The National Ignition Facility (NIF) & Photon Science Directorate at Lawrence Livermore National Laboratory, USA

A Nanophotonic Interconnect for High-Performance Many-Core Computation
A simplified schematic example of an optical arbitration network used to provision four system resources. This scheme can run in parallel to (and independently from) the network used to transmit data between the cores. For example, each transmitter can determine whether a particular target receiver is available without communicating with the receiver.
Welcome to the June LEOS Newsletter! This month, we have a feature article by Ray Beausoleil and colleagues at HP Laboratories describing a nanophotonic interconnect concept that has great promise for improved computing performance. We also have a summary of ongoing work in photonics at Lawrence Livermore National Laboratory in the United States, including the National Ignition Facility, home of the largest and highest-energy laser in the world.

LEOS conferences provide excellent opportunities to interact with fellow members and keep current with the latest technology. Given the large number of LEOS meetings, most members cannot attend them all, so we are presenting summaries and previews of meetings whenever possible. This month, we present highlights of the LEOS Winter Topical Meetings that took place in Sorrento, Italy in January, and offer a preview of ECOC which will be held in Brussels, Belgium in September.

We are also having a contest! LEOS often uses figures and images related to photonics in promoting the society. What better source of material than our members? Look for the contest announcement and details in this issue and on the LEOS Web Portal.

As always, please feel free to send any comments and suggestions to k.parameswaran@ieee.org. I would love to hear what you would like to see in future issues.

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I am writing this column shortly before the Conference on Laser and Electro-Optics (CLEO) held at the start of May in San Jose. This venue is a new venue for CLEO, located in the heart of Silicon Valley, and it will be interesting to see what impact the location will have on the meeting. The early indicators are auspicious; the number of submitted papers has increased and, in order to accommodate the best of them, the length of the conference day has been extended. Furthermore, the number of technical pre-registrations was significantly higher than at either the 2007 (Baltimore) and 2006 (Long Beach) meetings.

In reality three conferences are co-located in San Jose: CLEO itself, the conference on Quantum Electronics and Laser Science (QELS) and the conference on Photonic Applications Systems and Technologies (PhAST). PhAST is possibly the least prominent of these events, but is the conference experiencing the biggest changes. Historically, PhAST has been well attended, but principally by CLEO/QELS attendees. One of the aims of PhAST is to have a broad appeal and attract attendees in its own right. I have had the privilege of being one of this year’s PhAST co-chairs, along with David Roh, Andrew Masters, and David Huff. As in previous years there are three parallel sessions, but this year one of them has been organized entirely by the Optoelectronics Industry Development Association (OIDA). As a result two of the parallel sessions address product development while the OIDA session addresses business development.

The Product Development Sessions are:
- Lasers and LED Displays
- High-Power Semiconductor Lasers
- Trends in High-Power Diode Lasers
- Lasers in Manufacturing
- Laser Applications in the Photovoltaic Market

The Business Development Sessions are:
- Organic LED Technology for Lighting
- Business Growth for OLED Lighting
- Organic LEDs for Low Power Displays
- Organic Solar Cells
- Inorganic Solar Technology and Economics
- New Solar Technologies for Grid Parity

There is clearly some overlap, and hence synergy, between the two groups of topics, particularly in LEDs and photovoltaics, and it is therefore possible for attendees to cross between highly technical talks and business sessions addressing the same topics.

In my April column, I described how LEOS is developing a long term strategic plan, and that a Strategic Planning Workshop would be taking place at OFC. I view development and implementation of this plan as a key goal of my Presidency. I also believe LEOS can and should build activity in more application areas. As I write this column, the Strategic Plan has just been approved by the Board of Governors meeting at CLEO.

The goal for Technical Affairs is as follows:
"Photonics practitioners will consider that LEOS activities reflect the full scope of science, technology, and applications of photonics"

with the following objectives:
1. Improve response time for identifying emerging photonic technologies.
2. Increase scope of LEOS topics into underrepresented but appropriate technical areas.
3. Increase the activities targeted at the photonics markets.
4. Increase cooperation with other disciplines that would benefit from photonics science and technology.

(continued on page 27)
Research Highlights

Photonics Work at Lawrence Livermore National Laboratory

Tony Ladran, Deputy of Operations, Photon Science and Applications Program, Lawrence Livermore National Laboratory

The National Ignition Facility (NIF) & Photon Science Directorate at Lawrence Livermore National Laboratory comprises five programs, each focused on one or more aspects of NIF’s missions. They are:

National Ignition Facility
The National Ignition Facility Project is responsible for the construction and operation of NIF, a 192-beam experimental laser facility. This unique facility is the world’s largest and highest-energy laser, capable of creating temperatures and pressures similar to those that exist only in the cores of stars and giant planets and inside nuclear weapons.

National Ignition Campaign
The National Ignition Campaign (NIC) encompasses all of the experiments, hardware and infrastructure needed to carry out the initial ignition experiments on NIF beginning in 2010 and to continue research on ignition in the following years. NIC is a key element of the National Nuclear Security Administration.

Photon Science & Applications
The Photon Science & Applications (PS&A) Program provides advanced solid-state laser and optics technologies to the laboratory, government, and industry for important national needs. The primary activities of PS&A in recent years have been: (1) to complete the laser technology development and laser component testing for the U.S. Department of Energy’s NIF project, (2) to develop advanced solid-state laser systems and optical components for the Department of Defense and Department of Energy and (3) to address the needs of other government agencies and U.S. industry.

Inertial Fusion Energy
The Inertial Fusion Energy Program is exploring a variety of approaches to using inertial confinement fusion, NIF’s core technology to achieve energy gain and help lay the groundwork for the eventual use of fusion energy as a clean, safe, virtually limitless source of electricity.

Science at the Extremes
NIF will become a premier international center for experimental science early in the next decade. The extreme temperatures and pressures that will be created inside the NIF target chamber will enable scientists from around the world to conduct unprecedented experiments in high energy density science and to gain new insights into such mysterious astrophysical phenomena as supernovae, giant planets, and black holes.

NIF: The ‘Crown Joule’ of Laser Science
The National Ignition Facility (NIF) is the world’s largest laser. See Figure 1. NIF’s 192 intense laser beams will deliver to its target more than 60 times the energy of any previous laser system. When all 192 beams are oper-
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ational in 2009, NIF will direct nearly two million joules of ultraviolet laser energy in billionth-of-a-second pulses to the target chamber center.

When all that energy slams into millimeter-sized targets, it can generate unprecedented temperatures and pressures in the target materials - temperatures of more than 100 million degrees and pressures more than 100 billion times Earth's atmosphere. These conditions are similar to those in the stars and the cores of giant planets or in nuclear weapons; thus one of the NIF & Photon Science Directorate's missions is to provide a better understanding of the complex physics of nuclear weapons. Researchers can also explore basic science, such as astrophysical phenomena, materials science and nuclear science. NIF's other major mission is to provide scientists with the physics understanding necessary to create fusion ignition and energy gain for future energy production.

A Variety of Experiments

Not all experiments on NIF need to produce fusion ignition. Researchers are planning many other types of experiments that will take advantage of NIF's tremendous energy and flexible geometry in non-ignition shots. Non-ignition experiments will use a variety of targets to derive a better understanding of material properties under extreme conditions. These targets can be as simple as flat foils or considerably more complex. By varying the shock strength of the laser pulse, scientists can obtain equation-of-state data that reveal how different materials perform under extreme conditions for stockpile stewardship and basic science. They also can examine hydrodynamics, which is the behavior of fluids of unequal density as they mix.

NIF experiments also will use some of the beams to illuminate "backlighter" targets to generate an X-ray flash. This allows detailed X-ray photographs, or radiographs, of the interiors of targets as the experiments progress. In addition, moving pictures of targets taken at one billion frames a second are possible using sophisticated cameras mounted on the target chamber. These diagnostics can freeze the motion of extremely hot, highly dynamic materials to see inside and understand the physical processes taking place. As construction of the 48 "quads" of four beams each proceeded, many shots were already being performed using the first quad of beams. Experiments beginning in the winter of 2007-2008 will take advantage of additional quads as they come online.

New Technologies Make NIF Possible

Amplifying NIF's beams to record-shattering energies, keeping the highly energetic beams focused, maintaining cleanliness all along the beam's path, and successfully operating this enormously complex facility - all required NIF's designers to make major advances in existing laser technology as well as to develop entirely new technologies. Innovations in the design, manufacture, and assembly of NIF's optics were especially critical.

The Seven Wonders of NIF

While construction of the football-stadium-sized National Ignition Facility was a marvel of engineering, NIF is also a tour de force of science and technology development. To put NIF on the path to ignition experiments in 2010, scientists, engineers and technicians had to overcome a daunting array of challenges.

Working closely with industrial partners, the NIF team found solutions for NIF's optics in rapid-growth crystals, continuous-pour glass, optical coatings and new finishing techniques that can withstand NIF's extremely high energies. The team also worked with companies to develop pulsed-power electronics, innovative control systems and advanced manufacturing capabilities. Seven technological breakthroughs in particular were essential for NIF to succeed:

1. Faster, Less Expensive Laser Glass Production

Laser glass is the heart of the NIF laser system; it's the material that amplifies the laser light to the very high energies required for experiments. NIF's laser glass is a phosphate glass that contains a chemical additive with atoms of neodymium.

The NIF laser system uses about 3,070 large plates of laser glass. Each glass plate is about three feet long and about half as wide. If stacked end-to-end, the plates would form a continuous ribbon of glass 1.5 miles long. To produce this glass quickly enough to meet construction schedules, NIF uses a new production method developed in partnership with two companies - Hoya Corporation, USA and Schott Glass Technologies, Inc. - that continuously melts and pours the glass. See Figure 3. Once cooled, the glass is cut into pieces that are polished to the demanding NIF specifications.

Figure 2. Technicians adjust the target positioner inside the NIF Target Chamber.

Figure 3. NIF Glass laser slab in production.
ONE COMPLETE

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SIMULATION ENVIRONMENT

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2. Large Aperture Optical Switches
A key element of the amplifier section of NIF’s laser beam path is an optical device called a plasma electrode Pockels cell, or PEPC, that contains a plate of potassium dihydrogen phosphate (KDP). See Figure 4. This device, in concert with a polarizer, acts as a switch - allowing laser beams into the amplifier and then rotating its polarization to trap the laser beams in the amplifier section. A thin plasma electrode that is transparent to the laser wavelength allows a high electric field to be placed on the crystal, which causes the polarization to rotate. The trapped laser beams can then increase their energy much more efficiently using multiple passes back and forth through the energized amplifier glass. After the laser beams make four passes through the amplifiers, the optical switch rotates their polarization back to its normal configuration, letting them speed along their path to the target chamber.

3. Stable, High-Gain Preamplifiers
NIF uses 48 preamplifier modules, or PAMs, each of which provides laser energy for four NIF beams. The PAM receives a very low energy (billionth of a joule) pulse from the master oscillator room and amplifies the pulse by a factor of about a million, to a millijoule. It then boosts the pulse once again to a maximum of about ten joules by passing the beam four times through a flashlamp-pumped rod amplifier. To perform the range of experiments needed on NIF, the PAMs must perform three kinds of precision spatial, spectral and temporal shaping of the input laser beams.

4. Deformable Mirrors
The deformable mirror is an adaptive optic that uses an array of actuators to bend its surface to compensate for wavefront errors in the NIF laser beams. There is one deformable mirror for each of NIF’s 192 beams. Advances in adaptive optics in the atomic vapor laser isotope separation (AVLIS) program at Lawrence Livermore National Laboratory demonstrated that a deformable mirror could meet the NIF performance requirement at a feasible cost. Livermore researchers developed a full-aperture (40-centimeter-square) deformable mirror that was installed on the Beamlet laser in early 1997. Prototype mirrors from two vendors were also tested in the late 1990s. The first of NIF’s deformable mirrors were fabricated, assembled and tested at the University of Rochester’s Laboratory for Laser Energetics and installed and successfully used on NIF to correct wavefronts for the first beams sent to target chamber.

5. Large, Rapid-Growth Crystals
NIF’s KDP crystals serve two functions: frequency conversion and polarization rotation. The development of the technology to quickly grow high-quality crystals shown in this photo, were a major undertaking and is perhaps the most highly publicized technological success of the NIF project. NIF laser beams start out as infrared light, but the interaction of the beams with the fusion target is much more favorable if the beams are ultraviolet. Passing the laser beams through plates cut from large KDP crystal’s converts the frequency of their light to ultraviolet before they strike the target. The rapid-growth process for KDP, developed to keep up with NIF’s aggressive construction schedule, is amazingly effective: Crystals that would have taken up to two years to grow by traditional techniques now take only two months. In addition, the size of the rapid-growth crystals is large enough that more plates can be cut from each crystal, so a smaller number of crystals can provide NIF with the same amount of KDP.

6. Target Fabrication
To meet the needs of NIF experiments, NIF’s millimeter-sized targets must be designed and fabricated to meet precise specifications for density, concentricity and surface smoothness. When a new material structure is needed, materials scientists create the necessary raw materials. Fabrication engineers then determine whether those materials - some never seen before - can be machined and assembled. Manufacturing requirements for all NIF targets are extremely rigid. Components must be machined to within an accuracy of one micrometer, or one-millionth of a meter. In addition, the extreme temperatures and pressures the targets will encounter during experiments make the results highly susceptible to imperfections in fabrication. Thus, the margin of error for target assembly, which varies by component, is strict. Throughout the design process, engineers inspect the target materials and components using nondestructive characterization methods to ensure that target specifications are met and that all components are free of defects. Together, this multidisciplinary team takes an experimental target from concept to reality.
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Integrated Computer Control System

Fulfilling NIF's promise requires one of the most sophisticated computer control systems in government service or private industry. Every NIF experimental shot requires the coordination of complex laser equipment. In the process, some 60,000 control points for electronic, high voltage, optical and mechanical devices—such as motorized mirrors and lenses, energy and power sensors, video cameras, laser amplifiers, pulse power and diagnostic instruments—must be monitored and controlled. See Figure 9. The precise orchestration of these parts by NIF's integrated computer control system will result in the propagation of 192 separate nanosecond (billionth of a second)-long bursts of light over a one-kilometer path length. The 192 separate beams must have optical path-lengths equal to within nine millimeters so that the pulses can arrive within 30 picoseconds (trillionths of a second) of each other at the center of a target chamber ten meters in diameter. Then they must strike within 50 micrometers of their assigned spot on a target measuring less than one centimeter long—an accuracy comparable to throwing a pitch over the strike zone from 350 miles away.

Developing the State-of-the-art for National Security

The Photon Science and Applications (PS&A) program pursues national security missions by developing state-of-the-art optics and laser technology. Through research and development, PS&A is developing technologies that advance the frontiers of diode-pumped laser technology, high-power lasers and science, generation and application of bright, high-energy photons and fabrication of precision, meter-scale optics.

Tailored-Aperture Ceramic Laser

To improve the run time and beam quality of large, high-average-power (HAP), diode-pumped solid-state laser (DPSSL) systems, PS&A has developed a new slab laser technology called the tailored-aperture ceramic laser (TACL). A higher-performance descendent of the solid-state heat-capacity The TA CL laser (SSHCL) system shown, TACL in Figure 10 uses composite ceramic Nd3+:YAG/Sm3+:YAG slabs that are edge pumped.

By smoothing the high spatial frequency pump-deposition ripples that result from face pumping, edge pumping can improve system beam quality and runtime considerably. New diode-pump arrays are also employed in TACL that use high-performance microchannel cooling. The microchannel cooling of the arrays allows the diode packages to be run with a high duty cycle—continuously—while generating high average optical pump power. As a result, TACL designs can use as lit-
tle as one-tenth of the diode arrays employed by the SSH CL system while achieving the same power output capability.

**Solid-State Heat-Capacity Laser**

PS&A is developing a high-average-power (100-kW-class), diode-pumped, solid-state heat-capacity laser (SSH CL) suitable for use in military weapons. A mobile, compact, and lightweight SSH CL laser system capable of being deployed on a variety of platforms is also under development. Potential military applications of such a system include the targeting and destruction of short-range rockets, guided missiles, artillery and mortar fire, unmanned aerial vehicles and improvised explosive devices, or IEDs.

In 2006, PS&A achieved a major accomplishment when the SSH CL produced 67 kilowatts of power - a 50 percent increase in the world-record-setting power level achieved the previous year. See Figure 11. This class of power demonstrates that tabletop-sized solid-state lasers have come of age and can fulfill the performance requirements for their use in tactical weapon applications.

Additionally, improvements to the SSH CL's laser optics, both in material selection and geometric architecture, have greatly enhanced temperature profile uniformity throughout the lasing cavity, yielding a beam quality two times the diffraction limit for five seconds of run time in PS&A's unstable resonator. See Figure 12. Beam quality control is integral to PS&A's laser system development, and results like these portend the use of directed-energy weapons on the battlefield where they can effect "speed-of-light" engagement in compact, mobile packages.

The extremely high fracture toughness of ceramic YAG:Nd3+, along with its facility for use in composing larger slabs, makes it the ideal material for laser gain media.

![Figure 11. The 67 kilowatts of average power was achieved using five ceramic neodymium-doped yttrium aluminum garnet (YAG:Nd3+) laser-gain media slabs; model calculations were validated by experimental results as depicted in the graph.](image)

**Laser-Material Interaction**

PS&A's SSH CL test bed has afforded execution of extensive laser-material interaction experiments using a wide variety of materials such as steels, aluminums, titaniums and organic composites. Varying the spot size of the laser beam from a few millimeters to a 162-centimeter locus while sustaining an air flow rate of 100 meters per second at the point of laser-material interaction loosely simulates a target flying in the atmosphere. See Figure 13. All tests were conducted at the nominal 25 kilowatts of average laser power.

![10Gbps Compact Optical Sources and Receivers](image)

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![10G VCSEL Link Eye Diagram](image)

California Scientific is a manufacturer of high-speed optoelectronic test equipment based in San Jose, California

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These test results reveal the functioning of several mechanisms when the laser is used to destroy a target: thermal heating of the high explosive to ignition; increased material removal due to combustion of certain materials from the increased oxygen during air flight; and aerodynamic forces that literally rip the membrane from the annealed and weakened target, making it aerodynamically unstable.

**Potential Platforms**

The development of a prototype platform using SSHCL TACL technology suitable for testing at a proving ground or test range is the next step in the evolution of directed-energy weapons. See Figure 14.

The transition from a laser-technology demonstration device in the laboratory to a fully-operational, directed-energy weapon capable of engaging live targets under battlefield conditions is a key PS&A objective.

LLNL’s work on the SSH CL heat capacity concept has set the stage for a new generation of ceramic lasers and high-power laser architectures which will be capable of running continuously at high efficiency and with exceptional beam quality.

**Diode-Pumped Alkali Laser: A New Combination**

Since the advent of lasers more than four decades ago, solid-state and gas lasers have followed largely divergent development paths. Gas lasers are based primarily on direct electrical discharge for pumping (energizing), while solid-state lasers are pumped by flashlamps and semiconductor diode laser arrays.

The alkali-vapor laser’s intrinsically high efficiency and its compatibility with today’s commercially available diode arrays enable fast-track development paths to tactical systems, with mass-to-power ratios that far exceed what is possible with today’s other laser systems.

Building on alkali-vapor laser research done by Z. Konefal, PS&A’s Directed Energy Systems and Technology (DEST) program element recently developed a new class of laser that combines features of both gas and solid-state lasers, based on diode excitation of atomic alkali vapors. The defining features of the diode-pumped alkali laser (DPAL) are its ability to be incoherently pumped and its compatibility with diode arrays having several-nanometer-wide spectral emissions. These characteristics distinguish DPALs from previous demonstrations of alkali-based lasers that used narrow-band, coherent pumping to demonstrate lasing.

DEST’s extensive laser modeling capability, anchored to experimental laboratory demonstrations, supports extreme power scaling with good efficiency and beam quality.

DEST is the world leader in the development of this new class of laser; the first demonstration took place at Lawrence Livermore National Laboratory in 2002, see Figure 15, and it has been followed by many other demonstrations and developments.
Fusion Energy Systems and Science
Fusion is the process by which the sun and stars produce energy, and it is also responsible for much of the power of thermonuclear weapons. It also has the potential to be a source of unlimited, environmentally friendly energy for humankind.

The National Ignition Facility (NIF) is designed to demonstrate inertial confinement fusion, ICF, that involves the rapid compression of small fuel capsules, as shown in figure 15, to reach densities and temperatures greater than those in the core of the sun; when a sufficient energy density is reached, the fuel capsule ignites and then burns while confined by its own inertia. NIF is expected to demonstrate fusion ignition - the release of more energy via fusion burn than the laser energy used to initiate ignition - early in the next decade, but will only be able to do so at a rate of one experiment every few hours. For inertial fusion energy (IFE) production to become practical, targets will have to be ignited at a rate of several shots per second.

The mission of the Fusion Energy Systems and Science (FESS) program element of PS&A is to develop the laser driver technology necessary to make IFE production practical - including the development of low-cost, high-energy, high-efficiency laser drivers and components for repetition rates of several times a second. Concurrent with the development of the National Ignition Facility is another ambitious Livermore laser project named Mercury.

The Mercury laser project is an important part of the FESS mission. It is designed to produce 100-joule pulses at a ten-per-second repetition rate with one kilowatt of average power, using an architecture that could be scaled to IFE-relevant size. Mercury is a single-beam laser system, as shown in figure 16 that has developed capabilities that will build on NIF's accomplishments. As currently designed, NIF's 192 beams can fire simultaneously only once every few hours. After each shot, the thousands of optics must be given a chance to cool down to ensure that they can operate correctly for the next shot.

Mercury has developed a method of continuously cooling the optics, while at the same time allowing the laser to fire rapidly over extended periods.

The current technology propels high-velocity helium gas across the optics to keep them cool, while laser pulses pass through the optics at a sustained rate of ten shots a second.

Unlike NIF, which uses seven-foot tall flashlamps to energize the laser amplifiers, Mercury relies on diode lasers - similar to those in commercial read/write CD players - which give off one-third as much heat as flashlamps. Mercury's beam is amplified as it passes through slabs of specially grown ytterbium-strontium fluorapatite crystals, as opposed to NIF's neodymium-doped phosphate laser glass. More advanced amplifier media, such as transparent ceramics, are also being developed.

As of mid-2008, Mercury has been able to run continuously for several hours (300,000 shots), firing ten times a second at more than 50 joules per shot, each shot lasting just 15 nanoseconds (billionths of a second).

The project, which began in 1996 and was initially funded through LLNL's Laboratory Directed Research and Development (LDRD) office, has already been awarded three R&D 100 Awards, most recently for developing a unique frequency conversion crystal. Earlier awards were for the original design of Mercury's diode array and for its Pockels cell, a unique light-switching technology.

The long-term goal is a laser system capable producing of NIF's energy output, with Mercury's ability to rapidly fire shots, and ignite inertial fusion targets for electrical power generation.

High-Average-Power Laser-Diode Arrays
For 100-kW diode arrays to become a common reality, two elements of the technology must be realized: high-performance, reliable diode bars, and heat sinks that can sustain superior thermal management and precision-diode bar mounting.

The project, which began in 1996 and was initially funded through LLNL's Laboratory Directed Research and Development (LDRD) office, has already been awarded three R&D 100 Awards, most recently for developing a unique frequency conversion crystal. Earlier awards were for the original design of Mercury's diode array and for its Pockels cell, a unique light-switching technology.

The long-term goal is a laser system capable producing of NIF's energy output, with Mercury's ability to rapidly fire shots, and ignite inertial fusion targets for electrical power generation.
Lawrence Livermore National Laboratory (LLNL) has developed just such a package for diode bars, using silicon – the mainstay of the semiconductor industry.

LLNL uses photolithography and etching techniques to produce tens of thousands of 30-µm-wide channels in silicon substrates that carry cooling water. The water flowing through these microchannels significantly cools the laser-diode bars, which are mounted on the silicon less than 200 µm from the channels. Combining ten diode bars onto a single heat sink yields a ten-bar package (referred to as a "tile"), which constitutes the unit cell from which large, two-dimensional diode arrays can be built up through tiling.

The tiles used to make up these large arrays shown in Figure 18 are called silicon monolithic microchannels (SiMMs). Considerations that drove the SiMM package design included ease of fabrication and the ability to construct large laser-diode arrays with output power capabilities of ten to 100 kW. Of paramount importance in the design of the SiMM package was incorporation of the same aggressive heat removal capability that characterized LLNL's original, rack-and-stack silicon microchannel-cooled package. This was accomplished by placing the microchannels into the silicon directly below the location of the attached laser-diode bars. Like the rack-and-stack silicon microchannel cooler, the SiMM design maintains a very tight thermal circuit, with just 177 µm of silicon separating the heat-generating laser-diode bars and the microchannel fins that define the cooling channels.

The SiMM laser-diode array is a packaging technology for producing the smallest, most powerful and most inexpensive laser-diode pumps ever. Each package of ten laser-diode bars integrates the electrical, optical and hydraulic requirements necessary for high-average-power lasers. To date, arrays of up to 100 kW have been fabricated at LLNL, and arrays of up to 100 kW have been fabricated by SiMMtec, a commercial licensee of the technology.

With the relatively low cost of silicon, large arrays of these precision microchannels can be fabricated inexpensively using standard photolithography and etching techniques. Moreover, with silicon as the base material, individual diode bars can be precisely soldered to a package; each laser diode bar is connected to an LLNL-patented microlens, giving the SiMM package its unsurpassed optical brightness.
A Nanophotonic Interconnect for High-Performance Many-Core Computation

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Abstract
Silicon nanophotonics holds the promise of revolutionizing computing by enabling parallel architectures that combine unprecedented performance and ease of use with affordable power consumption. Here we describe the results of a detailed multiyear design study of dense wavelength division multiplexing (DWDM) on-chip and off-chip interconnects and the device technologies that could improve computing performance by a factor of 20 above industry projections over the next decade.

1. Introduction
Moore's Law is still a fundamental technology driver for the information technology industry: the ITRS Semiconductor roadmap \cite{1} shows, in the next decade and a half, a continued reduction in feature sizes from 40 nm to the sub-10-nm regime. This growth in circuit density has brought us into the multi-core CPU era, and we are on the eve of a many-core (16 or more cores per socket) era. As transistor density increases, the number of transistors comprising a single computer core is not growing; rather, it has pulled back for reasons of power efficiency, allowing the number of cores packaged on the die to grow exponentially. In the many-core era, on-chip and off-chip communication are the critical issues for sustaining performance growth for the demanding, data-intensive applications for which these many-core chips are intended. Computational bandwidth scales linearly with the exponentially growing number of cores, but the rate at which data can be communicated across a chip using top-level metal wires is increasing very slowly. The rate at which data can be communicated through pins at the chip edge is also growing more slowly than the computational bandwidth, and the energy cost of cross-chip and off-chip (from processor socket to DRAM) communication significantly limits the achievable bandwidth. As a result, the field of computer architecture is now in a crisis. It is not clear that many-core processors will find widespread

Figure 1: Schematic of the basic architecture for a 256-core processor. The cores are divided into clusters that share an L2 cache and control access to a particular unit of memory.
use program performance may be consistently disappointing due to limited communication bandwidths. In addition, exposing these limited bandwidths to the programmer makes the parallel programming task far more difficult.

If we strive to continue delivering exponential performance improvements over a broad range of computational applications during the next decade, then we are led inevitably to a symmetric architecture with the simplest possible crossbar interconnect that allows the programmer to exploit parallelism at a high level. But this simplicity requires that we rely on an interconnect technology that is no longer limited by the physics of copper wire. Here we argue that nanophotonics provides a feasible solution to this growing problem [2], and we present a simplified version of a novel photonic interconnect architecture to be presented at ISCA 2008 [3]. As we show in Section 6, the communication bandwidth per unit of dissipated power provided by this on-chip optical interconnect technology exceeds the maximum available from purely electrical interconnects by a factor of 20 for applications that heavily use the interconnect. Other proposals for on-chip nanophotonic interconnects have appeared recently, but most simply replace the long “global” wires with a bus [4] or a circuit-switched network [5]. These approaches do not efficiently use the advantages of nanophotonics and, as a consequence, have limited bandwidth and large latency.

2. Model architecture
In the many-core era, the critical problems facing general purpose computer design are heat generation and communication bandwidth. Architectural compromises forced by these issues make programming difficult and impair application performance. The projected energy cost of cross-chip electrical communication (in the year 2017) is expected to be 5.8 pJ/b; although an extreme Rambus solution for off-chip signaling could achieve (in principle) 2.2 pJ/b, current practice reaches about 20 pJ/b [6]. At these costs, all of the available power will be consumed moving data unless a severe bandwidth choke is imposed. With optics, however, over the next decade we believe that we can reduce the energy required for cross-chip communication to less than 0.5 pJ/band to 0.1 pJ/b for off-chip communication. By exploiting the ability to move data affordably, wherever it is needed, we can reduce both power and total cost while improving bandwidth, performance, and programmability.
In Fig. 1, we show a block diagram of a many-core processor illustrating the basic idea behind the architecture considered here. The device is tiled with 64 identical four-core compute clusters, each of which has a memory controller that either interfaces to stacked memory or drives a photonic connection to off-chip memory to provide bandwidth that scales with processor performance. We interconnect the clusters with a photonic crossbar, offering enormous bandwidth, modest latency, and very low power consumption. This creates a symmetric architecture in which all memory is close to all processors: the programmer expresses parallelism at a high level, and is not burdened by issues of locality, thereby greatly reducing the difficulty of parallel program development. Furthermore, we can provide bandwidth of one byte per double-precision floating-point operation (flop) all the way to DRAM, eliminating the need to exploit very complex software techniques (multilevel tiling, for example) to guarantee locality of reference. The bandwidth provided from DRAM is large enough to eliminate an entire layer of cache (L3), with significant savings in power and cost, while also reducing latency and hardware complexity.

Energy efficiency is the primary motivation for many-core, and small, power-efficient cores and caches achieve the best possible performance per unit energy. We don’t anticipate significant increases in CPU clock rates over the next decade, so we assume for our model that the cores use a 5 GHz clock. If we also assume that the cores are dual-issue, in-order, and multithreaded, and that they offer SIMD instructions allowing 4 multiply-accumulate and 4-word-wide load/store operations, then the compute bandwidth of the device is 10 teraflops (i.e., double-precision floating-point operations per second), requiring (at one byte per flop) 20 TB/s of bidirectional interconnect bandwidth. Our power models predict that this processor will dissipate approximately 200 W in the silicon itself.

3. The nanophotonic crossbar

Despite the remarkable progress made recently in broadband Mach-Zehnder electrooptic modulators [7] and quantum-well materials for electroabsorption modulators [8,9], we believe that — in the long term — the use of dense wavelength-division multiplexing (DWDM) in optical interconnects is inevitable. In order to minimize the need for buffering (and therefore eliminate the power dissipated by serialization and deserialization, or SERDES), we assume that we will be able to drive each physical channel at twice the clock frequency (i.e., read or write two bits per clock to/from digital registers), or 10 Gb/s. Therefore, we will need 16,000 physical channels in our interconnect to supply the required bidirectional bandwidth of 20 TB/s. However, in order to implement the crossbar with the performance specifications (particularly low latency) required by our architecture, we will need to avoid switching altogether and over provision the physical channels significantly. For example, in order to provide an all-to-all single-hop interconnect topology, we will require total direct connections between the clusters. (In other words, at any given time, each cluster may be sending data to only one of the other clusters, but each cluster must always be connected physically to all 63 of the other clusters.) If we assume that we are using wires, and that each waveguide (or wire) occupies an area with dimensions 2 cm × 3 μm on average, we find that the interconnect will require over 200 layers on the die, which is clearly infeasible, regardless of whether we are using wires, direct optical modulation, or optical coarse wavelength division multiplexing (CWDM). As we shall see next, using DWDM in our design allows us to provide extraordinarily high interconnectivity in only a single layer.

As illustrated to scale in Fig. 2, one implementation of the nanophotonic crossbar employs 64 wavelengths multiplexed over 270 parallel waveguides, with 256 waveguides allocated to control and data, 2 to broadcast, and 12 to arbitration. Each cluster “listens” to a single dedicated bundle of 4 waveguides, at all wavelengths. These 256 individual bit-wide channels are grouped into logical channels for data and control messages. The timing of these logical channels is synchronous, each channel being used by one sender to send to its destination in any given 24 clock “epoch.” A new, distributed, all-optical crossbar arbitration scheme described in Section 5 allocates the logical channels to sending clusters, allowing one sending cluster to transmit to a given destination cluster in a given epoch. Once granted permission by the arbiter to transmit, the sending cluster modulates all wavelengths on the allocated wavelengths.
channel in order to send to the destination cluster. This on-chip, low-cost, high-bandwidth, low-power crossbar is able to handle as many as 64 inputs and outputs simultaneously, and is a revolutionary development that will be significant in many applications; it enables the kind of flattened, symmetric architecture we desire.

The same high bidirectional bandwidth to off-stack memory is a requirement for our target performance. Even with the number of pins growing by 40 percent every generation, electrically-connectable memory will in 2017 provide only one fifth of a byte per flop to the processor. To fully exploit the advantages of optics, we reorganize memory into stacks with a photonic interface below the layers of DRAM, connected by fiber to the memory ports of the many-core processor stack. This approach provides adequate bandwidth of about one byte per flop (and eventually even more if necessary), solving the chip-edge bandwidth problem. It does so while saving considerable power (up to 200 W if communicating at 10 TB/s electrically at 2.2 pJ/b). Optical interfaces enable a single DRAM chip to source an entire cache line, making better use of the large internal DRAM memory bandwidth and reducing power even further. This will provide the bandwidth and power benefits of a processor-in-memory (PIM) architecture while keeping the programmability of a classical symmetric multiprocessor.

4. Nanophotonic components

This ultra-high-bandwidth DWDM network is enabled by a number of CMOS-compatible nanophotonic devices that are (at most) only a few years beyond the current state of the art:

1. Low-loss silicon-on-insulator (SOI) waveguides have measured losses as low as 0.2 dB/cm [10], and will not need much improvement. However, the commercially available SOI wafers used for this purpose today are custom-made to satisfy light confinement requirements by increasing the thickness of the traditional oxide buffer layer, and are therefore relatively expensive. In addition, this thick oxide layer confines heat within the thin top silicon layer, which translates into a large temperature build-up for sensitive resonant devices such as drop filters, modulators, and ring lasers. Therefore, in the long term, it will be important to develop means for creating nanophotonic components using pure silicon wafers, which provide high thermal conductivity at low cost.

2. Resonant receiver-less Ge detectors. The smaller bandgap of Ge than Si (0.7 eV vs. 1.1 eV) allows detection of optical signals in the 1300 nm wavelength range, and with proper design material can likely extend to 1550 nm. The potential ability to fabricate Ge layers on Si offers the possibility of integrating optical components with Si integrated circuits for efficient electric-optical transduction. Ge can be embedded into resonant detectors to allow a single wavelength in a waveguide to be detected. This also allows low-capacitance detectors that eliminate the need for power-hungry amplifiers and clock recovery to build a receiver-less detection scheme [11].

3. Resonant modulators. As described below, we propose to use ring resonators that selectively modulate a single wavelength on a given waveguide and can be moved to an "OFF" state where they are transparent to the data flux in the waveguide. The modulators work by changing the index of silicon rings using charge injection. Published results indicate that the target modulation rate of 10 Gb/s can be achieved with current technology [12]. These rings will need to be kept resonant with the chosen wavelength by thermal tuning of the refractive index.

4. Multiwavelength lasers with precisely controlled frequency intervals are ideal for low-cost DWDM systems. If only one of the frequency channels is servo-locked to an on-chip standard cavity, then all of the other frequency modes will track the controlled mode. One of the possible approaches is the Fabry-Perot comb laser based on quantum dots [13], which has already been used to demonstrate a bit-error-rate of at 10 Gb/s over ten longitudinal modes [14,15]. Another possible approach is the mode-locked hybrid Si/III-V evanescent laser [16], which uses a silicon-waveguide laser cavity wafer-bonded to a III-V gain region. In this case, any ambient temperature change in the environment will cause approximately the same refractive index shift in the laser cavity and the silicon waveguides and resonators that form the DWDM network. Our design study shows that the laser need only provide 1–2 W of total optical power to supply a 20 TB/s network if the detector capacitance is low enough that only 30,000 photons are needed to drive a 1 V swing at the detector’s output terminal.

In our design of a single-layer DWDM nanophotonic interconnect, we have chosen the silicon microring resonator as our foundational component because it has small size, high quality factor Q, transparency to off-resonance light, and no intrinsic reflections. Using injected charge, the refractive index of the microring can be changed, shifting the fundamental frequency of the cavity either into or out of resonance with an incident light field. The microring can act as an optical filter [17,18], and it can be made into electrooptic modulators [12,19,20], lasers [21] and detectors when carrier injection, optical gain, or optical absorption mechanisms are incorporated. In the past, the key characteristic of a silicon microring resonator yet to be

Figure 3: (a) An SEM picture with 40°-tilted view of a microring resonator with a 1.5-µm radius coupled to a waveguide with an optimized (reduced) width. (b) A microscope picture of cascaded microring resonators coupled to a U-shaped waveguide at the edge of the chip.
demonstrated experimentally is a radius approaching the minimum possible value that allows an intrinsic Q of 20,000, which is about 1.4 µm. As shown in Fig. 3(a), we have fabricated Si microrings with radii of 1.5 µm [22] with intrinsic Qs of 18,000 and effective mode volumes around 1.0 µm. When coupled to an optimally-designed silicon strip waveguide that minimizes spurious light scattering and increases the critical dimensions of the geometry (easing fabrication requirements), the coupled Q approaches the theoretical maximum possible value for a ring of that size (9,000 out of 10,000). In Fig. 3(b), we show cascaded silicon microring resonators that can be used as a modulator or filter bank in a nanophotonic network.

In the case where we use the microring as a modulator, a small size is critical for several reasons. First, a smaller size means that more modulators can be fit into a given area, therefore providing higher integration density. Second and more importantly, the power consumption of the modulator, which is a key performance factor for electrooptical modulators, is directly proportional to the circumference and inversely proportional to the Q of the resonator. Reducing the size of the ring without sacrificing the Q is critical for low-power operation. Third, the total bandwidth of a microring-based DWDM modulation system [20] is limited by the free spectral range (FSR) of the microring resonator, which is inversely proportional to the circumference of the ring. A smaller microring modulator has a larger FSR, which can therefore accommodate more wavelength channels and have higher aggregate data bandwidth. In our case, the choice of a 1.5 µm radius and the demonstration of the near-maximum-possible coupled Q of 9,000 provides a FSR of about 8 THz, and a filter bandwidth of about 20 GHz, which is nearly ideal for our interconnect architecture.

One of the most important requirements that must be met by a nanophotonic interconnect is that its total thermal dissipation...
remain below 25% that of the underlying silicon transistors, or less than 50 W for our target processor in 2017. As discussed above, we expect that the laser source will contribute about 5 W to this total, but the on-chip microrings will contribute a much larger quantity of heat. There are three possible modes for electrical power dissipation in rings: fabrication error trimming, resonance frequency biasing, and direct data modulation. Because of fabrication imperfections, each ring will have a resonance frequency that is slightly different from the design goal, and must be "trimmed" into the correct spectral location. We can rely on two schemes to fine-tune the rings: we can use carrier injection to blue-shift the resonance, and thermal heating to red-shift it. In the worst-case scenario we need 185 µW/nm to red-shift a 3-µm ring through heating and 125 µW/nm to blue-shift it through current injection. The approach that combines heating and current injection, however, is only viable if the critical dimension control of the fabrication process is better than 1 nm. If this condition is not met, then thermal control alone needs to be used at the expense of a much larger power consumption.

The electric current required to modulate a ring is given by \( I = \frac{E}{V} \), where \( I \) is the current, \( E \) is the voltage, and \( V \) is the voltage. If the laser is tunable, then \( E \) can be adjusted to modulate the ring during each clock cycle. However, the modulator voltage driver circuit will necessarily dissipate electrical power, since the modulator acts as a capacitive load with a 10 µA leakage current in the "on" state, and has a peak current of 1 mA during the transition. Recently, this problem has been solved on-die by manufacturers of packaged CMOS photonic devices using AD-DA conversion drivers, but the power dissipated in these drivers has been much greater than the power expended in the modulators themselves. Therefore, in the long term we believe that it will be important to develop purely analog CMOS drivers to reduce the electronic overhead by a factor of 30–100 over the current state-of-the-art. We believe that the efficiency of these drivers will scale only slowly with circuit feature size, resulting in a modulation power below 0.5 mW at the 17-nm technology node.

Generally, in the reconfigurable network we will trim all rings (i.e., both modulators and detectors) away from resonance, and then use current injection to bring the necessary rings online once arbitration is complete. Given the silicon parameters mentioned above, and that an active ring will be online during the entire epoch, the total power requirement per online ring is about 30 µW, or about 0.1 mW including analog driver overhead at the 17-nm technology node. Therefore, in 2017 we expect the power dissipated by all on-chip rings to be approximately 40 W. We have modeled the performance of the on-chip and off-chip interconnects shown in Fig. 2 at several technology nodes in Table 1. The total power consumption is the sum of the on-chip and off-chip estimates, and includes all of the laser, modulation, and trimming contributions outlined above.

### 5. All-optical arbitration

One of the most significant contributions to the interconnect latency is the time required to determine the availability of system resources, arbitrate collisions between requests, and then grant access to the resource requestors. For example, in an all-to-all multipath switched interconnect architecture (e.g., a torus), electrical signals representing requests must be sent to an arbitration processor, and wait for the outcome of a computation and then receipt of another electrical signal before transmission can commence. However, a key advantage of our solution is that — at the cost of overprovisioning the nanophotonic components — the transmitters themselves can reconfigure the crossbar in a few clock cycles, thus avoiding the need for hand-shaking procedures that increase latency. Nevertheless, we still require an arbitration system to handle collisions. The intrinsic parallelism of optical signals allows us to propose a novel, all-optical, low-latency arbitration system that does not require digital electronic computation or communication between the transmitter and receiver, using a protocol that can be run completely independently of the on-chip data network. Our analysis shows that this protocol provides nearly the best possible throughput under light and moderate loads, and about 90% of the best possible throughput under heavy loads.

A schematic diagram of a simple version of optical arbitration is shown in Fig. 4 for the case where there are four system resources (e.g., L2 caches in cores or clusters of cores) to be allocated. A four-wavelength (e.g., mode-locked) laser provides optical power to each component in a single distribution waveguide, and each wavelength is dropped onto the arbitration waveguide at a specified location in the ring. For example, the "red" wavelength (which in fact may belong to a particular channel near 1310 nm) is always dropped onto the arbitration waveguide by a microring resonator near component 1 that is always tuned to that wavelength. At the beginning of the first 24-clock-cycle "epoch," each resource is assigned a unique wavelength using a predetermined algorithm known to each component, and each component prepares a "bid" for a particular resource (in this case, the right to transmit data to another component). In an electrical arbitration system, this bid would be an electrical signal sent to a dedicated subprocessor; here the bid is made locally by tuning an adjacent drop filter to the wavelength assigned to the desired target resource. For example, here component 1 bids for resource 4 by activating (i.e., tuning into precise resonance) a local microring resonator that is designed to drop the wavelength currently assigned to resource 4 (i.e., "blue" during this epoch) onto an integrated photodetector. If the optical power sensed by the photodetector rises above a designated threshold, then component 1 has won the right to transmit to resource 4. However, in this epoch, component 2 also bids for access to resource 4; since component 2 is "upstream" from component 1, and the

**TABLE 2: HPCS benchmark performance for the proposed architecture at the 17-nm technology node.**

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Optical Performance</th>
<th>Electrical Performance</th>
<th>Scaled Optical/Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTRANS (GB/S)</td>
<td>9102</td>
<td>459.0</td>
<td>22</td>
</tr>
<tr>
<td>STREAM (GB/S)</td>
<td>10240</td>
<td>605.0</td>
<td>19</td>
</tr>
<tr>
<td>GUPS</td>
<td>40</td>
<td>2.4</td>
<td>19</td>
</tr>
<tr>
<td>DGEMM (Gflops)</td>
<td>37</td>
<td>37.0</td>
<td>1</td>
</tr>
<tr>
<td>FFT (Gflops)</td>
<td>1734</td>
<td>879.0</td>
<td>2</td>
</tr>
<tr>
<td>MPI (GB/s)</td>
<td>20</td>
<td>1.2</td>
<td>19</td>
</tr>
</tbody>
</table>
“blue” wavelength is dropped onto the arbitration waveguide near component 3, it is component 2 that wins the arbitration round and access to resource 4. Since the optical power at the “blue” wavelength is removed from the waveguide by component 2, the “blue” photodetector sees a low optical intensity, and must wait until the next epoch to try again to transmit data to resource 4. However, during the next epoch, the wavelengths representing the available resources are reassigned, and now component 1 wins the right to transmit to resource 4 even though component 3 tries to bid for the same resource. A more sophisticated token-ring optical arbitration scheme [3] eliminates the need to synchronize execution during epochs, and allows latency to be reduced even further.

6. System performance models
We have modeled the performance of the nanophotonic architecture described in the previous section (as well as an idealized electrical equivalent) for the HPC Challenge benchmarks [23], which typify high-performance data access patterns. In our model, we calculated performance limits due to CPU, interconnect, and memory bandwidths. We have assumed that the benchmarks have been implemented as multi-threaded shared-memory programs with data imperfectly placed, requiring communication through the on-chip interconnect. We compare our nanophotonic architecture to a many-core electrically-connected alternative system, for which we assume an on-chip mesh network, power limited to 50 W, and an electrical connection to memory with bandwidth limited by the pin count and pin bandwidth anticipated by ITRS in 2017. Our estimated results for the 17 nm technology node are shown in Table 2. The final column lists the modeled ratio of optical performance to electrical performance per unit of dissipated heat. Note that four of the benchmarks show a factor-of-20 improvement for nanophotonics over wires. The other two benchmarks do not show significant improvements because they are not bandwidth constrained.

7. Conclusion
The many-core architecture presented here — with the cores divided into silicon compute clusters, connected to each other and to off-chip memory using nanophotonic technology — will continue to evolve [3] as we further explore the implications of a highly parallel interconnect for the programmer. We believe that the use of DWDM in integrated-circuit interconnects is inevitable, and that the optical components that we describe here are essential elements of that approach. The potentially high bandwidth of an optical interconnect in general-purpose many-core processors will be significantly compromised if an electronically-reconfigurable circuit-switched mesh or torus architecture [5] (essentially a photonic implementation of today’s copper-wire global interconnects) is employed. Instead, we propose to build an all-optical arbitration system that relies on the same nanophotonic building blocks as the data-transmission network, allowing the transmitters themselves to determine whether a receiver is available, and to begin sending in only a few clock cycles. We have modeled the performance of this system using the HPC benchmarks, and we have found that a performance increase of 20 over a purely electronic interconnect — essentially 4–5 “extra” Moore’s Law generations — is possible for applications that heavily use the interconnect. This extraordinary performance boost is a critical goal for those of us advocating such a radical departure from current semiconductor engineering practice; the transition to this new interconnect technology will be so painful for the IT industry that only an order-of-magnitude improvement in compute bandwidth will make the risk and effort worthwhile.

References


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Call for Nominations: The 2009 Tyndall Award

Nominations are now being accepted for the 2009 Tyndall Award, which will be presented at OFC/NFOEC 2009.

This award, which is jointly sponsored by the IEEE Lasers and Electro-Optics Society and the Optical Society of America, is presented to a single individual who has made outstanding contributions in any area of lightwave technology, including optical fibers and cables, the optical components employed in fiber systems, as well as the transmission systems employing fibers. With the expansion of this technology, many individuals have become worthy of consideration. The deadline for nominations is 10 August, 2008.

For more information contact soc.leo@ieee.org or check the LEOS web for more details: www.i-leos.org – click “Awards” tab.

Call for Nominations: 2009 IEEE/LEOS Young Investigator Award

The IEEE LEOS Young Investigator Award was established to honor an individual who has made outstanding technical contributions to photonics (broadly defined) prior to his or her 35th birthday.

The award shall consist of a certificate of recognition and an honorarium of $1,000. The funding for this award is being sponsored by General Photonics Corporation.

Nomination packages will be due at the LEOS executive office by 30 September, 2008. Nominees must be under 35 years of age on Sept. 30th of the year in which the nomination is made. The award may be presented either at the Optical Fiber Communications Conference (OFC), or the Conference on Lasers and Electro-Optics (CLEO), to be selected by the recipient. The first award was CLEO 2007.

Nomination packages consist of a nomination cover page, a statement of the nominee’s research achievements in photonics, the nominee’s curriculum vitae, and three to five reference letters (to be received at the LEOS office prior to the deadline).

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For full information about the LEOS awards program look under the “Awards” tab on the LEOS web site (http://www.i-leos.org/)

Nomination form can be found on page 26.

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The deadline for submission of an official nomination form for any of the IEEE Medals and Recognitions is 1 July, 2008. For questions concerning the Potential Nominee Form, please contact awards@ieee.org.
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NOMINATION FORM

Deadline: 10 August

CRITERIA: Outstanding contribution of a single individual in any area of lightwave technology, including optical fibers and cables, the optical components employed in fiber systems, as well as the transmission systems employing fibers. Contributions must have proven benefit to science, technology, or society and may be experimental or theoretical. Nominees need not be members of the sponsoring societies.

Name of Nominee:

Address:

Phone: ______________________ Fax: ______________________

e-mail:

Academic Background: College or University/Location/Major Field/Degree/Year

__________________________________________________________

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Employment Background: Position/Employer/Duties/Dates

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Proposed Citation for the award (25 words or less):

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   Email: ________________________________

4. Nominee’s birthday (REQUIRED – Nominee must be under 35 years of age on 30 September of year
   in which nomination is made).

   Year ___________ Month ___________ Day ___________

5. Proposed Award Citation (20 words or less)

6. On separate sheets attach:

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      accomplishments (maximum of two pages).

   b. Nominee’s curriculum vita

   c. Endorsers: List the names, affiliations, addresses, and emails of individuals who have agreed to
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11-07
IEEE Fellow First Woman Honored with John Fritz Medal

Dr. Kristina M. Johnson, provost and senior vice president for Academic Affairs at Johns Hopkins University, recently received the John Fritz Medal from the American Association of Engineering Societies (AAES). She is the first woman so honored. Johnson was one of seven honorees during the AAES 29th annual awards ceremony in the Great Hall of the National Academy of Engineering on 5 May. She was cited for her internationally acknowledged expertise in optics, optoelectronic switching and display technology.

The John Fritz Medal, referred to as the highest award in the engineering profession, is presented each year for scientific or industrial achievement in any field of pure or applied science. It was established in 1902 as a memorial to the great engineer whose name it bears. Past recipients include Alexander Graham Bell (1907), Thomas Edison (1908), Alfred Nobel (1910), Orville Wright (1920) and Guglielmo Marconi (1923).

Johnson is an IEEE Fellow, LEOS member, and Electrical Engineer who, as the former dean of engineering at Duke University, increased the engineering faculty by 50 percent, tripled the size of the teaching and research facilities, and tripled the number of women engineering faculty, many in leadership positions. She co-founded the Colorado Advanced Technology Institute for Excellence in Optoelectronics and started several companies that are commercially successful in color projection devices and intellectual property licensing.

President’s Column
(continued from page 3)

The changes introduced this year in the PhAST program directly address the main goal through all of the objectives, but particularly through objectives 3 and 4.

PhAST is strongly focused on applications that are market driven (so addressing objective 3), with a program intended to present the latest technologies and the context in which they are deployed in applications.

Addressing objective 4 is more challenging. In practice, increased co-operation with other disciplines implies developing relationships with other societies, a process that takes time. LEOS is at the center of a number of “joined up” networks of societies. These networks include communications, displays, nanotechnology, biotechnology and biometrics, some of which have operated successfully for many years, with others, emerging only recently emerged.

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CLEO/QELS/PhAST falls in the former category and is owned and run by three co-sponsoring societies: LEOS, OSA and APS. The OIDA is involved in developing aspects of the PhAST program for the first time.

The OIDA involvement is bringing a completely new perspective to PhAST through the Business Development sessions. These sessions are aimed at developing an understanding of the entire product value chain, and developing roadmaps for the relevant industries going forward. This is being achieved through a mixture of presentations by senior managers and technologists followed by interactive panel sessions to develop further the ideas that emerge during the presentations.

The OIDA part of the program is furthermore focused on the emerging area of ‘green’ photonics. As well as resonating with the interests of LEOS, this also forms a link with IEEE as a whole, which has declared sustainable technologies a priority area. It is becoming clear that the photonics industry will provide many solutions for reducing environmental pollution and the world’s carbon footprint. These solutions include highly efficient solid-state lighting, efficient-free laser processing, new low energy display technologies and photovoltaic energy generation.

Other key parts of the program include the Power Lunch, organized by Milton Chang, and the PhAST/Laser Focus World Innovation Awards.

PhAST raises a number of questions for LEOS. The principal question is how readily the format could be used elsewhere. LEOS is already working with OIDA to explore extending the concept of matching technical and business sessions in a single workshop. LEOS is also actively working with other IEEE societies to identify more applications-focused topics that use photonics. A second point is that this year’s PhAST sessions are entirely invited, which is appropriate for certain meetings but clearly imposes limits on member participation. A third point is that there is no charge to attend PhAST. Many attendees will have registered for CLEO/QELS, but an intention of PhAST is to support the CLEO Exhibition by attracting walk-ins. Clearly having no registration fee is not an option for independent events.

My belief is that we can develop a model to address applications focused topics that combines the LEOS core values of volunteer service, education, integrity, technical rigor and inclusiveness, and at the same time is sustainable.

All of these questions will be addressed by LEOS over the coming months. The ultimate aim of LEOS is to serve its members and the photonics community. Moving into more areas of application is one way of addressing this aim and I would welcome your views on how this can best be achieved.

Finally, I would like to remind you of the appeal I made in January where I invited you to recruit one new member each in 2008. As the middle of the year approaches, LEOS membership has started to grow for the first time in several years. This is excellent news, but there is still much that could be done. The best recommendation is a personal one— if you value LEOS membership, please spread the message to your colleagues and build a stronger LEOS community.
News (cont’d)

Memoriam: Professor Pak Lim Chu

12 November 1940 - 15 March 2008

The fiber-optics community has lost a great icon with the passing of Prof. Pak Chu after a one year battle with cancer. His passing was commemorated with an extended service of thanksgiving, eulogy, tributes, and valediction at the West Sydney Chinese Christian Church that was attended by an overflowing congregation of colleagues, friends, and fellow Christians.

Prof. Chu is a great champion and a pioneer in the field of fiber optics in Australia. He set up the very first academic fiber-optics research laboratory in Australia at the University of New South Wales (UNSW) in 1970s. The laboratory was equipped with the first preform-making and fiber-drawing facilities in the country. For the last 30 years, Prof. Chu has made extensive contributions to the optical fiber technology. In early 1980s, he invented an acclaimed method to measure the refractive-index profiles of fiber preforms. The method was adopted in an advanced commercial instrument for the characterization of optical fibers. In the mid-1980s, he successfully solved the problem of soliton interaction, which laid an important foundation for soliton communications, a field in which he maintained an interest for over 20 years. In addition, Prof. Chu had worked on a large number of innovative optical devices, including nonlinear optical switches, fiber-optic acoustic sensors, polymer fiber Bragg gratings, and vertical optical polymer waveguide couplers. This work has attracted considerable attention over the years. His study on chaos communications is also very influential. In recent years, he spent much effort in promoting polymer optical fiber technology, a growing field with many potential applications in short-distance transmission and optical sensing. His contributions to the field of fiber optics are invaluable.

On the teaching side, Prof. Chu supervised over 40 doctoral and numerous honours students and developed the first undergraduate courses in optical communications technology in Australia. Prof. Chu was also active in fostering collaborations with industry and organising international conferences and training workshops to raise the profile of the photonics community in Hong Kong. After his retirement from UNSW in 2006, he joined a local company, LINKZ International Limited (the former Networking Cable Business Unit of LTK), where he continued to make contributions in photonics for the rest of his time in Hong Kong.

Prof. Chu is survived by his wife Eva, daughter Evelyn, son Desmond and five grandchildren.

Optoelectronics Group, Department of Electronic Engineering, City University of Hong Kong, April 2008.

Optoelectronics Group, Department of Electronic Engineering, City University of Hong Kong, April 2008.
2008 IEEE/LEOS Quantum Electronics Award Recipients: Jeffrey H. Shapiro and Horace P. Yuen

The Quantum Electronics Award is given to honor an individual (or group of individuals) for outstanding technical contributions to quantum electronics, either in fundamentals or application or both. The Award may be for a single contribution or for a distinguished series of contributions over a long period of time. No candidate shall have previously received a major IEEE award for the same work. Candidates need not be members of the IEEE or LEOS. The deadline for nominations is 16 February.

Jeffrey H. Shapiro is Director of the Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT). He received the S.B., S.M., E.E., and Ph.D. degrees in Electrical Engineering from MIT in 1967, 1968, 1969, and 1970, respectively. As a graduate student he was a National Science Foundation Fellow, a Teaching Assistant, and a Fannie and John Hertz Foundation Fellow. His doctoral research was a theoretical study of adaptive techniques for improved optical communication through atmospheric turbulence.

From 1970 to 1973, Dr. Shapiro was an Assistant Professor of Electrical Sciences and Applied Physics at Case Western Reserve University. From 1973 to 1985, he was an Associate Professor of Electrical Engineering at MIT, and in 1985, he was promoted to Professor of Electrical Engineering.

From 1989 until 1999 Dr. Shapiro served as Associate Department Head of MIT’s Department of Electrical Engineering and Computer Science. In 1999 he became the Julius A. Stratton Professor of Electrical Engineering. In 2001, Dr. Shapiro was appointed Director of RLE.

Dr. Shapiro’s research interests have centered on the application of communication theory to optical systems. He is best known for his work on the generation, detection, and application of squeezed-state light beams, but he has also published extensively in the areas of atmospheric optical communication, coherent laser radar, and quantum information science.

Dr. Shapiro is a fellow of the Institute of Electrical and Electronics Engineers, of the Optical Society of America, of the American Physical Society, and of the Institute of Physics, and he is a member of SPIE (The International Society for Optical Engineering). He has been an Associate Editor of the IEEE Transactions on Information Theory and the Journal of the Optical Society of America, and was the Principal Organizer of the Sixth International Conference on Quantum Communication, Measurement and Computing (QCMC’02). He currently co-chairs the Steering Committee for the International Conferences on Quantum Communication, Measurement and Computing, and is Co-Director of the W. M. Keck Foundation Center for Extreme Quantum Information Theory.

Horace P. Yuen is a Professor of Electrical Engineering and Computer Science and Professor of Physics and Astronomy at Northwestern University. He received his degrees in Electrical Engineering from Massachusetts Institute of Technology. His technical research interests are mainly in the areas of communication and cryptography, especially those with quantum effects. He is a recipient of the first International Quantum Communication Award presented by Tamagawa University of Japan, a fellow of the American Physical Society, and a senior member of IEEE. Several of his papers are collected in various special volumes, including “One Hundred Years of Physical Review,” which was published by the American Physical Society in 1993.
2008-09 Distinguished Lecturers:

The Distinguished Lecturer Awards are presented to honor interesting speakers who have made recent significant contributions to the field of lasers and electro-optics. The Distinguished Lecturers speak at LEOS Chapters worldwide. Please contact your local chapter to see when one of the Lecturers will be speaking in your area. A list of current LEOS Chapter Chairs is available on the LEOS web site (www.i-LEOS.org).

This year’s new Lecturers are:

**John C. Cartledge**, Queen’s University, Ontario, Canada
Topic of Lecture: Optical and Electronic Signal Processing for Fiber-Optic Communications

**John M. Dudley**, Laboratoire d’Optique P.M. Duffieux, France
Topic of Lecture: Nonlinear Fiber Optics and Supercontinuum Generation: New Fibers, New Opportunities

**Prem Kumar**, Northwestern University, IL, USA
Topic of Lecture: Fiber-Optic Quantum Communications and Information Processing

Lecturers serving a second term are:

**Weng Chow**, Sandia National Laboratory, NM, USA
Topic of Lecture: Many-Body Effects and Their Influences on Semiconductor Lasers

**Silvano Donati**, Universita Pavia, Italy
Topic of Lecture: Coupling in Lasers and Applications to Self-Mixing Interferometry and Chaotic Cryptography

**El-Hang Lee**, INHA University, South Korea
Topic of Lecture: Optical Printed Circuit Board (O-PCB) and VLSI Photonics

**Colin McKinstrie**, Bell Labs, Alcatel-Lucent, NJ, USA
Topic of Lecture: Optical Signal Processing by Parametric Devices

**Cun-Zheng Ning**, Arizona State University, AZ, USA
Topic of Lecture: Nanolasers Based on Semiconductor Nanowires and Surface Plasmons

2008-2009 LEOS Distinguished Lecturers

**John C. Cartledge** was a Member of the Scientific Staff at Bell-Northern Research, Ottawa, Ontario, Canada, from 1979 to 1982, where his work involved fiber-optic systems for the exchange access network and high-capacity digital radio systems. Since 1982 he has been with the Department of Electrical and Computer Engineering, Queen’s University. In July 2002 he was appointed an inaugural recipient of a Queen’s Research Chair. He has spent one-year sabbatical leaves with the Lightwave Systems Technology Research Division of Bellcore, Red Bank, NJ, in 1988-89, and with the Optical Communications Department of Tele Danmark Research, Hørsholm, Denmark in 1995-96. Dr. Cartledge has served as a consultant and instructor in the area of lightwave technology to several organizations. His current research interests include optical modulators, optical signal processing (wavelength converters, optical regenerators), electronic signal processing for arbitrary optical waveform generation, and dispersion compensating fiber Bragg gratings. Dr. Cartledge is Chair of the Optical Networks and Systems Committee, IEEE Lasers and
Career Section (cont’d)


Title of Talk: Optical and Electronic Signal Processing for Fiber-Optic Communications

Currently, there is a substantial research and development effort directed toward optical signal processing and electronic signal processing for fiber-optic communications. Much of the work is aimed at mitigating the effects of transmission impairments such as chromatic dispersion, polarization mode dispersion, fiber nonlinearities, amplifier noise, and band-limiting. It is being pursued in the presence of an ongoing interest in increasing the per-channel bit rate in order to meet the growing demand for telecommunication services. For optical signal processing, a variety of approaches are available for implementing functions such as 3R (re-amplification, reshaping and re-timing) regeneration. For electronic signal processing, advanced digital signal processing is being applied to both fiber-optic transmitters and receivers, and has lead to a renewed interest in coherent optical detection. This lecture presents an overview of optical and electronic signal processing technologies, including a critical assessment of each approach. Specific examples are considered in more detail to highlight key aspects of the technologies.

John Dudley received B.Sc and Ph.D. degrees from the University of Auckland in 1987 and 1992 respectively. In 1992 and 1993, he carried out postdoctoral research at the University of St Andrews in Scotland before taking a lecturing position in 1994 at the University of Auckland. In 2000, he was appointed Professor at the University of Franche-Comté in Besançon, France, where he currently heads the Optoelectronics and Photonics research group. He was named a member of the Institut Universitaire de France in 2005, and elected a Fellow of the Optical Society of America and a Senior Member of the IEEE in 2007. He serves on the Editorial boards of Optics Express, Optical and Quantum Electronics and Optical Fiber Technology. He is General Chair of CLEO Europe 2009 and currently serves as the secretary of the Quantum Electronics and Optics Division of the European Physical Society.

Title of Talk: Nonlinear Fiber Optics and Supercontinuum Generation: New Fibers, New Opportunities

Research in nonlinear fiber optics is currently undergoing dramatic expansion, motivated by advances and developments in new classes of optical fiber and the ready availability of a wide range of optical pump sources. This lecture will survey selected recent work in this field that has investigated novel propagation effects in both photonic crystal and highly nonlinear optical fibers, and will focus particular attention on the physics and applications of supercontinuum generation. The lecture will provide both a tutorial review of the basic supercontinuum generation broadening mechanisms as well as a discussion of recent developments and applications.

Prem Kumar is the AT&T Professor of Information Technology in the department of Electrical Engineering and Computer Science and Director of the Center for Photonic Communication and Computing in the McCormick School of Engineering and Applied Science at Northwestern University. He also holds an appointment as Professor of Physics and Astronomy and joined Northwestern in 1986 after spending five years at MIT as a research scientist. He received a Ph.D. in Physics from the State University of New York at Buffalo in 1980. He is the author or co-author of over 400 publications, including one edited book, six patents, over 140 papers in peer-reviewed journals, 40 articles in hard-bound volumes, and over 80 invited conference papers. His research focuses on the development of novel free-space and fiber-optic devices for ultrahigh-speed optical and quantum communication networks. He is a fellow of the Optical Society of America (OSA), a fellow of the American Physical Society (APS), a fellow of the Institute of Electrical and Electronic Engineers (IEEE), and a fellow of the Institute of Physics, UK (IOP). In 2006 he received the Martin E. and Gertrude G. Walder Research Excellence Award from Northwestern University and in 2004 he was
the recipient of the 5th International Quantum Communication Award established by the Tamagawa University in Tokyo, Japan. On the academic side, his professional services have included Associate Editor, Optics Letters; General (Program) Co-Chair, QELS 2008 (2006); Principal Organizer, 4th International Conference on Quantum Communication, Measurement, and Computing, 1998. On the business side, he is the founder of NuCrypt LLC, a startup company focusing on the commercialization of quantum encryption technology for securing the physical layer of fiber-optic and free-space optical networks.

**Title of Talk: Fiber-Optic Quantum Communications and Information Processing**

Recognizing the ubiquitous standard optical fiber for long-distance transmission and the widespread availability of efficient active and passive fiber devices, there are significant efforts underway to develop practical resources for quantum communications and information processing in optical fiber networks. Entanglement, which refers to the nonclassical dependency of physically separated quantum systems, is one such resource that is essential for implementing many of the novel functions of quantum information processing. Therefore, the efficient generation and distribution of quantum entanglement in fiber optical systems is of prime importance. Entanglement has been historically produced by use of the spontaneous parametric down-conversion process in second-order nonlinear crystals, wherein one higher-frequency pump photon splits into two lower-frequency daughter photons which can be entangled. Coupling such down-converted photons into optical fibers without degrading entanglement, however, has remained a challenging task. Fortunately, the prospects for ready availability of entanglement in the telecom band have dramatically improved in the last few years by the emergence of a new technique for generating entanglement directly in the fiber itself. This technique utilizes the Kerr nonlinearity of standard optical fiber to produce quantum correlated photons through the spontaneous four-wave mixing process. The correlated photons can be entangled in various ways by incorporating indistinguishable pathways in the four-wave mixing amplitude. In this lecture, I will review the status of this field by describing recent experiments that demonstrate the generation and distribution of quantum entanglement is wave-division multiplexed optical fiber systems. I will also present some recent results on utilizing such entanglement for quantum communications and information processing tasks.

**Weng Chow** received the Ph.D. degree in physics from the University of Arizona. His dissertation work involved fluctuation phenomena in quantum optics. At present, he is Distinguished Member of the Technical Staff at Sandia National Laboratories. Weng Chow’s primary research interest is in the application of microscopic theory to semiconductor laser device development. Some of this work is described in two texts, Semiconductor-Laser Physics and Semiconductor-Laser Fundamentals: Physics of the Gain Materials. His other interests include laser gyroes, phased arrays, coupled lasers, quantum optics and optical ignition of pyrotechnics.

Weng Chow also holds the position of Research Professor of Physics at Texas A&M University, Adjunct Professor of Optical Sciences at the University of Arizona and Honorary Professor of Physics at Cardiff University. He has served on the CLEO semiconductor laser program committee and is an associate editor of IEEE Journal of Quantum Electronics. Weng Chow is a fellow of the Optical Society of America, and recipient of the Dept of Energy, Basic Energy Science/Material Science Award, the Alexander von Humboldt Senior Scientist Award and the LEOS Distinguished Lecturer Award.

**Talk title: Many-Body Effects and Their Influences on Semiconductor Lasers**

The incorporation of many-body effects into semiconductor laser gain calculations has led to significant improvement in accuracy and predictive capability. This talk will explain the many-body effects and sketch the formulation of a laser theory containing the necessary physics. Examples of application of the theory will be presented. These examples involve laser systems ranging from VCSELs to wide-bandgap and quantum-dot lasers.

S. Donati is full Professor at University of Pavia since 1980. He authored 2 books (Photodetectors, Prentice Hall 1999, and Electro-optical Instrumentation, Prentice Hall 2004), about 250 papers in Journal and Conference Proceedings, and has been the Guest Editor of a dozen Special Issues (JSTQE, J O-A, Opt.Engineer., JQE, etc.). His seminal papers on self-mixing interferometry and optical chaotic cryptography have totaled 500+ citations. He is a Fellow of IEEE and of OSA. He has founded and has been the Chair of the LEOS Italian Chapter. Has been LEOS VP Region 8 membership and BoG member of the LEOS. He is presently the Chair of the IEEE Italy Section.
Title of talk: Coupling in Lasers and Applications to Self-Mixing Interferometry and Chaotic Cryptography

In this presentation, we start with a brief theoretical introduction to mutual and self coupling phenomena in laser oscillators and then describe in detail two applications. The first is self-mixing interferometry for measurements of displacement, distance, vibration, and angle, and physical parameters like coupling factors, line width, and alfa-factor. In this case, the laser undergoes self-injection at weak level, leading to an amplitude and frequency modulation driven by external optical path. The second application is optical chaos, which is generated by the laser source at strong level of injection. We describe mutual and self-injection generation of chaos, and the first step of development to cryptography, that is synchronization. Then, we will review several schemes of coding and decoding of information, i.e., chaotic masking and CSK (chaos shift keying) and how they can be implemented, along with theoretical and experimental results carried out recently.

El-Hang Lee obtained his B.S.E.E. (summa cum laude), at Seoul National University, Korea, 1970; M.S., M.Phil., and Ph.D., Applied Physics, at Yale University, 1973, 1975 and 1977, respectively, under Prof. John B. Fenn (Yale Nobel Laureate, Chemistry, 2002) and Prof. Richard K. Chang (Henry Ford II Professor, former student of Prof. N. Bloembergen, Harvard Nobel Laureate, Physics, 1981). He conducted teaching, research and management at Yale, Princeton, MEMC, AT&T Bell, ETRI (vice president), KAIST, and at INHA in the fields of semiconductor physics, materials, devices, optoelectronics, photonics, and optical communication. Founding Dean, School of Communication and Information Engineering; Dean, Graduate School of the Information Technology and Telecommunications; Founding Director, OPERA (Optics and Photonics Elite Research Academy) and m-PARC (micro/nano-Photonics Advanced Research Center); Vice President, Optical Society of Korea; Founding Director, IEEE-LEOS Korea; Founding Director, SPIE Korea. 230 international refereed SCI-covered journal and review papers; 640 international conference presentations; 100 plenary, keynote, and invited talks in international conferences; Edited books and international proceedings; 120 international patents; 100 services as international conference chair, committee member, and advisor. Fellow, IEEE (USA), IEE (UK), OSA (USA), SPIE (USA), APS (USA), KPS (Korea), IEEK (Korea), and Life Fellow, Korean Academy of Science and Technology. Recipient of 15 national and international awards, including Presidential Medal of Honor (Science), Korea; King Sejong Award (Science), Korea; IEEE/LEOS Chapter-of-the-Year Award, and the IEEE Third Millennium Medal, USA.

Title of Talk: Optical Printed Circuit Board (O-PCB) and VLSI Photonics

This lecture presents a comprehensive review and overview on the cutting-edge frontier science and engineering of micro/nano-photonic integration that we have been pursuing aiming for what we call “optical printed circuit boards” (O-PCBs) and VLSI photonic chips. It discusses on the theory, design, fabrication, and integration of micro/nano-scale photonic devices, circuits, and networks in the form of “VLSI photonic integrated circuits” (VLSI-PICs) and “optical micro/nano-networks (O-MNNs)” of generic and application-specific nature on O-PCB platforms. These systems are designed to be compact, high-speed, light-weight, low-powered, low-cost, intelligent, and environmentally friendly as applicable for datacom, telecom, transportation, aero-space, avionics, bio/medical, sensor, and environmental systems. The O-PCBs, VLSI-PICs and O-MNNs process optical signals through optical wires, devices, and circuits in contrast to the traditional electrical PCBs, VLSI-ICs, and networks. The O-PCBs and VLSI photonic systems are to overcome the limitations of the electrical PCBs and VLSI-IC systems and are also aimed to integrate convergent IT/BT/NT micro/nano-devices, circuits, and chips for broad based applications and usages. The new optical systems consist of 2-dimensional planar arrays of optical wires, circuits and devices of micro/nano-scale to perform the functions of sensing, storing, transporting, processing, switching, routing and distributing optical signals on flat modular boards or chips. The integrated optical components include micro/nano-scale light sources, waveguides, detectors, switches, modulators, sensors, directional couplers, multi-mode interference devices, AWGs, wavelength filters, micro-ring resonator devices, photonic crystal devices, plasmonic devices, and quantum devices, made of polymer, silicon and other semiconductor materials. The lecture discusses scientific and technological issues, challenges, and progresses regarding the miniaturization, interconnection and integration of micro/nano-scale photonic devices, circuits, and networks leading to ultra-small and very large scale integration and discusses their potential applications. The issues include the diverse compatibility issues between micro/nano-devices such as materials mismatch, size mismatch, shape mismatch, mode mismatch, optical mismatch, mechani-
Cal/thermal mismatch and the micro/nano-optical effects such as micro-cavity effects, non-linear effects, and quantum optical effects in small devices. Scaling rules for the miniaturization and integration of the micro/nano-photonic systems will also be discussed in comparison with those of the electrical systems. New physics, new materials, new designs, and new visions, issues and challenges of the optical micro/nano-optical circuits, networks and systems will be discussed along with the historical perspectives of the electrical technology. Recent progresses and examples will be presented along with the future outlook.

Colin J. McKinstrie received BSc and PhD degrees from the Universities of Glasgow and Rochester, in 1981 and 1986, respectively. From 1985 to 1988 he was a Postdoctoral Fellow of Los Alamos National Laboratory, where he was associated with the Applied Physics Division and the Center for Nonlinear Studies. In 1988 he returned to the University of Rochester as a Professor of Mechanical Engineering and a Scientist in the Laboratory for Laser Energetics, where his main research interests were plasma-based particle acceleration, laser-plasma interactions and nonlinear fiber optics. Since 2001 Dr. McKinstrie has been a Member of the Technical Staff at Bell Laboratories, where he has served on technical committees for CLEO, FiO, LEOS and OFC, and is the Chair of the OSA Quantum Electronics Division.

Title of Talk: Optical Signal Processing by Parametric Devices

Parametric devices based on four-wave mixing in fibers provide many functions that are required by optical communication systems. When operated in the linear regime, parametric devices provide amplification, frequency conversion and phase conjugation, all with high gain levels and broad bandwidths. They can also be used to buffer, monitor and switch optical signals. When operated in the nonlinear regime, parametric devices regenerate signals. They also produce entangled and squeezed states of light. In this talk recent research on parametric devices will be reviewed, and the implications of this research for classical and quantal communication systems will be discussed.

Colin J. McKinstrie

Cun-Zheng Ning obtained his PhD in Physics from University of Stuttgart. He was a Senior Scientist, group leader, or task manager at NASA Ames Center for Nanotechnology, NASA Ames Research Center from 1997-2006. He joined Arizona State University in 2006, where he is a Professor of Electrical Engineering with the Center for Nanophotonics, Arizona Institute of Nanoelectronics, and Affiliate Professor in Materials and in Physics. Dr. Ning has been conducting research in the general fields of laser physics, semiconductor lasers, optoelectronic device modeling and simulation for the last 20 years. Recently, he has also developed a significant experimental program in semiconductor nanowire research on nanowire growth, optical characterization, and device fabrication. His group was the first to grow antimonide nanowires and first to demonstrate a single-nanowire infrared laser. His group has also been actively engaged in semiconductor plasmonic devices focusing on integrating semiconductor nanostructures with metallic nanostructures for various applications such as nanolasers, solar cells and detectors. He has published 120 scientific papers and given many conference presentations including ~50 invited talks. He has served in many international conference committees including SPIE Photonics West, OSA annual meetings, and CLEO. He also served in editorial committee or as a special topic editor for a few journals including IEEE JQE, J. Special. Topics in Quantum Electron., J. Opt. Soc. Am., Optics Express, etc. For his research at NASA, he was winner of many NASA and NASA contractor awards.

Title of Talk: Nanolasers Based on Semiconductor Nanowires and Surface Plasmons

The pursuit of nanotechnology in general and miniaturization of electronic devices in particular have seriously challenged the optoelectronics community to develop ever smaller lasers and optoelectronic devices compatible with the trend in microelectronics. Vertical-cavity surface emitting lasers measured a few microns were once the smallest lasers. The situation is now rapidly changing over the last 5 years with the demonstration of lasing capability of a single semiconductor nanowire of ~ 100 nanometers in diameter. The question of great importance is: what is the ultimate size limit of a laser?

To answer this and related questions, my lecture will start with impressive recent progress in growth, fabrication, and characterization of semiconductor nanowires and
Career Section (cont’d)

demonstration of lasing activities in various wavelengths. These lasers represent the smallest lasers of any kind at present. We will show how this new type of miniaturized lasers differs from the conventional semiconductor lasers. To further reduce the dimension of nanowire lasers, a recent proposal of using metal coating of semiconductor wires will be evaluated. We will show that a proper design of a metal coated semiconductor nanowire can achieve lasing threshold despite significant metal loss. Very recent experimental results of demonstrating such lasers will be presented. Finally some recent novel ideas involving surface plasmonic excitations at metal-semiconductor interface will be discussed where much smaller lasers could be potentially made, with size independent of wavelengths.

Membership Section

Benefits of IEEE Senior Membership

There are many benefits to becoming an IEEE Senior Member:
- The professional recognition of your peers for technical and professional excellence
- An attractive fine wood and bronze engraved Senior Member plaque to proudly display.
- Up to $25 gift certificate toward one new Society membership.
- A letter of commendation to your employer on the achievement of Senior member grade (upon the request of the newly elected Senior Member.)
- Announcement of elevation in Section/Society and/or local newsletters, newspapers and notices.
- Eligibility to hold executive IEEE volunteer positions.
- Can serve as Reference for Senior Member applicants.
- Invited to be on the panel to review Senior Member applications.

The requirements to qualify for Senior Member elevation are, a candidate shall be an engineer, scientist, educator, technical executive or originator in IEEE-designated fields. The candidate shall have been in professional practice for at least ten years and shall have shown significant performance over a period of at least five of those years. “

To apply, the Senior Member application form is available in 3 formats: Online, downloadable, and electronic version. For more information or to apply for Senior Membership, please see the IEEE Senior Member Program website: http://www.ieee.org/organizations/rab/md/smprogram.html

New Senior Members

The following individuals were elevated to Senior Membership Grade thru March-May:

- Timothy J. Carrig
- Ching K. Chia
- Marc P. Christensen
- Dennis Derickson
- Glen P. Dudevoir
- Chang-Hee Lee
- Mark S. Leeson
- Yiu-Wing Leung
- Anhui Liang
- Alexander S. Logginov
- Sergei A. Malyshev
- Shahid Maqud
- Phyllis R. Nelson
- Jesper Nørregaard
- Daniel L. Peterson
- Aleksandar D. Rakic
- Jae-Hyun Ryu
- Masatoshi Saruwatari
- Hrayr A. Sayadian
- Michael A. Seigler
- Julian B. Soole
- Barton W. Stuck
- Anna Tzanak
- Timo Alto
- Guido Chiafetti
- R. P. Dahlgren
- David L. Esquivel
- Sarath D. Gunapala
- Lawrence A. Hornak
- Jianjiang Huang
- Shafiqul Islam
- Boero L. Paolo
- Yuan Shi
- Joseph J. Talghader
- Yuelin Wang
- Yong-Gang Zhang
Membership Section (cont’d)

LEOS Central New England Chapter (CNEC)

The 2007-08 academic year has been another busy year for the Central New England Chapter of LEOS, colloquially known as the Boston Chapter. As the oldest local LEOS Chapter in the IEEE, as well as one of its largest in a compact geographical area, with over 300 local active members, we strive to meet the high standards set by the many previous generations of past local chapter chairs. To this end, we maintain our chapter’s two strong traditions of holding 10 monthly technical seminars (Sept. – June) on current research topics in Lasers/Optics with truly outstanding speakers (see list below), and putting on a 10 speaker tutorial Workshop on a single current “hot” topic, with 2 speakers per night on 5 consecutive Wednesday nights (see list below) in the spring or fall. This year the workshop subject chosen was Plasmonics, which followed our previous years workshops on Terahertz Systems, Nanophotonics, and Photonic Crystals. We require pre-registration for our yearly workshop, and generally charge a minimal fee (e.g. $50 for all 5 nights) to cover the cost of refreshments during the breaks and printing of the handouts. Each year the number registering for our local workshop has increased, hitting 115 for this year’s fall Plasmonics Workshop. Equally rewarding, is that we are now receiving requests from speakers asking to give a talk at our local yearly workshop once the topic is announced. This year we had to include a third speaker on one night, as it is just getting harder and harder to down-select from the abundance of appropriate well-qualified speakers available.

Otherwise, on the mechanics of running our chapter, we find that most of our yearly changes are more in the category of fine-tuning, to better respond to our changing member’s needs, although we did make permanent the two major changes we instituted last year. First, we had moved our monthly meeting location to MIT Lincoln Laboratories in suburban Boston, after alternatively meeting in the old suburban Verizon / GTE Labs for over 20 years (Verizon after absorbing GTE closed its labs and sold the land to a developer), and at Boston University in downtown Boston (BU began charging for parking at evening meetings). But, perhaps even this change might not be final, as MIT Lincoln Laboratories is on Government property, we learned that we had no possible appeal, when in December an approaching snowstorm led officials to close the building we meet in, only hours before our meeting began. Second, we moved our meeting time to earlier in the evening and now serve free pizza and soft drinks during the networking hour before our monthly meetings. This was done because we learned, while being continuously re-educated over the past 25 years that our industrial members will not drive into downtown Boston to traffic to pay for parking at a University location, that free pizza always attracts graduate students to our meetings at such a location. Thus, we developed a hybrid approach to serve/attract at least part of the available student audience. By serving pizza during the hour between when the MIT Lincoln Lab workday ends, and our monthly meeting starts, some of the large number of MIT graduate students doing their daily research at Lincoln Lab delay their return to Cambridge for a couple of hours, to eat pizza, talk with us, and attend our meeting, before catching the last buses back to Cambridge at 7:30 PM. Hopefully, those that stay in the Boston area after graduation will continue to attend our meetings.

Already, a couple of recently graduated, new-hire Lincoln Lab staff members, who volunteered to help run our chapter, have greatly decreased the average age of our chapter officers. In addition, we have also worked diligently on maintaining, what might be thought of as a rather over-ambitious advertising campaign by those from outside of the suburban Boston area, of our monthly chapter meetings and Workshops to promote attendance. But, as we have learned from much past bitter experience, we are competing with all the daily seminars and departmental colloquiums of over 25 world-class Universities and Colleges in the Boston/Cambridge area, with their world-wide draw of technical speakers from every field in Physics, Engineering, and Biology. These day-time talks saturate the market for technical information for anyone associated with a University, College, or academic research institution in the city. While the downside is that it is very hard to convince an audience of faculty members and researchers working in the Boston/Cambridge area that we can produce better talks in their respective field at our evening chapter meeting, the upside is that we have the widest and deepest collection of talent from which to draw local speakers (we find that even out-of-country speakers, talking at a university during the day, are willing to give another talk that evening at the local LEOS chapter meeting). Hence, it is critical for us to design the advertising for our chapter talks to reach other audiences, which are mostly drawn from local industry surrounding suburban Boston, rather than from the research establishment at the Boston/Cambridge Universities.
Membership Section (cont'd)

We reach our intended audience by utilizing the IEEE Boston Section/CNEC newsmagazine "The Reflector", in both paper and electronic formats (paid circulation over 13,000 in eastern Mass, NH, Maine and RI), and on our own Web site <http://www.boston-leos.org>, as well as the local IEEE Web site <http://ieeeboston.org>. In addition we distribute at the September and January LEOS meetings, and by mail to the local Universities, Colleges, and Government and Corporate Research Labs, a one page poster of all the upcoming fall or spring talk's Titles and Speakers. An electronic PDF copy of the poster also gets e-mailed to all local LEOS's members, and any non-member who has added their email address to the attendee's list passed around at all chapter meetings. Furthermore, everyone on the two e-mail lists receives an automated reminder e-mail about each talk three days before it occurs.

Finally, we list CNEC LEOS's 2007-08 yearly program of monthly seminars and speakers, 3 of them local speakers, 7 from out-of-state, one a LEOS Distinguished Lecturer, and one a Nobel Prize winner:

1. September: “Energy Transfer and Light Emission from Erbium-doped Silicon Nanostructures,” Prof. Luca Dal Negro, Boston University, Boston, MA.


3. November: “Compact High Repetition Rate Soft X-Ray Lasers: A Doorway To High Intensity Coherent Soft X-Ray Science On A Table-Top” Prof. Jorge J. Roca, an IEEE LEOS Distinguished Lecturer, Colorado State University, Fort Collins, CO.

4. December: -- This meeting was canceled at last minute due to snow storm-- “Seeing The Invisible: Polarization Vision In Nature And Non-Invasive Imaging And Sensing,” Prof. Nader Engheta, University of Pennsylvania, Philadelphia, PA.


7. March: “Recent Results in Mid-Infrared Quantum Cascade Lasers,” Prof. Claire F. Gmachl, Princeton University, Princeton, NJ.

8. April: “New Forms of Matter - Created, Manipulated and Observed with Laser Light,” Prof. Wolfgang Ketterle, a Nobel Prize winner (Physics), MIT, Cambridge, MA.


10. June: “Quantum Imaging,” Prof. Yanhua Shih, University of Maryland, Baltimore County, Baltimore, MD.

And in conclusion, we list the talks and speakers at the CNEC LEOS's fall 2007 Plasmonics Workshop (5 of them local speakers, 6 from out-of-state):


2. “Metamaterials: from Near-Infrared to Visible,” Prof. Vladimir Shalaev, Purdue University, West Lafayette, IN.

3. “Nanostructures by the Square Yard: Large-Area Plasmonic and Negative-Index Materials,” Prof. Steve Brueck, University of New Mexico, Albuquerque, NM.

4. “Nanophotonics in Mid-IR: from Superlenses to Transmission Lines,” Prof. Gennady Shvets, University of Texas, Austin, TX.


6. “Plasmonics at Terahertz and Mid-Infrared Frequencies,” Prof. Richard Averitt, Boston University, MA.


9. “Coherent, Nonlinear, and Ultrafast Nanoplasmonics,” Prof. Mark Stockman, Georgia State University, Atlanta, GA.

10. “Giant Field Enhancement and Localization in Aperiodic Plasmonic Structures,” Prof. Luka Dal Negro, Boston University, Boston, MA.


William H. Nelson
member Technical Program Committee
LEOS CNEC Chapter
Conference Section

Recognition at OFC 2008

John H. Marsh, LEOS President, recognized the following LEOS members who have been elevated to the grade of IEEE Fellow: (From left to right) Radhakrishnan Nagarajan, Patrick Iannone, Kazuo Hagimoto, Janet Jackel, John Marsh (LEOS President), Susumu Noda, Akihiko Kasukawa, David Welch, and Kit Lia Paul Yu.

Joe C. Campbell (left) received the 2008 IEEE Photonics Award, “for seminal and sustained contributions to the development of high-speed, low-noise long wavelength avalanche photodiode. The award, which is sponsored by LEOS, was presented to Dr. Campbell by Dr. Lewis M. Terman, IEEE President.

The 2008 John Tyndall Award was presented to Robert W. Tkach, “for pioneering breakthroughs in high-capacity transmission systems and networks, including the invention of NZDF (non-zero dispersion fiber) and dispersion management of optical fiber nonlinearities”. This award is jointly sponsored by LEOS, OSA, and endowed by Corning Inc.
Summer Topicals 2008

Next Frontiers in Optical Communications & Optofluidics

July 21 - 23, 2008
Fairmont Acapulco Princess
Acapulco, Mexico

www.i-leos.org
Conference Section

2008 IEEE/LEOS
International Conference on
Optical MEMS & Nanophotonics

August 11-14, 2008
Conference Center "Konzerthaus"
Freiburg, Germany

CALL FOR PAPERS
Submission Deadline: 2 May 2008

Freiburg, Germany

2008 IEEE/LEOS Avionics
Fiber-Optics and Photonics Conference

September 30 - October 2, 2008
Holiday Inn on the Bay
San Diego, California

CALL FOR PAPERS
Submission Deadline: 28 May 2008
ECOC is the largest conference on optical communication in Europe, and one of the most respected and long-standing events of its kind in the world. ECOC 2008, from 21 to 25 September 2008, will be the 34th edition, which indicates the stability and the attractiveness of this conference as one of the world’s major events in the field, providing a prime forum for new developments and results in optical communication techniques and networks.

ECOC travels around Europe from year to year and now returns to Brussels. It was there for the first time in 1995, marking the start of the link between a commercial exhibition and the conference. In response to the increasing interest in the field of optical communications both in research and industry, the event has grown since then, both in size and importance and has successfully withstood the internet-bubble and the crisis in the telecommunication industry. ECOC 2007 in Berlin was again a great success and ECOC 2008 will continue this trend with even more exhibitors, papers and consequently a higher number of attendees, from all over the world.

The program consists of a set of high-level plenary speakers, tutorials, invited papers, workshops, symposia, and most importantly, parallel sessions with your contributions, technical papers and posters. The program will highlight new breakthroughs in the field of optical communications in different areas such as: Fibers, Fiber Devices and Amplifiers; Waveguide and Optoelectronic Devices; Subsystems and Network Elements for Optical Networks; Transmission Systems; Backbone and Core Networks; Access and Local Area Networks. As has been the case at ECOC 2006, Brussels will also host a CLEO Focus Meeting “Physics in Optical Communications” within the ECOC 2008 program. For the first time, the 14th Microoptics Conference (MOC ’08) will be co-located with ECOC.

We welcome you to ECOC 2008 in Brussels - the Bustling Heart of Europe, well-known for its tradition of chocolates, beers, French fries, biscuits,..., with over 1,800 restaurants, trendy bars and taverns in the city centre. Brussels also hosts numerous museums exhibiting work from world-famous artists, from Magritte to Rubens. It is the city of Comic Strips and the World Capital of ‘Art Nouveau’, amongst other highlights thanks to Victor Horta. Brussels also hosts the headquarters of NATO, is home to over 1,200 NGOs and over 1,700 international associations. On top of this, Brussels is home to the European Commission and the majority of the European Union’s Institutions, making it the bustling political heart of Europe.

Check for details and for further information at www.ecoc2008.org and make ECOC 2008 your event, by joining us in Brussels for an exciting conference!

Peter Van Daele & Dian Kroe, General Co-Chairs

Piet Demeester & Ton Koonan, Technical Program Co-Chairs

Roel Baets & John Dudley, Technical Program Co-Chairs
CLEO-Focus Meeting

www.ecoc2008.org
LEOS 2008

The 21st Annual Meeting of the IEEE Lasers & Electro-Optics Society

9 - 13 November 2008
Marriott Newport Beach Hotel & Spa
Newport Beach, CA

Paper Submission Deadline: 9 July 2008

Conference Chair: Sheryl Woodward,
AT & T Labs, Middletown New Jersey, USA
Program Chair: Chennupati Jagadish,
Australian National University, Canberra, Australia
Member at-large: Selim Unlu,
Boston University, Boston, Massachusetts, USA

www.i-leos.org
The Winter Topicals Conference in Sorrento, Italy 14-16 January 2008, brought together leading experts from research and industry, providing a familiar atmosphere for discussing new, innovative and upcoming technology trends in one of the most exciting topic of optics and photonics, the microstructured optical fibers, also called Photonic Crystal Fibers (PCFs) or holey fibers. PCFs have generated great interest in the scientific community as they offer the possibility to control the propagation of light with flexibility not obtainable with conventional optical fibers.

In a PCF, light can be guided using either total internal reflection or a photonic band-gap arising from some specific periodic arrangements of the air-holes. When a defect is introduced into such a structure, a localized state is created within the band-gap, and the light guiding becomes possible along the PCF. Solid-core and hollow-core PCFs are recognized as promising structures to exploit different regimes of light propagation and different media characteristics. Due to their unique properties, PCFs have important applications in several fields, such as telecommunications, metrology, spectroscopy, microscopy, astronomy, lithography, coherent optical tomography.

The Topical Meeting on “Photonic Crystal Fibers: Technology and Applications” gave the opportunity to exchange ideas between scientists working on technology and applications by covering a variety of topics related to PCF based devices and phenomena, including lasers and amplifiers, high nonlinearities, numerical design and analysis, supercontinuum generation, optical sensors, technologies and materials, band-gap effects, wide-band transmissions, birefringence. Nine regular sessions plus one Joint Session covered the cited topics, enriched by sixteen invited papers given by scientists from all over the world who provided an effective overview about this rapidly growing area, stimulating particular interest on topics like high power applications, nonlinear phenomena and properties of band-gap PCFs. The meeting gave the sensation that the recent progresses and the future potentials, not yet fully exploited, will for sure drive an exciting PCF development still able to attract attention and research efforts for years, to find ever interesting and new applications in many areas of human activity.

The pleasant location on the Sorrento coast and the proper selection of correlated topics in photonics, “Chip-Scale Nonlinear Optical Devices”, “Fibre Optical Parametric Amplifiers and Related Devices” and “Nonlinear Optics in Liquid Crystals”, helped in gathering a number of interested people from research and industry.

As the meeting Chair, I would like to thank the Co-chair, Prof. Kunimasa Saitoh, for the invaluable help, all the invited speakers for the outstanding presentations, all the participants for their contributions and the LEOS staff, which helped assuring the successful organization of the meeting.

Prof. Stefano Selleri
University of Parma, Italy
Chair of the Winter Topicals Conference
Photonic Crystal Fibers: Technology and Applications
SUBMISSION DEADLINE 3 October 2008
REGISTRATION DEADLINE 12 December 2008

LEOS Winter Topicals 2009

CALL FOR PAPERS

Nano & Nonlinear Photonics

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Min Qiu, Royal Institute of Technology, Sweden

Nonlinear Dynamics in Photonic Systems
Co-Chairs:
Trevor M. Benson, University of Nottingham, UK
Marcin Marciniak, National Institute of Telecommunications, Poland

Nonlinear Processing in Optical Fibers
Co-Chairs:
Michel Marhic, Swansea University, UK
Stojan Radic, University of California-San Diego, USA
CALL FOR PAPERS

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Sponsored by LEOS and EDS

Paper submission deadline:
15 December | 2008

For full conference information visit:
www.i-leos.org

May 10-14
Newport Beach Marriott Hotel and Spa
Newport Beach | California
Call for Papers

JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS ON HIGH POWER FIBER LASERS
Submission Deadline: September 1, 2008

IEEE Journal of Selected Topics in Quantum Electronics invites manuscript submissions in the area of solid state photonics. The purpose of this issue of JSTQE is to document recent advances in the areas of high power fiber laser technology. Broad technical areas include (but are not limited to):

- Fiber design, fabrication and properties; components
  - design, fabrication and characterization techniques for novel fibers, fiber materials and dopants
  - photodarkening
  - large-mode-area and dispersion-tailored fibers in glass-air or all-glass geometries
  - distributed filtering
  - polarization preservation
  - fiber and volume Bragg gratings and other components
- Fiber lasers and amplifiers
  - modeling and realization of fiber lasers and amplifiers for all wavelengths, linewidths, and temporal regimes
  - beam propagation control and pulse shaping
  - thermal management
  - pump coupling, and all aspects of packaging and integration
- Fiber nonlinearities
  - management and application of fiber nonlinearities (FWM, SPM, SRS, SBS, etc.)
  - spatial Kerr effects

The Guest Editors for this issue are Johan Nilsson, University of Southampton - Optoelectronics Research Center, Southampton, UK; Siddharth Ramachandran, OFS Labs, Somerset, NJ, USA; Thomas Shay, Air Force Research Labs – DELO, Kirtland AFB, Albuquerque, NM, USA, and Akira Shirakawa, University of Electro-Communications – Institute for Laser Science, Tokyo, Japan

The deadline for submission of manuscripts is September 1, 2008; publication is scheduled for January/February of 2009.

Online Submission is Mandatory at: http://mc.manuscriptcentral.com/leos-ieee Please select the Journal of Selected Topics Of Quantum Electronics Journal from the drop down menu. Contributed papers should be up to eight pages in length, and invited up to 12 pages. Beyond that, a charge of $220 per page apply. All submissions will be reviewed in accordance with the normal procedures of the Journal. You may find the Tools for Authors link useful: http://www.ieee.org/web/publications/authors/transjnl/index.html.

For inquiries please contact: JSTQE Editorial Office - Chin Tan-yan IEEE/LEOS 445 Hoes Lane Piscataway, NJ 08854 USA Phone: 732-465-5813 Email: c.tan-yan@ieee.org

Contact c.tan-yan@ieee.org for any questions about this issue. For all papers published in JSTQE, there are voluntary page charges of $110.00 per page for each page up to eight pages. Invited papers can be twelve pages and Contributed papers should be 8 pages in length before overlength page charges of $220.00 per page are levied. The length of each paper is estimated when it is received. Authors of papers that appear to be overlength are notified and given the option to shorten the paper. Additional charges will apply if color figures are required.

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JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS ON PRELIMINARY CALL:
SEMICONDUCTOR LASERS
Submission Deadline: November 1, 2008

We invite authors to submit manuscripts in the area of semiconductor lasers. The purpose of this issue of JSTQE is to document the current state-of-the-art and basic research in semiconductor lasers through a collection of original papers.

Although the issue serves as a venue for publication of full length journal articles expanding upon presentations at the 2008 International Semiconductor Laser Conference, issue is open to any research topic that is relevant to the semiconductor laser field.

The Primary Guest Editor for this issue is Prof. Luke F. Lester of the University of New Mexico, USA. The Guest Co-Editors include Prof. Thomas L. Koch of Lehigh University, USA and Prof. Johann Peter Reithmaier of the Universitaet Kassel, Germany.

The deadline for submission of manuscripts is November 1, 2008; publication is scheduled for May/June of 2009.

Online Submission is Mandatory at: http://mc.manuscriptcentral.com/leos-ieee Please select the Journal of Selected Topics Of Quantum Electronics Journal from the drop down menu.

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All submissions will be reviewed in accordance with the normal procedures of the Journal.

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<table>
<thead>
<tr>
<th>Page #</th>
<th>Advertiser</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVR2</td>
<td>R Soft</td>
</tr>
<tr>
<td>CVR3</td>
<td>Tempo Plastics</td>
</tr>
<tr>
<td>CVR4</td>
<td>Mathworks</td>
</tr>
<tr>
<td></td>
<td>Optivane</td>
</tr>
<tr>
<td>9</td>
<td>IEEE MDL</td>
</tr>
<tr>
<td>11</td>
<td>CSI</td>
</tr>
<tr>
<td>17</td>
<td>Corning Incorporated</td>
</tr>
<tr>
<td>21</td>
<td>Third Millenium</td>
</tr>
<tr>
<td></td>
<td>IEEE Marketing</td>
</tr>
<tr>
<td></td>
<td>General Photonics</td>
</tr>
</tbody>
</table>

LEOS Mission Statement

LEOS shall advance the interests of its members and the laser, optoelectronics, and photonics professional community by:
- providing opportunities for information exchange, continuing education, and professional growth;
- publishing journals, sponsoring conferences, and supporting local chapter and student activities;
- formally recognizing the professional contributions of members;
- representing the laser, optoelectronics, and photonics community and serving as its advocate within the IEEE, the broader scientific and technical community, and society at large.

LEOS Field of Interest

The Field of Interest of the Society shall be lasers, optical devices, optical fibers, and associated lightwave technology and their applications in systems and subsystems in which quantum electronic devices are key elements. The Society is concerned with the research, development, design, manufacture, and applications of materials, devices and systems, and with the various scientific and technological activities which contribute to the useful expansion of the field of quantum electronics and applications. The Society shall aid in promoting close cooperation with other IEEE groups and societies in the form of joint publications, sponsorship of meetings, and other forms of information exchange. Appropriate cooperative efforts will also be undertaken with non-IEEE societies.
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