



# REPORT FROM FiO: Global

Patricia Daukantas

For its 90<sup>th</sup> annual meeting, OSA returned home to its birthplace of Rochester, N.Y. In addition to presenting recent research in pure and applied optics, speakers at the 2006 Frontiers in Optics (FiO) conference challenged the optics community to work toward solving some of society's most urgent problems, including the need to find alternative energy sources and halt the progression of Alzheimer's disease.

**A**s OSA entered its tenth decade, its leaders and members reflected on the past, present and future of optics at the 2006 FiO meeting—and on the role that the Society has played in shaping and strengthening the international optics community. Attendees could view exhibits detailing the discoveries and achievements of the past, including the birth of the laser, the first uses of holography and the rise of optical communications, and then learn about optics' growing influ-

ence on current areas of scientific interest, such as biomedicine, nanotechnology and ultrafast physics.

OSA began in 1916 with a small gathering of 30 scientists in Rochester, N.Y. Most of its initial members were part of a tight-knit community of applied practitioners. Yet, even in the beginning, the Society had been more than a trade association; its constitution stated that its aim was “to increase and diffuse the knowledge of optics...” After the invention of the laser in 1960, the field

of optics exploded, and a huge wave of interest swept the physics and engineering communities.

Today, the Society has evolved to serve more than 14,000 optical physicists, engineers and entrepreneurs around the globe. And the field itself has never been more relevant. Indeed, if the myriad presentations at the annual meeting demonstrate anything, it is that the reach of optics in our society is both broad and deep, penetrating nearly every aspect of how we live today.



A twilight view  
of the downtown  
Rochester skyline.

Greater Rochester Visitors Association

# Issues, Optics Solutions

## Tapping new energy sources

Nearly a decade ago, OSA Honorary Member Steven Chu shared a Nobel Prize for laser cooling and trapping of atoms. Now, as director of the U.S. Energy Department's Lawrence Berkeley National Laboratory (LBL), he has a personal and scientific passion for environmental and energy issues.

Global warming is of particular concern. In light of worrisome elevations in human-generated greenhouse gases, the growing strength of tropical storms and rising sea levels, Americans must learn to maximize energy efficiency, minimize energy use and develop new sources of clean energy, Chu said.

The first U.S. energy crisis of the early 1970s illustrates that scientists can make a difference. Back then, an LBL physicist named Art Rosenfeld, who had been the last student of the legendary nuclear physicist Enrico

Fermi, lobbied at the state and national levels for minimum efficiency standards for refrigerators.

Appliance makers initially fought the proposals tooth and nail but ultimately started to make their products more efficient even before the standards took effect—a powerful lesson for today's researchers. More recently, LBL researchers developed the technology that made compact fluorescent lights and infrared-reflecting windows commercially feasible.

While reviewing the supply side of the energy problem, Chu predicted that "clean coal" technologies won't happen unless governments enact a "carbon tax" to reverse the cost advantage to releasing greenhouse gases into the atmosphere.

Cheaper, more efficient photovoltaic cells are needed for widespread deployment. New thin-film solar technologies

in the pipeline could eventually make the cells inexpensive. For photovoltaic technology to provide the full level of carbon-free electricity this country needs, solar power's cost would need to drop to about 2 cents per kilowatt-hour, according to Chu.

Chu also suggested using 50 million acres of U.S. excess agricultural capacity to raise crops for biomass fuel research. LBL has proposed a project called Helios that would pursue new methods such as nanotechnology to convert sunlight into carbon-neutral energy sources.

Soon, teams of LBL scientists will work on energy solutions that could be deliverable in 10 to 15 years. "To have some of our best basic scientists be willing to work under these conditions—like in making radar, making the [nuclear] bomb—is something that is very heartening to me," Chu said. "I think it should be done worldwide."



OSA Honorary Member and Nobel laureate Steven Chu delivers a warning on greenhouse gases and global warming.

## A window into Alzheimer's disease

Lee E. Goldstein, assistant professor of psychiatry at Harvard Medical School, turned the audience's attention to a looming public health problem: the growth of Alzheimer's disease among a population that is otherwise living longer than ever.

Alzheimer's disease, first identified 100 years ago, is the result of a sticky, neurotoxic peptide called amyloid-beta that invades the brain and destroys its cells. Unfortunately, by the time the clinical symptoms of the disease manifest themselves, the illness has been progressing for a decade or more, and the damage is irreversible.

Two years ago, Goldstein and colleagues were the first to identify amyloid-beta plaques inside the lenses of the eyes of Alzheimer's patients. "We had a great deal of trouble getting this published, because no one believed it," he said. "It's a brain disease—why would it be present in the lens?" But it was the first evidence that Alzheimer's is indeed a systemic disease and not just a neurological disorder.

Not only do these lens plaques look different from age-related cataracts, they also present an optically accessible diagnostic window. Goldstein and his team, which includes laser physicist Anca Mocofanescu, are working to develop

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screening techniques for detecting amyloid-beta aggregates as small as 30 nm in patients' eyes. Quasi-elastic infrared light scattering is a non-invasive technique that holds much promise for identifying the peptide so that physicians can start treating Alzheimer's patients at a much earlier stage of the disease.

## Silicon photonics

Integrating silicon photonics into computer chips could remove a big bottleneck in the data streams within computers. However, because of silicon's indirect

bandgap, it has been extremely difficult to make a light source that is compatible with low-cost CMOS manufacturing techniques.

Finding ways to bypass that indirect bandgap has become a major goal in photonics research. In light of potentially groundbreaking research that appeared in *Optics Express* last fall, FiO planners scheduled a last-minute talk by Alexander Fang of Intel Corp., one of the developers of a newly announced hybrid silicon laser (*Opt. Express*, 14, 9203, and *OPN* November 2006, p. 8). Fang and colleagues devised an electrically pumped laser combining silicon and indium phosphide.

Cary Gunn, vice president for technology of Luxtera Inc. of Carlsbad, Calif., said his company is already making processors with external light sources for optical communications. Luxtera uses Freescale Laboratories' 0.13- $\mu\text{m}$  silicon-on-insulator manufacturing process, which was also used for the Motorola Corp. PowerPC chips that formerly powered Apple Macintosh computers. "We've lowered the cost of the optics so much that the packaging is the dominant cost factor," Gunn said.

Luxtera's products include one chip with two independent 10-Gbit/s transceivers and another with a single 40-Gbit/s wavelength division

multiplexed transceiver. The company is not pursuing the silicon laser, but rather has embedded other optical components into CMOS chips. Its products are expected to hit the market in early 2007.

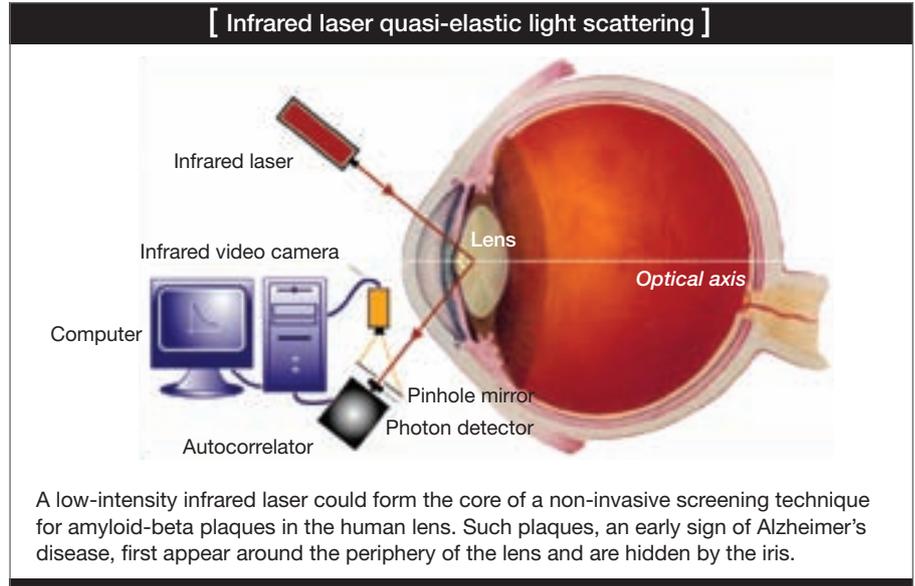
### Ultrafast optics

FiO and its companion American Physical Society conference, Laser Science XXII (LS), kicked off with two plenary lectures on femtosecond and attosecond physics—two of the hottest topics in optics.

The field of femtosecond optics is already more than 30 years old, with the first sub-picosecond pulses coming in the early 1970s, recalled Erich P. Ippen, a past OSA president (2000) and a physics and engineering professor at the Massachusetts Institute of Technology. The advent of compact solid-state lasers in the late 1980s led to additional breakthroughs in the discipline.

Applications of ultrafast phenomena have exploded into other fields, especially biology and chemistry, Ippen said in his acceptance speech for the Frederic Ives Medal/Jarus W. Quinn Endowment. In 1999, Ahmed Zewail of Caltech won the Nobel Prize in chemistry for studying chemical-reaction transition states with femtosecond spectroscopy.

Even shorter wavelengths are coming in the future, from attosecond pulses to femtosecond X-rays, Ippen said. X-ray free-electron lasers—fourth-generation light sources—will bring new insights into molecular structural dynamics.



Lee Goldstein, Harvard Medical School

In the LS plenary talk, the winner of the APS's Arthur L. Schawlow Prize, Paul B. Corkum of the National Research Council of Canada, called the attosecond world a blend of optical science and collision physics. Attosecond physics is becoming a rich technology that can be applied to many subjects such as atomic and molecular dynamics, Corkum said.

From a classical perspective, a strong electric field drives an electron from an atom. The electron can collide with the ion from which it left and it can do one of three things: knock an electron free, Coulomb-deflect or elastically scatter, or recombine to the level from which it left. In the last case, it emits a burst of light, which is the attosecond pulse. From the

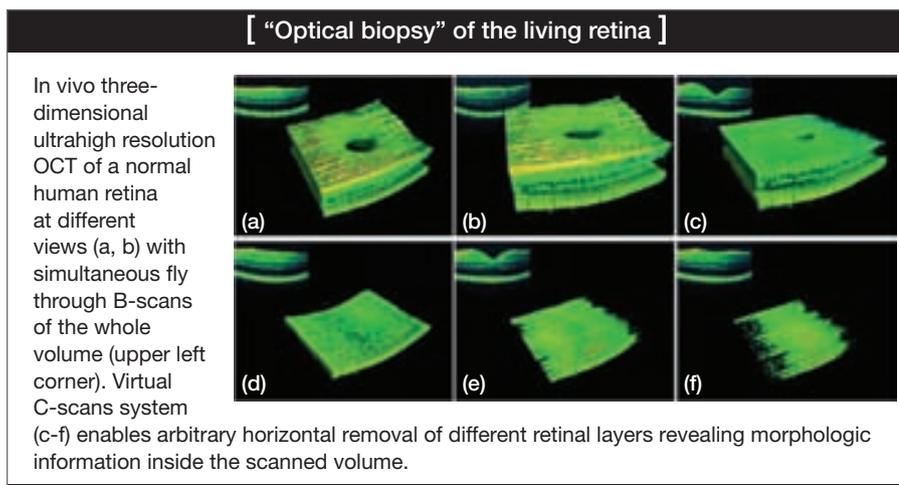
perspective of quantum mechanics, one portion of the wave stays behind while another travels along another path, making an interferometer.

### Adaptive optics and other types of imaging

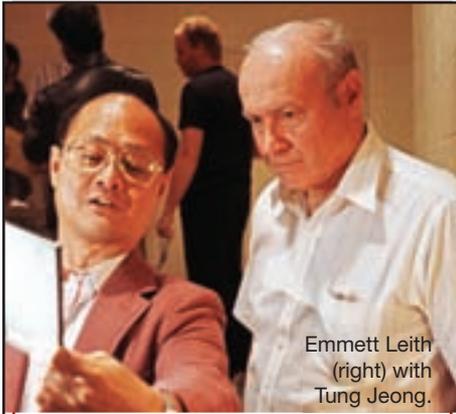
Researchers from the University of California reported that they had developed a scanning laser ophthalmoscope that could be used in a patient care setting. The device uses a micro-electro-mechanical (MEMS) deformable mirror in its adaptive optics (AO) system, according to Yuhua Zhang of UC-Berkeley. The ophthalmoscope, which the team also described in an *Optics Letters* article, provides increased brightness and improved contrast over non-AO systems and could improve the diagnosis of retinal disease.

In a related talk, Donald T. Miller of Indiana University showed that two kinds of AO cameras can image retinal photoreceptors. In addition to their conventional flood illumination camera, Miller's team built a device using ultra-high spectral-domain optical coherence tomography (OCT).

A group led by Wolfgang Drexler of Cardiff University (Wales) used ultra-high-resolution OCT to perform an "optical biopsy" of the living retina. The researchers' three-dimensional scanning achieved a resolution of 3  $\mu\text{m}$ .



Wolfgang Drexler, Cardiff University; C. Glittenberg, S. Binder, Ludwig Boltzmann Institute, Vienna, Austria



Emmett Leith (right) with Tung Jeong.

## Remembering Emmett Leith

A daylong FIO symposium paid special tribute to Emmett Leith, the University of Michigan holography pioneer who died in late 2005 (OPN, April 2006, p. 48). Fourteen speakers reviewed holography's evolution—from Leith's seminal contributions, including the creation of the first techniques to allow 3-D images to be captured on photographic film, to today's applications and techniques, such as volume holograms on fiber lasers, ultrafast and time-resolved imaging and holographic optical tweezers.

Leith earned his Ph.D. relatively late in life—more than a decade after his seminal holography papers in the early 1960s, said one of Leith's Michigan faculty colleagues, Kim Winick. His Wayne State University dissertation ended up being a compilation of his most important work, including a previously classified 1956 memorandum on synthetic aperture radar techniques.

Leith's friend and colleague Tung H. Jeong spoke not just of Emmett's scientific contributions, but also of who he was as a person. He talked about Emmett's love of opera and his generosity in giving back to the optical community. For example, when the fees for scientific meetings had been waived for Emmett, he insisted on donating an equivalent amount to other holographic artists and researchers.

*Applied Optics* will publish a special issue dedicated to the research that Leith's work made possible, Winick said. The deadline for submissions is March 1; publication is tentatively scheduled for December 2007.

OSA is also establishing an Emmett N. Leith Award in honor of the late professor. A six-member committee is soliciting applications for the medal, which will be awarded for the first time in 2008.

Of course, AO is most famous for its use in astronomy, and Lawrence Livermore National Laboratory is developing a pulsed 589-nm laser system that would create a sodium guide star at an altitude of roughly 100 km. The preferred upgrade architecture includes six 50-W pulsed lasers with dynamic refocusing, according to Livermore scientist Deanna M. Pennington.

As telescope apertures grow, elongation of the laser spot becomes a significant issue because it causes inaccuracies in closing the AO loop. Spot elongation can be mitigated by tracking laser pulses in the 10-km-thick sodium layer of the upper atmosphere. Custom CCDs with elongated pixels are required to track the pulse propagation through the sodium layer, and it appears to be practical to make such CCDs, Pennington said.

Livermore's laser will be installed at Lick Observatory in late 2007 for a visible-light demonstration with an AO-corrected laser uplink, according to Pennington.

## Biomedical imaging, biomedical optics

What happens inside a brain during a stroke, and can neurons recover from an ischemic attack? In vivo two-photon

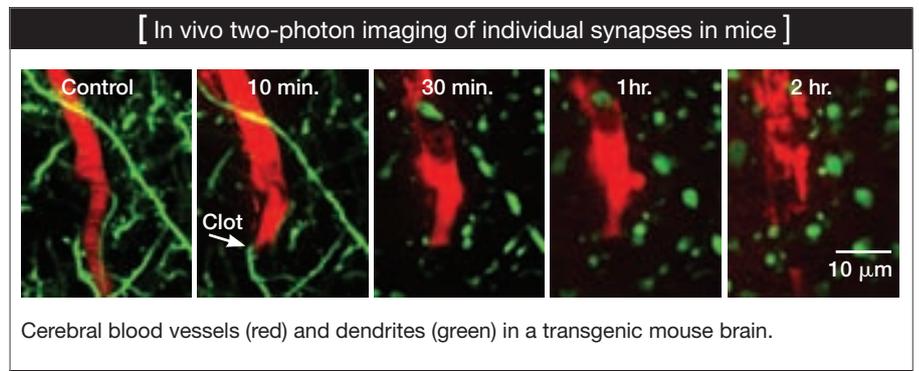
imaging of individual synapses in mice could shed light on ischemic damage and recovery in humans, said Timothy H. Murphy of the University of British Columbia in Canada.

Murphy and his colleagues studied the spatial and temporal relationships between the loss of blood flow to a synapse and the synapse's structure and function. In mice, synapses are less than 1  $\mu\text{m}$  across, but two-photon imaging can still resolve them.

By injecting a tiny bit of a dye called rose Bengal and exciting the dye with a 910-nm femtosecond laser, the researchers could induce a tiny stroke in the part of the mouse brain that controls limb movement. In the case of 10 minutes of blocked blood flow, the dendritic structure can recover with two hours of reperfusion. "Ten minutes post-stroke—that's before people even get to the hospital," Murphy said.

Two different kinds of spectroscopic technology could provide a non-invasive way to screen women for cervical cancer. Shabbir Bambot of Guided Therapeutics Inc. of Norcross, Ga., described his company's prototype diagnostic machine, which uses both fluorescence (300-500 nm) and reflectance (350-900 nm) spectroscopy to measure biochemical markers and angiogenesis in early-stage cervical cancers.

## In vivo two-photon imaging of individual synapses in mice could shed light on ischemic damage and recovery in humans.



Timothy H. Murphy, University of British Columbia

The LightTouch research prototype is built with off-the-shelf components. It takes less than a minute to perform a test with immediate results, Bambot said. One early study of the device by a Medical College of Georgia researcher examined 630 women (ages 16 to 75) in four clinics and detected 18 cases of high-grade precancers missed or misclassified by the standard Pap test. A larger regulatory study is scheduled for completion within a few months.

Near-infrared scanning laser polarimetry is a useful tool for studying diabetic retinopathy, said Benno Petrig of Indiana University. Broadband light at visible wavelengths fails to penetrate moderate cataracts, which many elderly diabetic patients have in addition to retinal problems.

Petrig's group, which included researchers from Tokyo Medical University and University Hospital in Aachen, Germany, used a 780-nm polarized laser source to image 15-degree-square sections of the retinas of 12 patients (average age: 69) with Type 2 diabetes. The team found excellent contrast in depolarized light images of both arteries and veins.

### High-power optics: state of the art

Linda Young of Argonne National Laboratory presented a tutorial on ultrafast X-ray sources and science, and several other speakers from U.S. national laboratories described the challenges in building and using cutting-edge sources of intense radiation from terahertz to X-rays.

Present tabletop X-ray sources using high harmonic generation (HHG) still offer the ultimate in pulse length (below  $10^{-3}$  ps), but they produce less than  $10^3$  photons per pulse. By 2009, free-electron lasers (FELs) will offer researchers  $10^{12}$  or more photons per pulse, although pulse lengths will be only 0.1 to 1 ps.

Researchers can build their own ultrafast X-ray sources with nearly standard lasers, Young said. For example, a Ti:sapphire laser focused onto a copper target can generate 8-keV X-rays with a pulse length below 200 fs. HHG systems also fall into the tabletop-source category.

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Synchrotron radiation sources produce radiation from relativistic electrons accelerated in a magnetic field. Unlike older, circular facilities, modern synchrotrons consist of many straight sections containing periodic magnetic structures that produce tightly controlled electron beams. FELs direct a relativistic electron beam past an undulator, a periodic array of powerful magnets, to generate a high-energy photon beam in a process called self-amplified stimulated emission.

Ultrafast X-ray sources will have many applications from determining the structure of biomolecules to viewing motion at atomic time and length scales, Young said.

Michelle D. Shinn of the Thomas Jefferson National Accelerator Facility (JLab) works on the optical components for the laboratory's FEL program. The existing FEL covers the mid-infrared region, but planned upgrades will allow production of a UV beam of wavelengths as short as 250 nm.

Conditions in the JLab FEL environment are optically extreme: a high vacuum ( $10^{-7}$  Torr or better) with high intracavity average power (20-100 kW). The environment also must handle sub-picosecond pulses with interpulse periods from 13 to 200 ns.

Shinn and her team found increases in short-wavelength optical performance as they develop and test low-absorption coatings. The FEL researchers also had to solve problems with intracavity scattered light. Scattered light was absorbed on poorly heat-sunk optical mounts. The

absorption warmed up the mounts, causing outgassing and flexing. Water-cooled plates installed before the cavity mirrors shield the optics and the hardware.

The Linac Coherent Light Source (LCLS) is scheduled to be the world's first X-ray FEL when it gets switched on in 2009, said John Arthur of the Stanford Linear Accelerator Center (SLAC). European and Japanese researchers are also developing similar sources of pulsed, monochromatic, extremely intense X-rays.

The relativistic electrons are accelerated inside the long (approximately 100 m) undulator within a portion of the SLAC linear accelerator, Arthur said. Key features of the LCLS include sub-picosecond pulses (230-fs FWHM) and very high peak power and brightness (more than  $10^{12}$  monochromatic photons per pulse).

Optics issues facing the LCLS team include high peak power, synchronization and conserving beam brightness, Arthur said. LCLS's planned peak power (9 GW) and fluence at the source ( $10^{14}$  W/cm<sup>2</sup>) will require optical materials with high melting temperatures and low cross-sections for X-ray absorption, such as beryllium, diamond and silicon carbide.

### See you in San Jose

The next Frontiers in Optics conference takes place a month earlier than usual: September 16-20, 2007, in San Jose, Calif. APS, OSA's technical partner, will also present Laser Science XXIII. Visit [www.frontiersinoptics.org](http://www.frontiersinoptics.org) frequently for updates. ▲

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