in the areas of laser technology and electro-optics. The 2015 competition results will be announced during the Wednesday Award ceremony. The award is endowed by a grant from HRL Laboratories LLC, the IEEE Photonics Society and the APS Division of Laser Science and is administered by the OSA Foundation.

Congratulations to our finalists:

Muhammad Rodlin Billah, *Karlsruhe Institute of Technology, Germany*

Philipp Tonndorf, *University of Münster, Germany*

Richard Geiger, *Paul Scherrer Institute, ETH Zürich, Switzerland*

Shuo Sun, *University of Maryland, United States*

Wenyan Yu, *University of Victoria, Canada*

Special Symposia

Single-photon Nonlinear Optics

Monday, 11 May, 08:00–12:30
Executive Ballroom 210E, San Jose Convention Center

Organizers
Alexey Akimov, *Russian Quantum Center, Russia*
Sergey Polyakov, *NIST, USA*
Alexander Szameit, *Friedrich-Schiller-Universität Jena, Germany*

Attaining a nonlinear regime with extremely weak optical powers is a sought-after fundamental and practical goal, in particular for quantum and classical information processing. Yet, in conventional optical materials, the nonlinearity at light powers corresponding to single photons is negligibly weak. Recently, a number of arrangements that exhibit nonlinearity at single photon light levels have been demonstrated. Such advances were reported in a diverse range of physical systems: from high-finesse optical cavities to Rydberg atoms to nanostructured materials and graphene. This symposium is aimed at covering a significant recent progress and a rapid expansion of this field, and its applications. This symposium will serve as an interdisciplinary forum for presenting recent progress in demonstrating single-photon nonlinearities in diverse physical systems, latest theoretical results that lead to novel optical arrangements, and will cover select applications stemming from those achievements. Those include both quantum and classical applications.

Invited Speakers

Demetrios Christodoulides, *CREOL, USA*
Canonical Nonlinear Phenomena with Faint States of Light

Barak Dayan, *Weizmann Inst. of Science, Israel*
Demonstration of Deterministic Photon-Photon Interactions with a Single Atom

Sebastian Hofferberth, *Univ. Stuttgart, Germany*
Single-photon Nonlinear Optics

Robert Schoelkopf, *Yale Univ., USA*
The Birth, Care, and Feeding of Cat States in Circuit QED: Quantum Jumps of Photon Parity

Jacob Taylor, *JQI/NIST, USA*
Nonlinear Optics via Hybrid Quantum Systems

Remote Atmospheric Lasing

Monday, 11 May, 08:00–12:30
Salon IV, Marriott

Organizers
Andrius Baltuska, *Technische Universität Wien, Austria*
Ya Cheng, *Shanghai Inst. of Optics and Fine Mech., China*
Pavel Polynkin, *Univ. of Arizona, USA*

The focus of this special symposium is on the remote generation of population-inverted atomic or molecular states, based on which an impulsive free-space lasing can be initiated in atmospheric air. This phenomenon, which is referred to as "air lasing", has recently attracted significant attention. Several approaches to air lasing are investigated including femtosecond laser filamentation, pumping by optically-driven electron impact, pumping by femtosecond mid-IR laser pulses and pulse sequences, and photodissociation and resonant two-photon pumping of oxygen and nitrogen by deep-UV laser beams at specific wavelengths. So far, only the latter approach has succeeded in producing backward lasing with measurable pulse energies in real air, but the alternative approaches are getting close to achieving that goal. Air lasing is a novel nonlinear optical phenomenon that holds great promise for remote sensing applications. It involves a complex interplay between various effects in atoms and molecules driven by intense laser fields such as dissociation, excitation and ionization of molecules, alignment of molecules and molecular ions in laser fields, establishment of population inversion, different mechanisms of optical gain, etc. The investigations of air lasing cross boundaries between the diverse disciplines of femtosecond laser filamentation, strong-field molecular physics, and ultrafast nonlinear spectroscopy.

Invited Speakers

Joakim Bood, *Lund Univ., Sweden*
Early Experiments on Deep-UV Two-photon Pumping of Fluorescence and Stimulated Emission in Oxygen and Nitrogen Atoms in Flames

Robert Boyd, *Univ. of Ottawa, Canada; Univ. of Rochester, USA*
How Do Basic Nonlinear Optical Processes Lead to Atmospheric Lasing?

Arthur Dogariu, *Princeton Univ., USA*
Remote Backward-propagating Lasing in Air

Daniil Kartashov, *Friedrich-Schiller Univ. Jena, Germany*
Standoff Sources of Coherent Radiation Initiated by Femtosecond Filaments

Andre Mysyrowicz, *ENSTA, France*
Lasing from Plasma Filaments in Air

Marlan Scully, *Texas A&M Univ. & Princeton Univ., USA*
From Single Photon Superradiance to Coherence-Brightened Lasers in the Sky

Advanced Optical Microscopy for Brain Imaging

Tuesday, 12 May, 08:00–12:30
Executive Ballroom 210D, San Jose Convention Center

Organizers
Na Ji, *Howard Hughes Medical Inst., USA*
Chris Xu, *Cornell Univ., USA*

Recent years have witnessed the rapid expansion of molecular and genetic tools for neuroscience research and the dramatic advancement of a suite of optical imaging methods to utilize these tools for monitoring and manipulating brain activity. This symposium showcases the recent advances in optical microscopy techniques and their applications to *in vivo* brain imaging in model organisms.

Invited Speakers

Eric Betzig, *Howard Hughes Medical Inst., USA*
Rapid Adaptive Optical Recovery of Diffraction-Limited Resolution Over Large Multicellular Volumes

Valentina Emiliani, *Paris Descartes Univ. & CNRS, France*
Wave Front Shaping and Optogenetics

Philipp Keller, *Howard Hughes Medical Inst., USA*
Reconstructing Nervous System Development and Function with Light-Sheet Microscopy

David Kleinfeld, *Univ. California San Diego, USA*
Multi-photon Microscopy to Image Neuronal and Vascular Function in the Mammalian Brain

Michael Lin, *Stanford Univ., USA*
Ultrafast Fluorescent Probes for Brain Activity Imaging

Austin Roorda, *Univ. of California Berkeley, USA*
Adaptive Optics to Study the Structure and Function of the Human Visual System

Michael Roukes, *Caltech, USA*
Integrated Neurophotonics: Toward Massively-Parallel Mapping of Brain Activity

Lihong Wang, *Washington Univ. St. Louis, USA*
Photoacoustic Tomography: Ultrasonically Beating Optical Diffusion and Diffraction

Breaking Limits with Unconventional Optical Fields

Tuesday, 12 May, 08:00–12:30
Salon I-II, Marriott

Organizers
Qiwen Zhan, *Univ. of Dayton, USA*
Uriel Levy, *Hebrew Univ. of Jerusalem, Israel*

Recently there is an increasing interest in unconventional optical fields with spatially variant amplitude, phase and/or polarization within the beam cross-section. Scalar optical vortices carrying orbital angular momentum and vectorial vortices such as radially, azimuthally polarized beams are among the most intensively studied examples. The added degrees of freedom arising from the amplitude, phase and polarization diversity within the beam cross-section enables scientists and engineers to break the limits imposed by conventional wisdom in many optical and photonic applications. Applications of these unconventional optical fields in many promising areas and new commercial products continue to emerge. This special symposium aims to serve as a forum that brings together international experts in this and related areas.

Invited Speakers

Sergio Carbajo, *Deutsches Elektronen Synchrotron[1], MIT[2]; [1]Germany, [2]USA*
Relativistic Few-cycle Cylindrical Vector Beams for Novel Particle Accelerators

Robert Fickler, *Universitat Wien, Austria*
Increasing the Quantum Number, Dimensionality and Complexity of Entanglement

Andrew Forbes, *CSIR-National Laser Centre, South Africa*
Tailoring Light at the Source: Structured Light from Laser Resonators

Alfred Meixner, *Univ. of Tübingen, Germany*
Cylindrical Vector Beams for Spectroscopic Imaging of Single Molecules and Nanoparticles and Localization with Nanometer Precision in Tunable Microresonators

Shunichi Sato, *Tohoku Univ., Japan*
Smaller Spot Formation by Vector Beam for Higher Resolution Microscopy

Cavity Quantum Electrodynamics

Wednesday, 13 May, 08:00–15:00
Executive Ballroom 210A, San Jose Convention Center

Organizers
Alexia Auffèves, *CNRS, France*
Pascale Senellart, *CNRS-Laboratoire Photonique et Nanostrutures, France*
Glenn Solomon, *Joint Quantum Inst., USA*

The interaction of a quantum emitter with a confined mode of the electromagnetic field is well described using the formalism of cavity quantum electrodynamics (CQED). First developed in atomic physics, the concepts of CQED are now successfully used over a wide range of the electromagnetic spectrum, from the visible to microwave; and for a wide range of emitters, including for example, trapped ions, defect centers in diamond, semiconductor quantum dots and Josephson junctions. Both theoretically and experimentally, this model system has been effectively used to investigate the foundations of quantum theory, quantum measurement and the quantum-classical boundary, as well as to implement elementary protocols for quantum information processing and communication.

Over the last decade, impressive results have been obtained in a wide variety of atomic-like CQED systems, with increasing control over the light-matter coupling. While the application of the theory is broad, each system operates in a different limit of light-matter coupling, with different coupling to the environment. As expected, new developments further highlight the strengths and weaknesses of each system: some systems have natural applications as quantum light sources, others store quantum information on long time scales, and still others promote investigating the foundations of quantum theory. These specifics have led to various challenges that each community has addressed by developing specific techniques, meanwhile generating new ideas and prospects.

Invited Speakers

Dirk Englund, *MIT, USA*
Towards Scalable Quantum Networks of Spin Qubits in Photonics Integrated Circuits

Michael Köhl, *Univ. of Bonn, Germany*
Cavity-QED with a Trapped Ion in an Optical Fiber Cavity

Peter Lodahl, *Univ. Copenhagen, Denmark*
Quantum Information Processing with Quantum Dots in Photonic Crystals

Jean-Michel Raimond, *Universite Pierre et Marie Curie, Paris/ENS, France*
Quantum State Control with Atoms and Cavities

Andreas Wallraff, *ETH Zurich, Switzerland*
Exploring Cavity QED with Superconducting Circuits

Photonics in Surgery

Wednesday, 13 May, 13:00–17:30
Meeting Room 212 A/C, San Jose Convention Center

Organizers
Nicusor Iftimia, *Physical Sciences Inc., USA*
Jin Kang, *John Hopkins Univ., USA*

Photonic technologies are finding new applications in a wide range of surgical scenarios with the recent surge of advanced optical imaging techniques for intraoperative surgical guidance and the advent of a wide range of compact and highly efficient medical lasers. The symposium will further stimulate the dialog between photonics engineers, scientists, clinical researchers and surgeons, and perhaps motivate researchers across a broad range of optics disciplines to implement and more rapidly transition various photonic technologies to clinical use.

Invited Speakers

Bernard Choi, *Univ. of California Irvine, USA*
Clinical Embodiments of Laser Speckle Imaging for Real-Time Blood-Flow Monitoring

Christopher Contag, *Stanford Univ., USA*
Optical Surgical Navigation for Medulloblastoma

Boncheol Goo, *Lutronic Corporation, Korea*
Photosurgery for the Skin: Younger, Healthier and Easier

Brian Pogue, *Dartmouth College, USA*
Molecular Guided Surgery - Quantitative Immunologic Guidance with Optical Imaging

Robert Redmond, *Harvard Medical School, USA*
Clinical Potential of Light-Activated Tissue Crosslinking

Science and Technology of Laser Three Dimensional Printing

Thursday, 14 May, 14:00–18:30
Executive Ballroom 210A, San Jose Convention Center

Organizers
Yves Bellouard, *Ecole Polytechnique Fédérale de Lausanne, Switzerland*
Saulius Juodkazis, *Swinburne Univ. of Technology, Australia*
Timo Mappes, *Carl Zeiss AG, Germany*

Three-dimensional (3D) printing is a rapidly emerging manufacturing process that has the potential to revolutionize the way we make things. Lasers and optics more generally play a key role in three-d printing. From 3D direct write methods to modify and structure materials in microscale volume, to localized metal sintering and three dimensional polymerization, the potential seems infinite: medical implants perfectly adjusted to the patient's need, on-demand microparts, additive manufacturing, integrated optical circuits and 3D interconnects are just a few examples of applications. This symposium will explore the science and technology of laser 3D manufacturing.

3D structuring spans meso-scale applications (from nm to mm) where light is a method of material processing (larger dimensions) and an enabling tool to apply force and torque at the nanoscale. Light intensity localization by scattering and absorption for tissue engineering to nanoscale in sensing applications spans several orders of magnitude. Together with the "disruptive" character of 3D printing using simple setups, light sources and materials new practical applications emerge from tissue engineering to food printing.

Invited Speakers

Martin Booth, *Oxford Univ., UK*
Dynamic Optics for Three-Dimensional Laser Material Processing

Martin Hermatschweiler, *Nanoscribe, Germany*
3D Laser Lithography

Theobald Lohmüller, *LMU Munich, Germany*
Strategies for Nanofabrication based on Optothermal Manipulation of Plasmonic Nanoparticles

Koji Sugioka, *RIKEN, Japan*
Hybrid Subtractive and Additive Micromanufacturing using Femtosecond Laser for Fabrication of True 3D Biochips

Jan Torgersen, *Stanford Univ., USA*
Multiphoton Processing Technologies for Applications in Biology and Tissue Engineering

Michael Withford, *Macquarie Univ., Australia*
Laser Written 3D Lightwave Circuits and Applications

OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology

Friday, 15 May, 08:00–12:30
Salon IV, Marriott

Organizers
Dong Eon Kim, *Pohang Univ. of Science & Technology, South Korea*
Thomas Metzger, *TRUMPF Scientific Lasers GmbH, Germany*
Albert Stolow, *National Research Council, Canada*

Optical parametric chirped pulse amplification systems are the only method to date by which high-energy few-cycle coherent light pulses have been generated above the mJ-level. For example, at kHz-repetition rates, they hold the promise for new exciting experiments in the field of attosecond physics. Maintaining measurement and integration times within a reasonable interval of a few minutes is crucial for attosecond spectroscopy. Short-pulse-pumping of optical parametric chirped pulse amplification has demonstrated successfully its capability for highly efficient ultra-broadband optical parametric amplification to generate few-cycle pulses. Therefore the prerequisite for short-pulse-pumped OPCPAs as high harmonic driver sources for attosecond spectroscopy are ps-lasers with kHz repetition rates, high pulse energies and as a result high average powers. The symposium will focus on new developments of OPA/OPCPA systems, on pump laser technology and as an addition on applications for few-cycle pulses.

Invited Speakers

Giulio Cerullo, *Politecnico di Milano, Italy*
Tunable Few-optical-Cycle Pulses by Group-velocity-matched OPAs

Hannieh Fattahi, *Max Planck Inst. of Quantum Optics, Germany*
Third-generation Femtosecond Technology

Franz Kaertner, *Univ. of Hamburg DESY, Germany; MIT, USA*
High Energy and Power Optical Waveform Synthesizers

Uwe Morgner, *Leibniz Universität Hannover, Germany*
Few-Cycle and Phase Stable OPCPA Systems with High Repetition Rate

Applications & Technology Topical Reviews

Advances in Molecular Imaging

Wednesday, 13 May, 13:00–17:30
Executive Ballroom 210H, San Jose Convention Center

Organizer
Javier A. Jo, *Texas A&M Univ., USA*

Our understanding of the molecular mechanisms associated with disease development and progression has greatly advanced over the last thirty years. This enabled the development of new therapeutic approaches, targeting specific molecular pathways, and matching the genetic profile of each patient. All these led to an urgent need for the development of advanced tool that could enable molecular pathways diagnosis. Fortunately, recent developments in optical imaging instrumentation are facilitating real-time high-resolution in vivo molecular imaging. Advancements in targeted, optically active contrast agents are allowing exquisite levels of molecular specificity.

This topical review will bring together scientists working on the forefront of optical molecular imaging, and therefore will highlight the new advances in the technology meant to improve clinical diagnosis, guide selection of targeted therapy, and evaluate therapy efficacy. Areas to be covered include, but are not limited to advances in instrumentation and algorithms for optical molecular imaging, novel molecular probe design, molecular and functional imaging of normal and diseased tissue, image-guided clinical intervention, and monitoring therapeutic response.

Invited Speakers

Brian Applegate, *Texas A&M Univ., USA*
Ultra High-Resolution Photoacoustic Microscopy Using a Novel Transient Absorption Technique

Yu Chen, *Univ. of Maryland, USA*
Multi-Scale Optical Molecular Imaging

Xavier Intes, *Rensselaer Polytechnic Inst., USA*
Wide-Field Lifetime-Based Förster Resonance Energy Transfer in Live Animals

Xingde Li, *John Hopkins Univ., USA*
Fiber-optic Endomicroscopy for Label-free Optical Histology

Mary Ann Mycek, *Univ. of Michigan, USA*
Label-Free Optical Molecular Imaging for Clinical Tissue Diagnostics

Eric Potma, *Univ. of California Irvine, USA*
Molecular Imaging with Sum-frequency Generation Microscopy

Melissa Skala, *Vanderbilt Univ., USA*
Fluorescence Lifetime Imaging of Cellular Heterogeneity in Cancer Drug Response

Adam Wax, *Duke Univ. USA*
Molecular Contrast in Interferometric Imaging

Optofluidics Microsystems

Wednesday, 13 May, 13:00–17:30
Meeting Room 212 B/D, San Jose Convention Center

Organizer
Xudong Fan, *Univ. of Michigan, USA*

This topical review will serve as an interdisciplinary forum for presenting recent progress in optofluidics that combines photonics and microfluidics for enhanced performance. Emphasis of this special topic will be placed on translating optofluidic technologies to applications. However, basic research, new optofluidic technology development, and theoretical work are also welcome.

Invited Speakers

Stephen Arnold, *NYU Polytechnic School of Engineering, USA*
Real-time Size/Mass Spectrometry in Solution using Whispering Gallery Micro-Global Positioning

Brian Cunningham, *Univ. of Illinois at Urbana-Champaign, USA*
Photonic Crystal Enhanced Microscopy

William McGuigan, *STRATEC Biomedical, USA*
Microfluidic Isolation and Fluorescence Microscopy in a Fully Automated Digital Diagnostic Instrument (SIMOA HD-1)

Lingling Shui, *South China Normal Univ., China*
What Is the Microfluidics Doing in Electrowetting Displays?

Hong Tang, *Yale Univ., USA*
Fluid Coupled Optomechanical Oscillators

High Performance Optics

Friday, 15 May, 08:00–10:00
Executive Ballroom 210E, San Jose Convention Center

Organizer

Vladimir Pervak, *Ultrafast Innovations GmbH[1], Ludwig-Maximillians-Universität Munchen[2; 1,2]Germany*

Multilayer optics is widely used nowadays for broadest range of applications: from relatively simple antireflection coatings on glasses to extremely complicated mirrors in laser systems. Performance requirements employed in modern optical systems often are extreme: the tailored transmission and reflection properties, high laser damage threshold, low scattering and absorption losses, environmental and mechanical stability, controllable phase characteristics on reflection or/and on transmission.

Invited Speakers

Vitaly Gruzdev, *Univ. of Missouri, USA*
Laser-Induced Ionization and Damage of High-Performance Optics by Ultrashort Pulses

Gabriel Tempea, *FEMTOLASERS Produktions, Austria*
Dispersive Mirror Compressors for Few-Cycle Laser Pulses

Michael Trubetskov, *Max Inst. of Quantum Optics, Germany*
Multilayer Optics for Ultrafast Applications

Zhanshan Wang, *Tongji Univ., China*
Laser-induced Damage of Nodular Defects in Dielectric Multilayer Coatings

Short Courses

Short Course Chairs

Sasan Fathpour, *CREOL, Univ. of Central Florida, USA*
Ben Eggleton, *Univ. of Sydney, Australia*

The CLEO: 2015 Short Course Program includes a range of topics at a variety of educational levels. Widely recognized experts in industry and academia lead attendees in building skills and/or achieving new insight, and the small-classroom setting provides a tremendous, interactive learning opportunity. Short Courses are an excellent opportunity to learn about new products, cutting edge technology and vital information at the forefront of the laser science and electro-optics fields.

Certificates of Attendance are available for those who register and attend a course. You may request a certificate upon completion of the online course evaluation. If you have any questions about receiving a Certificate of Attendance or completing the course evaluation, please email *shortcourses@cleoconference.org* with your name and course name(s).

Sunday, May 10

08:30–11:30

SC424 Optical Terahertz Science and Technology
Instructor: David G. Cooke, *McGill Univ., Canada*

08:30–12:30

SC149 Foundations of Nonlinear Optics
Instructor: Robert Fisher; *R. A. Fisher Associates, USA*

SC221 Nano Photonics: Physics and Techniques
Instructor: Axel Scherer; *Caltech, USA*

SC361 Coherent MidInfrared Sources and Applications
Instructor: Konstantin Vodopyonov; *CREOL, The College of Optics & Photonics, Univ. Central Florida, USA*

13:30–17:30

SC157 Laser Beam Analysis, Propagation, and Shaping Techniques
Instructor: James Leger; *Univ. of Minnesota, USA*

SC378 Introduction to Ultrafast Optics
Instructor: Rick Trebino; George Inst. of Technology, USA

SC396 Frontiers of Guided Wave Nonlinear Optics
Instructor: Ben Eggleton; *Univ. of Sydney, Australia*

14:00–17:00

SC403 NanoCavity Quantum Electrodynamics and Applications
Instructor: Jelena Vuckovic; *Stanford Univ., USA*

Monday, 11 May

12:00–16:00

SC270 High Power Fiber Lasers and Amplifiers
Instructor: W. Andrew Clarkson; *Optoelectronics Res. Ctr., Univ. of Southampton, UK*

SC301 Quantum Cascade Lasers: Science, Technology, Applications and Markets
Instructor: Federico Capasso; *Harvard Univ., USA*

13:00–16:00

SC271 Quantum Information—Technologies and Applications
Instructors: Paul Toliver[1] and Gregory Kanter[2,3]; [1]*Applied Communication Sciences, USA,* [2]*NuCrypt, LLC, USA* [3]*Northwestern University, USA*

SC376 Plasmonics
Instructor: Mark Brongersma; *Stanford Univ., USA*

Tuesday, 12 May

09:00–12:00

SC352 Introduction to Ultrafast Pulse Shaping—Principles and Applications
Instructor: Marcos Dantus; *Michigan State Univ., USA*

SC362 Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light
Instructor: Tobias Kippenberg; *Ecole Polytechnique Federale de Lausanne, Switzerland*

SC410 Finite Element Modelling Methods for Photonics and Optics
Instructor: Arti Agrawal; *City Univ., UK*

“ *This short course contained a lot of useful information and was very information heavy. Despite the large amount of technical material, the presenter clearly conveyed all of the information without the course feeling rushed or overly dense.* ”

— SC301 Short Course Attendee

Short Course Descriptions

Courses are listed by date and time. Complete **course description**s are available at *www.cleoconference.org/shortcourses.*

Instructors have designated a course level to help you select a course that best fits your educational background and goals.

Beginner: No background or minimal training is necessary to understand course material.

Advanced Beginner: Basic understanding of topic is necessary to appreciate course material.

Intermediate: Prior knowledge of topic is necessary to follow course material.

SC424 Optical Terahertz Science and Technology

Sunday, 10 May, 08:30–11:30
David G. Cooke, *McGill Univ., Canada*

Level: Advanced Beginner

Course Description

The purpose of this short course is to introduce time-domain optical techniques based on femtosecond lasers for generating, manipulating and detecting light in the 0.1 – 10 THz region, and demonstrate how this interesting part of the spectrum can be used to improve our understanding of materials. I will discuss THz imaging and sensing applications that are driving the development of this technology and discuss new physics that can be probed with short pulses of THz light.

Course outline:

- The THz spectrum
- Optical methods for THz generation
- Techniques for THz detection
- Optics for THz light
- THz waveguides
- THz imaging
- THz time-domain spectroscopy
- Applications of THz light

Benefits and Learning Objectives

This course should enable you to:

- Explain methods for the generation and detection of coherent terahertz radiation
- Explain and apply methods for terahertz time - domain spectroscopy
- Understand the physical phenomena taking place on the picosecond - time scale
- Gain hands-on experience with advanced experimental equipment and numerical tools
- Understand and explain the pump - probe techniques for time-resolved spectroscopic measurements in the terahertz range
- Explain and interpret experimental measurements based on the theoretical models

Intended Audience

This course is aimed at graduate students interested in the field of time-domain THz spectroscopy and imaging techniques. Basic knowledge of electromagnetic waves and condensed matter systems is suggested.

SC149 Foundations of Nonlinear Optics

Sunday, 10 May, 08:30–12:30
Robert Fisher; *R. A. Fisher Associates, USA*

Level: Beginner

Course Description

This introductory and intermediate level course provides the basic concepts of nonlinear optics. Although some mathematical formulas are provided, the emphasis is on simple explanations. It is recognized that the beginning practitioner in nonlinear optics is overwhelmed by a constellation of complicated nonlinear optical effects, including second-harmonic generation, optical Kerr effect, self-focusing, self-phase modulation, self-steepening, fiberoptic solitons, chirping, stimulated Raman and Brillouin scattering, and photorefractive phenomena. It is our job in this course to demystify this daunting collection of seemingly unrelated effects by developing simple and clear explanations for how each works, and learning how each effect can be used for the modification, manipulation, or conversion of light pulses. Examples will address the nonlinear optical effects that occur inside optical fibers, and those which occur in liquids, bulk solids, and gases.

Benefits and Learning Objectives

This course should enable you to:

- Define and manipulate the Slowly-Varying Envelope Approximation (SVEA)
- Recognize what nonlinear events come into play in different effects
- Appreciate the intimate relationship between nonlinear events which at first appear quite different
- Discuss how a variety of different nonlinear events arise, and how they affect the propagation of light
- Explain how wavematching, phase-matching, and index matching are related
- Summarize how self-phase modulation impresses "chirping" on pulses
- Describe basic two-beam interactions in photorefractive materials
- Develop an appreciation for the extremely broad variety of ways in which materials exhibit nonlinear behavior

Intended Audience

Although we start at the very beginning of each topic, we move quite rapidly in order to grasp a deep understanding of each topic. Therefore both beginners and intermediates will benefit greatly from this course. The material will be of interest to graduate students, to researchers, to members of the legal profession, to experts who are just transferring to this field, to managers, and to anyone else who just wants to learn how nonlinear optics works.

SC221 Nano Photonics: Physics and Techniques

Sunday, 10 May, 08:30–12:30
Axel Scherer; *Caltech, USA*

Level: Intermediate

Course Description

Students will learn about the applications of printed and integrated optical devices. In particular, optical microcavities and vertical cavity lasers, silicon photonics and plasmonic systems will be introduced and compared. Integrated opto-electronic and opto-fluidic systems for communications and biomedical sensing will be compared.

Benefits and Learning Objectives

This course should enable you to:

- Compare dielectric (total internal reflection and Bragg reflectors) with metallic (surface plasmon) geometries for confining and guiding light
- Identify opportunities for using printed optical systems in silicon (silicon photonics)
- Describe methods for creating quantum-mechanical systems from optical nanostructures
- Design lithographically defined micro- and nanocavities for resonators and lasers
- Define applications of printed optics in biochemical sensing
- Summarize the evolution of printed optical integrated circuits and devices, such as modulators and switches
- Determine the applications of interdisciplinary integration of optics with electronics and fluidics
- Describe optical performance of semiconductor structures when these are made with nanoscale dimensions

Intended Audience

This course is designed for participants with interest in miniaturizing optical devices. Methods of microfabricating dielectric and plasmonic devices will be described, along with examples of their applications and description of future opportunities.

SC361 Coherent MidInfrared Sources and Applications

Sunday, 10 May, 08:30–12:30
Konstantin Vodopyonov, *CREOL, The College of Optics & Photonics, Univ. Central Florida, USA*

Level: Intermediate

Course Description

The course covers fundamental principles of mid-IR generation and considers different approaches for producing coherent light in this important yet challenging spectral region. These techniques represent diverse areas of photonics and include rare earth and transition metal solid-state lasers, fiber lasers, semiconductor lasers (including intra- and intersubband cascade lasers), and laser sources based on nonlinear optical frequency conversion. The course reviews several emerging technologies such as supercontinuum and frequency combs generation. It will cover several important mid-IR applications including trace molecular sensing and standoff detection, coherent spectroscopy using frequency combs, biomedical applications and others.

Benefits and Learning Objectives

This course should enable you to:

- Identify direct mid-IR laser sources including rare earth and transition metal solid-state lasers, fiber lasers, semiconductor heterojunction and quantum cascade lasers
- Identify laser sources based on nonlinear-optical techniques including optical parametric oscillators and amplifiers, and get the idea of emerging nonlinear materials such as quasi-phase-matched zinc-blende crystals
- Distinguish between different temporal formats of existing mid-IR laser sources, from continuous-wave to ultrafast
- Understand what are frequency combs and how they can be used for advanced mid-IR spectroscopic detection
- Summarize the benefits of each technique for producing mid-IR and choose which of them is most suitable for a given task.

Intended Audience

Students, academics, researchers and engineers in various disciplines who require a broad introduction to the subject and would like to learn more about the state-of-the-art and upcoming trends in mid-infrared coherent source development and applications. Undergraduate training in engineering or science is assumed.

SC157 Laser Beam Analysis, Propagation, and Shaping Techniques

Sunday, 10 May, 13:30–17:30
James Leger, *Univ. of Minnesota, USA*

Level: Beginner

Course Description

The performance of conventional high power lasers is often compromised by one or more physical effects, limiting the maximum power that can be obtained from a single lasing element. To increase the power from these individual elements, laser beam combining can be employed to convert the outputs from several lower-power modules into a single, high-power beam. This short course establishes general beam combining principles relevant to all laser systems, and emphasizes the limits that are achievable with different approaches. The practicing engineer and technical manager will be introduced to a wide variety of beam combining methods. Incoherent beam combining attempts to maximize the radiance of an array of incoherent sources. The theoretical limits of this approach will be derived, and a design methodology developed to achieve maximum radiance. Spectral and polarization beam combining techniques employ wavelength and polarization sensitive elements to sum laser power. Several practical issues of this technique will be discussed, and specific systems described. Coherent beam combining is introduced by exploring methods of establishing mutual coherence across laser arrays. The properties and characteristics of these coherent techniques are quantitatively analyzed using simple modal theories. Methods of converting arrays of coherent beams into a single beam are explored, and the sensitivity of these approaches to path length errors investigated. Real-world examples will be used as case studies to illustrate design principles. This offering of the course will make use of recently developed material on coherent beam combining architectures.

Benefits and Learning Objectives

This course should enable you to:

- Describe the requirements for laser beam combining of all types
- Estimate the optimum brightness enhancement achievable from incoherent combining
- Design an ideal incoherent beam combiner
- Design spectral beam combiners and estimate performance limitations
- Compare different architectures for establishing mutual coherence across laser arrays
- Determine the effects of path length errors on beam combining performance
- Design optical systems to convert coherent arrays of laser beams into a single beam
- Describe the performance characteristics of several laser systems that utilize beam combining

Intended Audience

The course is designed for students, engineers, scientists and technical managers who are interested in understanding the basics of laser beam combining. No advanced knowledge of laser systems is assumed.

SC378 Introduction to Ultrafast Optics

Sunday, 10 May, 13:30–17:30
Rick Trebino; Georgia Inst. of Technology, USA

Level: Beginner

Course Description

Ultrafast Optics—the science and technology of ultrashort laser pulses—is one of the most exciting and dynamic fields of science. While ultrashort laser pulses seem quite exotic (they're the shortest events ever created!), their applications are many, ranging from the study of ultrafast fundamental events to telecommunications to micro-machining to biomedical imaging, to name a few. Interestingly, these lasers are readily available, and they are easy to understand. But their use requires some sophistication. This course is a basic introduction to the nature of these lasers and the pulses they generate. It will discuss the principles of their generation and amplification and describe their most common distortions in space and time and how to avoid them—or take advantage of them. In addition, it will cover the nonlinear optics of ultrashort pulses for converting pulses to almost any color, as well as the additional interesting and potentially deleterious effects nonlinear optical processes can cause. Finally, it will cover techniques for ultrashort-pulse measurement.

Benefits and Learning Objectives

This course should enable you to:

- Understand how ultrashort-pulse lasers and amplifiers work.
- Understand and describe ultrashort pulses and their many distortions.
- Use nonlinear optics to convert ultrashort laser pulse to virtually any wavelength.
- Take advantage of, or avoid, nonlinear-optical high-intensity effects.
- Meaningfully measure ultrashort pulses.

Intended Audience

Any scientist or engineer interested in the science and technology of the shortest events ever created, especially those new to it.

SC396 Frontiers of Guided Wave Nonlinear Optics

Sunday, 10 May, 13:30–17:30
Instructor: Ben Eggleton, *Univ. of Sydney, Australia*

Level: Advanced Beginner

Course Description

This course will review recent research and applications in the field of nonlinear guided wave optics with emphasis on both fundamentals and emerging applications. Starting from a strong foundation in the principles of nonlinear optics, I will review recent progress in emerging nonlinear optical platforms with an emphasis on the different materials, including silicon, chalcogenide, III-V semiconductors, lithium niobate, photonic crystal fibres, nanophotonic circuits and others. I will establish key figures of merit for these different material systems and a general framework for nonlinear guided wave optics with emphasis on the applications in emerging areas of science and technology. I will then review recent progress and breakthroughs in the following areas: All-optical processing; Ultra-fast optical communications; Slow light; highly nonlinear and emerging waveguides; Ultrafast measurement and pulse characterization; Frequency combs and optical clock; Optical parametric amplifiers and oscillators; Generation and applications of optical super-continuum; Nonlinear localization effects and solitons; Nonlinear optics for quantum information.

Benefits and Learning Objectives

This course should enable you to:

- Discuss state of the art knowledge of nonlinear optics in emerging waveguides and materials
- Explain the applications of nonlinear optics in key applications
- Describe the foundation of nonlinear waveguide physics for emerging applications and science

Intended Audience

This course assumes some basic knowledge/familiarity of nonlinear optics. Individuals lacking such knowledge should consider taking SC149: Foundations of Nonlinear Optics first.

SC403 NanoCavity Quantum Electrodynamics and Applications

Sunday, 10 May, 14:00–17:00
Jelena Vuckovic, *Stanford Univ., USA*

Level: Beginner

Course Description

Strong localization of light in nanophotonic structures leads to enhanced light-matter interaction, which can be employed in a variety of applications, ranging from improved (higher speed, lower threshold) optoelectronic devices, to biophotonics, quantum information, and low threshold nonlinear optics.

In particular, quantum dots in optical nanocavities are interesting as a test-bed for fundamental studies of such light-matter interaction (cavity quantum electrodynamics - QED), as well as an integrated platform for information processing. As a result of the strong field localization inside of sub-cubic wavelength volumes, they enable very large emitter-field interaction strengths (vacuum Rabi frequencies in the range of 10's of GHz – a few orders of magnitude larger than in atomic cavity QED). In addition to the study of new regimes of cavity QED, this can also be employed to build devices for quantum information processing, such as ultrafast quantum gates, nonclassical light sources, and spin-photon interfaces. Beside quantum information systems, many classical information processing devices greatly benefit from the enhanced light matter interaction in such structures; examples include all-optical switches operating at the single photon level, electro-optic modulators controlled with sub-fJ energy and operating at GHz speed, and lasers with threshold currents of 100nA.

This course will introduce cavity QED (e.g., strong and weak coupling regimes, Purcell effect, etc.), with particular emphasize on semiconductor nanocavities. We will also describe state of the art in solid state cavity QED experiments and applications.

Benefits and Learning Objectives

This course should enable you to:

- Explain light matter interaction in optical nanostructures
- Discuss state of the art in solid state cavity QED
- Identify benefits of employing nano-cavity QED for certain applications

Intended Audience

Scientists and engineers interested in cavity QED and nanophotonic devices in general. Some background in electromagnetics, quantum mechanics, and optoelectronics is helpful, but not required.

SC270 High Power Fiber Lasers and Amplifiers

Monday, 11 May, 12:00–16:00
W. Andrew Clarkson, *Optoelectronics Res. Ctr., Univ. of Southampton, UK*

Level: Beginner

Course Description

Recent advances in cladding-pumped fiber lasers and amplifiers have been dramatic, leading to unprecedented levels of performance in terms of output power, efficiency, beam quality and wavelength coverage. These achievements have attracted growing interest within the community and have fueled thoughts that fiber-based sources may one day replace conventional "bulk" solid-state lasers in many application areas. The main attractions of cladding-pumped fiber sources are derived directly from their geometry, which simultaneously allows very efficient generation of coherent light and almost complete immunity from the effects of heat generation, which are so detrimental to the performance of other types of lasers.

This course aims to provide an introduction to high power fiber lasers and amplifiers, starting from the basic principles of operation and ending with examples of current state-of-the-art devices and some thoughts on future prospects. The course will cover a range of topics, including basic fiber laser and amplifier theory, spectroscopy of the relevant rare earth ions for high power devices, a discussion of the factors influencing laser and amplifier performance, fiber design and fabrication, pump sources and pump launching schemes, fiber resonator design, master-oscillator and power-amplifier configurations, linewidth control and wavelength selection, transverse mode selection, nonlinear loss processes (SBS and SRS) and their impact on performance, and heat generation and its impact on power scalability. The course will also give an overview of techniques (e.g. coherent and spectral beam combining) for further scaling of output power and provide an introduction to hybrid fiber-bulk laser schemes for scaling pulse energy.

Benefits and Learning Objectives

This course should enable you to:

- Calculate threshold pump power and slope efficiency, and estimate the maximum output power that can be obtained from a given fiber laser oscillator or amplifier configuration
- Select the optimum pump source for a given rare earth ion transition and fiber design
- Design the pump light collection and coupling scheme and estimate the pump launch efficiency
- Specify the fiber parameters (e.g. cladding design, core size, rare earth ion concentration) required for a particular laser or amplifier configuration
- Design the fiber laser resonator and amplifier and select the operating wavelength
- Estimate thermally induced damage limit
- Estimate the power scaling limit
- Measure fiber laser performance characteristics and relate these to fiber design and resonator parameters

Intended Audience

This course is intended for individuals with a basic knowledge of lasers and optics who wish to learn about the basic principles and capabilities of fiber lasers and amplifiers when operating at high power levels. The course will also cover some of the practical issues of operating these devices and provide an update for those wishing to learn about some of the latest developments in this rapidly advancing field.

SC301 Quantum Cascade Lasers: Science, Technology, Applications and Markets

Monday, 11 May, 12:00–16:00
Federico Capasso, *Harvard Univ., USA*

Level: Beginner

Course Description

Quantum Cascade Lasers (QCLs) are fundamentally different from diode lasers due to their physical operating principle, which makes it possible to design and tune their wavelength over a wide range by simple tailoring of active region layer thicknesses, and due to their unipolar nature. Yet they use the same technology platform as conventional semiconductor lasers. These features have revolutionized applications (spectroscopy, sensing, etc.) in the mid-infrared region of the spectrum, where molecules have their absorption fingerprints, and in the far-infrared or so called Terahertz spectrum. In these regions until the advent of QCLs there were no semiconductor lasers capable of room temperature operation in pulsed or CW, as well high output power and stable/wide single mode tunability. The unipolar nature of QCL, combined with the capabilities of quantum engineering, leads to unprecedented design flexibility and functionality compared to other lasers. The physics of QCLs, design principles, supported by modeling, will be discussed along with the electronic, optical and thermal properties. State-of-the-art performance in the mid- IR and Terahertz will be reviewed. In particular high power CW room temperature QCLs, broadly tunable QCL, short wavelength MWIR QCLs and recent breakthroughs in THz room temperature operation will be presented. A broad range of applications (IR countermeasures, stand-off detection, chembio sensing, trace gas analysis, industrial process control, medical and combustion diagnostics, imaging, etc.) and their ongoing commercial development will be discussed.

Benefits and Learning Objectives

This course should enable you to:

- Describe underlying QC laser physics, operating principles and fundamental differences between standard semiconductor lasers and QC lasers
- Explain quantum design of the key types of QC lasers, which have entered real world applications, and how their electrical and optical properties can be tailored to optimize performance in the mid-infrared and THz regions.
- Discuss experimental device performance, including physical limits, design constraints and comparison with theory and determine device characteristics (current-voltage and light-current curves; differential and power efficiency, threshold, gain and losses; spectral behavior, single mode operation; high speed operation)
- Explain the basics of QC laser device technology: fabrication process, materials growth options
- Illustrate the basics of a chemical sensing system; discuss applications of state-of the-art mid-infrared QC lasers to sensing and present several examples of QC laser commercialization
- Discuss current and future markets of QC lasers

Intended Audience

Graduate students; qualified undergraduates (mostly senior level) majoring in EE or physics/applied physics; researchers in industry, academia and government labs; engineers, sales reps and technical managers.

Education: Undergraduate degree or a PhD or pursuing a PhD in EE, Physics or Applied Physics, with knowledge of introductory level semiconductor devices.

SC271 Quantum Information–Technologies and Applications

Monday, 11 May, 13:00–16:00
Paul Toliver[1] and Gregory Kanter[2,3]; [1]*Applied Communication Sciences, USA,* [2]*NuCrypt, LLC, USA* [3]*Northwestern University, USA*

Level: Advanced Beginner

Course Description

This course will describe how quantum signals are used in applications such as quantum key distribution and the enabling technologies employed in such systems. The concept of entanglement will be introduced and its essential role in quantum communications will be elucidated. The course will then describe the various technologies that are maturing rapidly for the practical realization of quantum communications. Techniques for generating, distributing, and measuring entanglement in the near infrared part of the optical spectrum for free-space applications and in the 1550 nm wavelength band for applications over the standard optical fiber will be described. Particular emphasis will be placed on the application of quantum communications to quantum cryptography. In the context of quantum cryptography, the objective of key generation/distribution will be differentiated from that of direct data encryption at high speeds. Both single-photon based quantum key distribution approaches and high data-rate quantum data encryption techniques will be described. Recent progress in demonstrations of quantum communications technologies in optical transmission links and quantum network testbeds, both fiber-based and using free-space optical approaches, will be presented. The course will also examine commercial activity in quantum technologies as well as provide considerations for compatibility with conventional optical networking technologies. It will conclude with an outlook on the possible adoption of the quantum technologies in future optical networks and systems.

Benefits and Learning Objectives

This course should enable you to:

- Compare and contrast quantum communication versus classical communication.
- Describe the concept of entanglement and its role in quantum communication.
- Summarize the state-of-the-art of single photon detector technology
- Utilize techniques for generating entanglement in the various optical bands.
- Explain the practicality of quantum cryptography for free-space, as well as fiber-based, optical networks.
- Explore new applications of conventional technologies with knowledge of the current status of research and commercial activities in quantum technologies.

Intended Audience

The audience may include optical networking and optoelectronic technology researchers with an interest in quantum communications, as well as managers of research groups and engineers who want a glimpse into the new and forward-looking technologies in the optical arena. An undergraduate-level understanding of quantum mechanics would be helpful.

SC376 Plasmonics

Monday, 11 May, 13:00–16:00
Mark Brongersma, *Stanford Univ., USA*

Level: Beginner

Course Description

Plasmonics is an exciting new field of science and technology that aims to exploit the unique optical properties of metallic nanostructures to enable routing and active manipulation of light at the nanoscale. Nanometallic objects derive these properties from their ability to support collective electron excitations, known as surface plasmons (SPs). Presently we are witnessing an explosive growth in both the number and range of plasmonics applications; it is becoming eminently clear that both new fundamental science and device technologies are being enabled by the current plasmonics revolution. The intention of this tutorial is to give the participants a fundamental background and working knowledge of the main physical ideas used in plasmonics, as well as an overview of modern trends in research and applications.

The course will begin with a general overview of the field of plasmonics. This will be followed by an introduction to the basic concepts that enable one to understand and design a range of plasmonic functionalities. This part will be followed by an in-depth discussion of a range of active and passive plasmonic devices that have recently emerged. Particular attention will be given to nanometallic structures in which surface plasmons can be generated, routed, switched, amplified, and detected. It will be shown that the intrinsically small size of plasmonic devices directly results in higher operating speeds and facilitates an improved synergy between optical and electronic components. The field of plasmonics is rapidly growing and has started to provide a whole range of exciting new research and development opportunities that go well beyond chipscale components. A number of such developments will be investigated, including new types of optical sensors, solar cells, quantum plasmonic components, nonlinear, and ultrafast devices. At the end of the course, a critical assessment of the entire field is given and some of the truly exciting new opportunities for plasmonics are identified.

Benefits and Learning Objectives

This course should enable you to:

- Identify key physical concepts used in Plasmonics that enable light manipulation at ultra small length- and time-scales.
- Explain choices of different metal types, shapes, and sizes to accomplish different plasmonic functionalities.
- Summarize common electromagnetic computational tools to design plasmonic structures and devices.
- Discuss the current state of the field in terms of fundamental understanding as well as device applications.
- Discuss the most recent trends and developments in research and applications.

Intended Audience

Optical engineers and scientists who are interested in learning about the rapidly emerging field of plasmonics and its potential impact. A basic knowledge of electromagnetism will be very helpful.

SC352 Introduction to Ultrafast Pulse Shaping–Principles and Applications

Tuesday, 12 May, 09:00–12:00
Marcos Dantus, *Michigan State Univ., USA*

Level: Beginner and Advanced Beginner

Course Description

This course begins by describing pulse shaping with a hands-on computer simulation that allows one to get a sense of how femtosecond pulses change in response to different phases and amplitudes. The essential physics and a brief background of the development of shapers are provided. The course goes over the experimental implementation requirements and then covers some of the most salient applications of pulse shapers, among them: (a) pulse compression, (b) pulse characterization, (c) creation of two or more pulse replicas, and (d) control of nonlinear optical processes such as selective two-photon excitation and selective vibrational mode excitation (e) material processing, (f) microscopy and others.

Benefits and Learning Objectives

This course should enable you to:

- Gain a better understanding of femtosecond laser pulses and their applications
- Learn pulse shaper design principles
- Compare among different pulse shaper designs and determine which one is best suited for a particular application
- Simulate the output pulse from a pulse shaper given a particular phase and amplitude modulation
- Predict the effect caused by introducing a simple phase such as a linear, quadratic or cubic function on a transform-limited pulse
- Learn two different approaches to creating pulse replica that can be independently controlled with attosecond precision in the time domain using the pulse shaper
- Measure the spectral phase of laser pulses using the pulse shaper itself as the measurement tool, and eliminating phase distortions to compress the output pulses
- Summarize the advantages of having an adaptive pulse shaper for controlling the output of ultrafast lasers

Intended Audience

This course, updated yearly, is intended for everyone that uses or intends to use femtosecond laser pulses in academic research or industry. Attendees will learn how pulse shaping can greatly enhance femtosecond laser applications. No prior knowledge about pulse shaping is required.

SC362 Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light

Tuesday, 12 May, 09:00–12:00
Tobias Kippenberg, *Ecole Polytechnique Federale de Lausanne, Switzerland*

Level: Advanced Beginner

Course Description

Radiation pressure denotes the force that optical fields exert and which have wide ranging applications in both fundamental science and applications such as Laser cooling or optical tweezers. Radiation pressure can however also have a profound influence on micro- and nanophotonic devices, due to the fact that radiation pressure can couple optical and mechanical modes. This optomechanical coupling gives rise to a host of new phenomena and applications in force, displacement and mass sensing. This course is intended to give an introduction of the Physics and Applications of cavity optomechanics and highlight the rapid developments in this emerging field. Optomechanical coupling can be used to both cool and amplify mechanical motion and thereby allow new light driven photon clocks. Optomechanical refridgeration of mechanical modes gives insights into the quantum limits of mechanical motion. In addition radiation pressure coupling enables new ways of processing light – optically enabling optical mixers, delay lines or storage elements. Moreover, the basic limitations of optomechanical displacement measurements, due to quantum noise and practical laser phase noise limitations will be reviewed, relevant across a wide range of sensing experiments.

The course will make contact to practical applications of optomechanics in Metrology (force sensors, mass sensors and light driven optical clocks) and review fundamental design principles of optomechanical coupling and the design of high Q mechanical oscillators. The use of finite element simulations will be covered.

Benefits and Learning Objectives

This course should enable you to:

- Discuss gradient and scattering light forces in micro-cavities and micromechanical systems
- Design high –Q nano-and micro- mechanical oscillators (finite element modeling, FEM)
- Explain the fundamental limits of mechanical Q in NEMS/MEMS
- Explain the fundamental and practical limits of displacement sensors
- Identify applications of optomechanics in mass and force sensing
- Define the basic optomechanical phenomena (amplification, cooling)
- Describe the standard quantum limit (SQL)
- Characterize radiation pressure driven oscillations in terms of fundamental oscillator metrics
- Discuss phase and frequency noise of oscillators
- Explain the influence of phase and amplitude noise of a wide variety of laser systems (fiber lasers, TiSa, diode lasers) in optomechanical systems

Intended Audience

This course is intended for physicists and optical and electrical engineers desiring both focused fundamental knowledge of cavity optomechanical coupling (i.e radiation pressure coupling of light and NEMS/MEMS) but also a view of emerging applications of this new technology. The instruction will be at a level appropriate for graduate students and will assume some basic knowledge of the topic.

SC410 Finite Element Modelling Methods for Photonics and Optics

Tuesday, 12 May, 09:00–12:00
Arti Agrawal, *City Univ., UK*

Course Description

Numerical modelling and simulation of optical devices and components is a key tool in improving performance by reducing time and monetary costs, design optimization and characterization as well as innovating new ideas. Both passive and active devices are modelled and optimized numerically. In some cases simulation is the only way to explore phenomena where technology is not advanced enough for fabrication. The interaction of the optical beam with physical effects such as non-linearity, stress, strain, change in refractive index due to temperature, application of electric fields etc. are now hugely important. Modelling complements experimental work perfectly and almost no research is conducted without it.

The Finite Element (FE) method is one of the most popular and powerful methods for modelling in Photonics. This short course starts with Maxwell's equations and explains the basic principles of numerical modelling, the key assumptions involved. This foundation is used to develop the FE method, including a brief tour of the mathematics. How the method can be applied to various optical devices is discussed in detail. How can physical effects be included with the FE method for modelling is considered. The course ends with an explanation of FE based beam propagation methods and how these can be used to find the evolution of the optical fields.

Some salient features of the short course include:

- Emphasis on practical application of FEM for modelling of devices
- Discussion on developing code
- Perfectly Matched Layer and Periodic boundary condition
- Generating mesh for structures, post-processing of results
- Discussion on popular commercial software such as COMSOL and how to best utilize these

Methods covered include:

- Full vector Finite Element method for modal solutions
- FEM with physical effects
- Finite Element Beam Propagation Methods (FE BPM)

Practical illustrations include:

- Optical fibers including photonic crystal fibers
- Si slot waveguides, nanowires and high index contrast structures

- Bent waveguides and loss
- Plasmonic waveguides
- Second Harmonic generation in waveguides: FE BPM

Benefits and Learning Objectives

This course should enable you to:

- Identify and explain basic principles of numerical modelling in Photonics
- Discuss and explain Full vector Finite Element Method (FEM) for modal solutions
- Discuss FEM with physical effects (non-linearity, stress/strain, acousto-optic, electro-optic effect etc.)
- Discuss Finite Element Beam Propagation Methods (FE BPM)
- Discuss and explain how to incorporate Perfectly Matched Layer and Periodic boundary condition
- Summarize how to generate mesh for structures and post-processing of results
- Discuss popular commercial software such as COMSOL and how to best utilize these
- Discuss the application of the method to practical devices: nano wires, optical fibers, sensors etc.
- Identify the appropriate modeling method for your problem
- Use commercial Finite Element based solvers for simulation incorporating PML boundary conditions as well as write your own code.

Intended Audience

This course is intended for researchers, engineers and students who use simulation in their work in both fundamental and applied aspects of Optics and Photonics, especially for components and devices. The course is useful for members of both academic and industrial institutions. Basic background and familiarity in Optics will be sufficient.

Special Events

OSA Technical Group Poster Sessions

Monday, 11 May, 18:30–19:30
Technical Session Corridor near 210 A-D, San Jose Convention Center

Join the OSA Technical Groups for a series of focused poster sessions. These events will bring together colleagues from the Nanophotonics, Optoelectronics, and Optical Fabrication and Testing Technical Groups for an opportunity to share their latest research findings, exchange ideas, and facilitate collaborations in relevant areas.

- Nanophotonics Technical Group, *Volker Sorger, Chair*
- Optoelectronics Technical Group, *Weidong Zhou, Chair*
- Optical Fabrication and Testing Technical Group, *Rajesh Menon, Chair*

Optical Material Studies Technical Group Networking Event

Monday, 11 May, 18:30–19:30
Meeting Room 211 B/D, San Jose Convention Center

Join members of the Optical Material Studies Technical Group for a chance to learn more about this group and connect with fellow attendees who share an interest in optical materials. This networking event will be hosted by Shekhar Guha and Howard Lee of the technical group's executive committee.

OSA Student Member Happy Hour

Monday, 11 May, 18:30–20:30
South First Billiards, 420 S 1st St

All OSA student members attending CLEO are invited to join OSA for a happy hour! RSVP to chaptersandsections@osa.org. Tickets are first-come, first-served so sign up early.

IEEE Journal of Quantum Electronics Celebrates 50 Years

Tuesday, 12 May, 16:30–18:00
Willow Glen, Marriott

Please join the IEEE Photonics Society as we commemorate the 50th anniversary of the Journal of Quantum Electronics (JQE). Refreshments will be served as Photonics Society President Dalma Novak, current JQE Editor-in-Chief Aaron Hawkins, and Amnon Yariv, one of the journal's founding editors, discuss the evolution of the journal and their vision for its future.

Conference Reception and Poster Session

Tuesday, 12 May, 18:00–20:00
Exhibit Halls, San Jose Convention Center

Sponsored by THORLABS

Enjoy a festive evening with your colleagues, while intermingling with the exhibitors and viewing the first poster session. Full conference technical attendees will receive drink tickets with their registration material and a cash bar will also be available to purchase drinks. The reception is open to all attendees and badges must be worn to enter the reception.

Poster Sessions

Exhibit Halls, San Jose Convention Center

Poster Sessions are an integral part of the Technical program. Each author is provided with a board with six-foot-high by four-foot-wide (183cm x128cm) of usable space on which to display the summary and results of his or her paper. Authors should remain in the vicinity of their presentation board for the duration of the sessions to answer questions from attendees. Authors may set up one hour prior to their assigned session and must remove their poster one hour following the session. Authors may submit their poster PDF for publication, visit page 6 for more information.

*Held jointly with the Conference Reception.

Tuesday, 12 May *	18:00–20:00
Wednesday, 13 May	10:00–12:00
Thursday, 14 May	11:30–13:00

OSA Members, Family and Friends Event

Wednesday, 13 May, 12:30–15:30
The Intel Museum

OSA members and their families are invited to visit The Intel Museum as guests of OSA. The group will have the opportunity to go behind the scenes in the high-tech world of California's famed Silicon Valley. See what it's like inside an ultra-clean, highly automated silicon chip factory, and connect with technologies that give us new ways to work, learn, play, and communicate. The Intel Museum is 10,000 square feet of fun, interactive learning for children and adults. The event is free to OSA members, their families and friends. Children are welcome. To reserve a spot, visit the OSA Membership Booth no later than Tuesday, 12 May at 12:00 to see if space is available.

VIP Industry Leaders Networking Event: Connecting Corporate Executives, Young Professionals and Students

Wednesday, 13 May, 12:00–13:30
Exhibit Hall 3, San Jose Convention Center

Sponsored by GoFoton

This session brings together Industry Executives to share their business experience – from how they started their careers and lessons learned along the way, to using their degree in an executive position – with Young Professionals and Students. The program starts with informal networking during lunch and then transitions into "speed meetings" – small, brief visits with each executive to discuss careers, industry trends or other career topics. This program is free of charge and includes a box lunch for students and young professionals.

Advance registration is required. Contact vipevents@osa.org to register for this event.

Exhibit Happy Hour and International Year of Light Celebration

Wednesday, 13 May, 16:30–18:30
Exhibit Halls, San Jose Convention Center

Sponsored by PHOTONICS MEDIA

Don't miss the new Exhibit Happy Hour and IYL Celebration on the CLEO show floor which will feature special entertainment and a toast to IYL 2015. This will be a perfect time to relax after a full day of sessions and walking the show floor, while networking with exhibitors and colleagues. IYL 2015 was adopted by the United Nations and endorsed by a number of international scientific unions and the International Council of Science. The IYL consortium consists of over 100 major international learned societies, volunteer organizations, and other international bodies from over 85 countries around the world. Be part of IYL 2015 and help promote public understanding of the importance of light in our daily lives and to the development of society.

The happy hour is open to all attendees. Badges must be worn to enter the exhibit hall.

After the happy hour, go to the plenary and awards ceremony to celebrate your colleagues' achievements.

Pizza Lunch at the CLEO:Expo

Thursday, 14 May, 12:30–14:00
Exhibit Halls, San Jose Convention Center

Join your colleagues on the CLEO show floor to enjoy a pizza lunch and a final networking opportunity with the exhibitors.

Postdeadline Paper Sessions

Thursday, 14 May, 20:00–22:00
Locations announced in the Postdeadline Paper Digest

The Technical Program Committee has accepted a limited number of postdeadline papers for oral presentation. The purpose of postdeadline papers is to give participants the opportunity to hear new and significant materials in rapidly advancing areas.

CLEO Committees

CLEO: Applications & Technology

Yu Chen, *Univ. of Maryland at College Park, USA*, **General Chair**
Eric Mottay, *Amplitude Systemes, France*, **General Chair**
Nicusor Iftimia, *Physical Sciences Inc., USA*, **Program Chair**
Christian Wetzel, *Rensselaer Polytechnic Inst., USA*, **Program Chair**

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CLEO A&T 2: Industrial Applications

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CLEO A&T 3: Photonic Instrumentation & Techniques for Metrology & Industrial Process

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CLEO A&T 4: Laser & Photonics Applications for Energy & Environment

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CLEO S&I 1: Light-Matter Interactions and Materials Processing

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Gagan Saini, *Halliburton Energy Services, USA*
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CLEO S&I 2: Advanced Science and Technology for Laser Systems and Facilities

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Bedrich Rus, *ELI-Beamlines, Czech Republic*
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CLEO S&I 3: Semiconductor Lasers

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CLEO S&I 4: Nonlinear Optical Technologies

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CLEO S&I 5: Terahertz Technologies and Applications

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CLEO S&I 6: Optical Materials, Fabrication and Characterization

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CLEO S&I 7: Micro- and Nano-Photonic Devices

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CLEO S&I 8: Ultrafast Optics, Optoelectronics & Applications

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CLEO S&I 9: Components, Integration, Interconnects and Signal Processing

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CLEO S&I 10: Biophotonics and Optofluidics

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CLEO S&I 11: Fiber Photonics

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CLEO S&I 12: Lightwave Communications and Optical Networks

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Malin Premaratne, *Monash Univ., Australia*
Takashi Sugihara, *Mitsubishi Electric Corporation, Japan*
Michael Vasilyev, *Univ. of Texas at Arlington, USA*

CLEO S&I 13: Active Optical Sensing

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Frank K. Tittel, *Rice Univ., USA*
Damien Weidmann, *STFC Rutherford Appleton Lab, UK*
Michael Wojcik, *Space Dynamics Lab, USA*

CLEO S&I 14: Optical Metrology

Axel Ruehl, *Deutsches Elektronen Synchrotron, Germany*, **Subcommittee Chair**
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Youichi Bitou, *National Inst. of Advanced Industrial Science and Technology, Japan*
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Yurii A. Vlasov, *IBM TJ Watson Research Center, USA*, **Program Chair**

FS 1: Quantum Optics of Atoms, Molecules and Solids

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Boris Blinov, *Univ. of Washington, USA*
M. V. Gurudev Dutt, *Univ. of Pittsburgh, USA*
Ping Koy Lam, *Australian National Univ., Australia*
Joshua Nunn, *Univ. of Oxford, UK*
Sergey V. Polyakov, *NIST, USA*
Monika Schleier-Smith, *Stanford Univ., USA*
Holger Schmidt, *Univ. of California Santa Cruz, USA*
James Thompson, *JILA / Univ. of Colorado at Boulder, USA*
Yanhong Xiao, *Fudan Univ., China*
Ite A. Yu, *National Tsing Hua Univ., Taiwan*

FS 2: Quantum Science, Engineering and Technology

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Warren P. Grice, *Oak Ridge National Lab, USA*
Elanor H. Huntington, *Univ. of New South Wales, Australia*
Antia Lamas-Linares, *National Univ. of Singapore, Singapore*
Nathan Kim Langford, *Technische Universiteit Delft, Netherlands*
Kae Nemoto, *National Inst. of Informatics, Japan*
Todd B. Pittman, *Univ. of Maryland Baltimore County, USA*
Qudsia Quraishi, *US Army Research Lab, USA*
Charles M Santori, *Hewlett Packard Company, USA*
Hiroki Takesue, *NTT Basic Research Laboratories, Japan*
Sebastien Tanzilli, *Universite de Nice Sophia Antipolis, France*
Tzu-Chieh Wei, *State Univ. of New York at Stony Brook, USA*

FS 3: Metamaterials and Complex Media

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Filippo Capolino, *Univ. of California Irvine, USA*
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Stefan Linden, *Universitat Bonn, Germany*
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Alejandro Rodriguez, *Princeton Univ., USA*
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Vera Smolyaninova, *Towson Univ., USA*
Alexey G Yamilov, *Missouri Univ of Science & Technology, USA*
Anatoly V Zayats, *Univ of London King's College London, UK*
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FS 4: Optical Excitations and Ultrafast Phenomena in Condensed Matter

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Jeffrey Allan Davis, *Swinburne Univ. of Technology, Australia*
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FS 5: Nonlinear Optics and Novel Phenomena

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FS 6: Nano-Optics and Plasmonics

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FS 7: High-Field Physics and Attoscience

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Jeff Shapiro, *MIT, USA*
Yurii Vlasov, *IBM TJ Watson Research Center, USA*

Invited Speakers

Science & Innovations

S&I 1: Light-matter Interactions and Materials Processing

Cyril Hnatovsky, *Australian National Univ., Australia*
Materials Processing based on Unconventional Femtosecond Laser Beams

Yi Liu, *Laboratoire d'Optique Appliquée, France*
Optical Aspect of Ultrafast Laser Ablation on Transparent Dielectrics: Ciliary White Light

S&I 2: Advanced Science and Technology for Laser Systems and Facilities

John Collier, *STFC Rutherford Appleton Laboratory, UK*
Scaling High Peak Powers to High Average Powers – Opportunities in Innovation and Technology

Alan Fry, *SLAC National Accelerator Laboratory, USA*
Laser Technologies and Challenges for XFEL Beamlines

S&I 3: Semiconductor Lasers

Raffaele Colombelli, *Universite Paris Sud and CNRS, France*
Perspectives for Intersubband Polariton Lasers and Bose-Einstein Condensation of Intersubband Polaritons

Gadi Eisenstein, *Technion Israel Institute of Technology, Israel*
Quantum Coherent Interactions in Room Temperature InAs/InP Quantum Dot Amplifiers

Yong-Hee Lee, *Korea Advanced Inst of Science & Tech, South Korea*
Nanophotonics and Nanolasers

S&I 4: Nonlinear Optical Technologies

Aleksandr Aleksandrovsky, *L.V.Kirensky Institute of Physics, Russia*
Nonlinear Optical Processes and DUV Generation in Random Domain Structures of SBO

Giuseppe Leo, *Universite Paris-Diderot Paris VII, France*
AlGaAs Guided-Wave Optical Parametric Oscillator: Results and Perspectives

Espen Lippert, *Forsvarets Forskningsinstitutt, Norway*
High Power and High Energy Infrared Parametric Sources

Dmitry Strekalov, *Jet Propulsion Lab, USA*
Nonlinear and Quantum Optics with Whispering Gallery Resonators

S&I 5: Terahertz Technologies and Applications

Jure Demsar, *Johannes Gutenberg Universitat Mainz, Germany*
Probing Superconducting Gap Dynamics with THz Pulses

Koichiro Tanaka, *Kyoto Univ., Japan*
Terahertz Nonlinear Magnetic Response in in Antiferromagnets

Alessandro Tredicucci, *Universita di Pisa, Italy*
Coherent Absorption Control in Polaritonic Systems

S&I 6: Optical Materials, Fabrication, and Characterization

Delphine Marris-Morini, *Institut d'Electronique Fondamentale, France*
Optical Interconnects based on Ge/SiGe Multiple Quantum Well Structures

S&I 7: Micro- and Nano-Photonic Devices

Keren Bergman, *Columbia Univ., USA*
Integrated Hardware-Software Implementation of Silicon Photonic Interconnected Computing System

Nader Engheta, *Univ. of Pennsylvania, USA*
Nanophotonic Metastructures: Functionality at the Extreme

A. Mark Fox, *Univ. of Sheffield, UK*
Integrated Photonic Devices with Single Quantum Dots

Philip Russell, *Max-Planck-Inst Physik des Lichts, Germany*
Optomechanical Nonlinearities in Microstructured Optical Fibers

Fengnian Xia, *Yale Univ., USA*
Two-Dimensional Material Nanophotonics

S&I 8: Ultrafast Optics, Optoelectronics, and Applications

Peter Hommelhoff, *Friedrich-Alexander-Universität Erlangen, Germany*
Laser Acceleration of Non-relativistic Electrons at Dielectric Structures: Status and Outlook

Robert Levis, *Temple Univ., USA*
Filament-Based Impulsive Raman Excitation of Vibrational and Rotational Modes of Polyatomic Molecules

Tim Paasch-Colberg, *TOPTICA Photonics, Germany*
Solid State Light Field Sampling and Light Phase Detection

S&I 9: Components, Integration, Interconnects, and Signal Processing

Minghua Chen, *Tsinghua Univ., China*
Silicon-photonics-based Signal Processing for Microwave Photonic Frontends

Shayan Mookherjea, *Univ. of California San Diego, USA*
Nonlinear Integrated Optoelectronics

S&I 10: Biophotonics and Optofluidics

Nils Kronenberg, *Univ. of St. Andrews, UK*
Micro-Cavity based Force Sensors - A Novel and Simple Interferometric Tool for Cell-Mechanical Investigations

Giuliano Scarcelli , *Harvard Medical School, USA*
Brilluoin Microscopy for Tissue and Cell Biomechanics

S&I 11: Fiber Photonics

Ayman Abouraddy, *Univ. of Central Florida, CREOL, USA*
Multimaterial Chalcogenide Fibers and Devices for the Mid-IR

Joss Bland-Hawthorn, *Univ. of Sydney, Australia*
Astrophotonics: The Future of Astronomical Instrumentation

Jungwon Kim, *Korea Advanced Inst. of Science & Tech., South Korea*
Ultralow-jitter Mode-locked Fiber Lasers and their Applications

Patrick Windpassinger, *Johannes Gutenberg Universitat Mainz, Germany*
Towards Nonlinear Optics with Cold Rydberg Atoms Inside a Hollow Core Fiber

Andrew Yablon, *Interfiber Analysis, USA*
Novel Technologies for High Precision Characterization of Fibers

S&I 12: Lightwave Communications and Optical Networks

Takayuki Mizuno, *NTT Network Innovation Lab, Japan*
Dense Space Division Multiplexed Transmission Technology

Tiejun Xia, *Verizon Communications Inc, USA*
High Speed and High Capacity Optical Transport Network Technology

S&I 13: Active Optical Sensing

Bernhard Lendl, *Technische Universität Wien, Austria*
Mid-IR Quantum Cascade Lasers as an Enabling Technology for Analytical Chemistry

Frank Vollmer, *Max-Planck-Inst Physik des Lichts, Germany*
Single Nucleic Acid Interactions monitored with Optical Microcavity Biosensors

S&I 14: Optical Metrology

Kjeld Eikema, *Vrije Univ. Amsterdam, Netherlands*
Ramsey-comb Spectroscopy: Power and Precision Combined

Hidetoshi Katori, *Univ. of Tokyo, Japan*
Frequency Comparisons of Sr, Yb, and Hg based Optical Lattice Clocks and their Application

Applications & Technology

A&T 1: Biomedical Applications

Stephen Boppart, *Univ. of Illinois at Urbana-Champaign, USA*
Finding Bugs in your Ear: Clinical Imaging of Middle-ear Infections and Biofilms using OCT

Robert Campbell, *Univ. of Alberta, Canada*
Engineering the next Generation of Optogenetic Reporters to Illuminate Neuronal Activity

Audrey Ellerbee, *Stanford Univ., USA*
Multipurpose Information Encoding using interleaved Optical Coherence Tomography

Nam Seong Kim, *Lutronic, Inc, South Korea*
Medical Laser Market Overview and Optical Insights on the Laser-tissue Treatments using multiple Wavelengths in Single Medical Laser Equipment

Do-Hyun Kim, *Food and Drug Administration, USA*
Multi-spectral Imaging for Determining End-point of Photo-thermal Damage on Tissue

Seemantini Nadkarni, *Harvard Medical School, USA*
Blood Coagulation Sensing at the Point of Care

Mark Schnitzer, *Stanford Univ., USA*
Visualizing Mammalian Brain Area Interactions by Dual-axis Two-photon Calcium Imaging

Shy Shoham, *Technion Israel Institute of Tech., Israel*
Photonic Interfacing with Large Scale Natural and Bioengineered Neuronal Networks

Yuankai Tao, *Cole Eye Institute, Cleveland Clinic, USA*
Integrative Advances for OCT-Guided Ophthalmic Surgery and Intraoperative OCT

Ping Xue, *Tsinghua Univ., China*
The Ultimate Road to Real Time 3D Optical Coherence Tomography Imaging

Yoshiaki Yasuno, *Univ. of Tsukuba, Japan*
Quantitative Imaging of Tissue Polarization Property by Jones Matrix Optical Coherence Tomography

Seok-Hyun Yun, *Harvard Medical School, USA*
The Cell Laser

A&T 2: Industrial Applications

Ilya Bezel, *KLA-Tencor Corp, USA*
High Power Laser-Sustained Plasma Lightsources for KLA-Tencor Broadband Inspection Tools

Mark Dugan, *Translume, USA*
Microfabrication of Ion Trap Platforms with Integrated Optics and Three-dimensional Electrodes

Lukas Emmenegger, *EMPA, Switzerland*
MIR Spectroscopy beyond Trace Levels - Environmental and Industrial Applications

Akira Endo, *HiLase Center, Czech Republic*
Status and Potential of Laser based EUV Sources

Peter Herman, *Univ. of Toronto, Canada*
Laser Processing of Optofluidic Devices for Lab-on-a-chip and Lab-in-fiber

Tony Hoult, *IPG Photonics Corp, USA*
Lasers in the 2um SWIR spectral regime and their Applications

Seung-Woo Kim, *Korea Advanced Inst of Science & Tech, South Korea*
Advanced optical distance measurements using femtosecond laser pulses.

Stefan Nolte, *Friedrich-Schiller-Universität Jena, Germany*
Ultrashort Pulse Lasers for Precise Processing: Results of a Recent German Research Initiative

Rainer Paetzel, *Coherent GmbH, Germany*
Excimer Laser Annealing for LTPS on Large Substrates

Dimitrij Walter, *MANZ, Germany*
Industrial Processing of Various Materials using Ultrashort Pulsed Laser Sources

A&T 3: Photonic Instrumentation & Techniques for Metrology & Industrial Process

Christopher Chunnilall, *NPL, UK*
Metrology for Quantum Communications

William Kessler, *Physical Sciences Inc., USA*
Diode Laser Spectroscopy based Monitoring of Pharmaceutical Freeze Drying: Linking Measurements to Critical Process Parameters

Mark Witinski, *EOS Photonics, USA*
Monolithic Quantum Cascade Laser Arrays for Broadband Portable Infrared Spectroscopy

A&T 4: Laser & Photonics Applications for Energy & Environment

Roger Angel, *Univ. of Arizona, USA*
High Concentration Solar Photovoltaic Systems using Glass Dish Collectors

Ronald Cohen, *Univ. of California Berkeley, USA*
Observing and Understanding How NO2 Controls the Chemistry of the Atmosphere

Peter Kozodoy, *Glint Photonics, Inc., USA*
Self-Tracking Concentrator for Photovoltaics

Roland Winston, *Univ. of California Merced, USA*
Wide-angle Nonimaging Optics for Concentration and Illumination; Principles and Applications

Tutorial Speakers

Fundamental Science/QELS

FS 1: Quantum Optics of Atoms, Molecules and Solids

Jun Ye, *Univ. of Colorado at Boulder, JILA, USA*
Making the World's Best Atomic Clock

FS 2: Quantum Science, Engineering and Technology

Aephraim Steinberg, *Univ. of Toronto, Canada*
Quantum Measurement Techniques: Modern Approaches and Trends

FS 3: Metamaterials and Complex Media

Xiang Zhang, *Univ. of California Berkeley, USA*
Recent Progress in Optical Metamaterials

FS 4: Optical Excitations and Ultrafast Phenomena in Condensed Matter

Jacqueline Bloch, *CNRS, France*
Manipulating Quantum Fluids of Light in Microstructured Semiconductor Cavities

FS 5: Nonlinear Optics and Novel Phenomena

Immanuel Bloch, *Max Planck Institute of Quantum Optics, Germany*
Probing and Controlling Quantum Matter in Crystals of Light

FS 6: Nano-Optics and Plasmonics

Marin Soljačić, *MIT, USA*
Nanophotonics in Material-systems of Large Sizes

FS 7: High-Field Physics and Attosciences

Ursula Keller, *ETH Zurich, Switzerland*
Attosecond Ionization Dynamics and Time Delays

Science & Innovations

S&I 1: Light-matter Interactions and Materials Processing

Shuji Sakabe, *Kyoto Univ., Japan*
Nano-ablation by Femtosecond Laser-matter Interactions

S&I 2: Advanced Science and Technology for Laser Systems and Facilities

Paul Crump, *Ferdinand-Braun Institute, Germany*
High Power Diode Lasers for Pumping High Energy Solid State Lasers

S&I 3: Semiconductor Lasers

Jerry Meyer, *US Naval Research Laboratory, USA*
High-Brightness Interband Cascade Lasers

S&I 4: Nonlinear Optical Technologies

Martin Fejer, *Stanford Univ., USA*
Engineering Nonlinear Interactions with Aperiodic QPM

S&I 5: Terahertz Technologies and Applications

Matthias Hoffmann, *SLAC National Accelerator Laboratory, USA*
Nonlinear THz Optics and Control in Complex Solids

S&I 6: Optical Materials, Fabrication, and Characterization

S. J. Ben Yoo, *Univ. of California Davis, USA*
Heterogeneous 2D and 3D Photonic Integration for Future Chip-Scale Microsystems

S&I 7: Micro- and Nano-Photonic Devices

Federico Capasso, *Harvard Univ., USA*
Nanophotonics on Metasurfaces

S&I 8: Ultrafast Optics, Optoelectronics, and Applications

F Omer Ilday, *Bilkent Univ., Turkey*
Nonlinearity Engineering with Ultrafast Lasers and Photonic Systems

S&I 9: Components, Integration, Interconnects, and Signal Processing

Lute Maleki, *OEwaves Inc, USA*
Selected Applications of Ultra-high Q Whispering Gallery Mode Resonators

S&I 10: Biophotonics and Optofluidics

Susan Cox, *King's College London, UK*
Accelerating Localisation Microscopy

S&I 11: Fiber Photonics

Benjamin Eggleton, *Univ. of Sydney, Australia*
New Directions for Chip-based Nonlinear Optics

S&I 12: Lightwave Communications and Optical Networks

Stojan Radic, *Univ. of California, San Diego, USA*
Optical and Hybrid Signal Processing

S&I 13: Active Optical Sensing

Ronald Hanson, *Stanford Univ., USA*
Advances in Tunable Diode Laser Absorption Spectroscopy (TDLAS) for Measurements of Gas Properties in Combustion Systems

S&I 14: Optical Metrology

Nathan Newbury, *NIST, USA*
Frequency and Timing Distribution using Optical Methods

Applications & Technology

A&T 3: Photonic Instrumentation & Techniques for Metrology & Industrial Process

Richard Crocombe, *Thermo Fisher Scientific, USA*
Miniature and Handheld Spectroscopic Instruments for Chemical Sensing and Security Applications: Enabled by Photonics