

Report from **FiO**: Showcasing the Very Small and *Ultrafast*

Patricia Daukantas

Frontiers in Optics (FiO), OSA's 89th annual meeting, focused on recent research and applications in nanophotonics, biomedical imaging, quantum electronics, organic optoelectronics and other emerging areas of interest. The presence of three new Nobel laureates at the meeting created an added buzz among the gathering of 1,335 attendees.

In honor of the 2005 World Year of Physics, which marked the centennial of Albert Einstein's crucial papers on the photon and special relativity, FiO kicked off with a story about scientists' quest to verify one of Einstein's last unconfirmed predictions of the theory of general relativity—the presence of ripples in space-time moving at the speed of light.

The presentation was part of the meeting's opening plenary, which OSA held jointly with the American Physical Society (APS). As in years past, the APS's

21st Laser Science (LS) conference was held at the same time and place as FiO.

Stan Whitcomb, the deputy director of the Laser Interferometer Gravitational Wave Observatory (LIGO) project, explained that detection of the space-time ripples, or gravitational waves, has eluded scientists to this day. LIGO researchers are currently trying to detect such waves at two observatories 3,002 km apart—one in Hanford, Wash., and the other in Livingston, La. Each facility houses a Michelson interferometer with a beam length of 4 km. The devices had

to meet the challenging requirement of measuring length changes of roughly 10^{-18} m.

As a result, Whitcomb said, the LIGO instruments use some of the highest-precision optics ever made. The mirrors' coatings are uniform to about 1 atom in thickness, and the pointing accuracy of these mirrors is about 10^{-9} radian. The LIGO team was scheduled to start the search for gravitational waves in November, despite some minor storm damage to the Livingston observatory from Hurricanes Katrina and Rita.



LIGO staff installing a mode-matching mirror and suspension into a vacuum chamber during the construction of LIGO.

Speed and precision in quantum optics

Ferenc Krausz of the Max Planck Institute for Quantum Optics and Ludwig Maximilians University in Germany delivered the LS XXI plenary speech on his research into attosecond physics. He explained that electron wave packets, when perturbed, evolve on fast time scales, as short as a few tens of attoseconds (one attosecond is 10^{-18} s).

Krausz and collaborators have created 250-attosecond extreme ultraviolet light pulses, the shortest reproducible events

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Attosecond physics is still in its infancy, but it is expanding quite rapidly, because of the breadth and depth of the scientific questions that it can answer experimentally, Krausz said. For example, recent experiments suggest that it may be possible to develop an attosecond hard X-ray source, which may pave the way toward 4D electron imaging with subatomic resolution in space and time.

Months before FiO, OSA had announced that the Frederic Ives Medal/Jarus W. Quinn Endowment would go to Theodor W. Hänsch, director of the Max Planck Institute for Quantum Optics, and one of the 2005 Nobel physics laureates.

Hänsch's quest for higher and higher precision in making wavelength mea-

surements began in the early 1970s, when he worked with the late Arthur L. Schawlow at Stanford University. By now, the optical spectroscopy of hydrogen has reached 14 or 15 digits of ever-increasing precision. The developments for which Hänsch and Hall received the Nobel prize have made it possible to imagine building optical

atomic clocks with precision in the 10^{-16} to 10^{-18} range.

Marlan O. Scully of Texas A&M University, winner of the APS Arthur L. Schawlow Prize, gave an overview talk tracing the history of Bose-Einstein condensates from the development of the theory (S.N. Bose's original paper was first rejected by journals,

Nobel Laureates Are the Toast of FiO

The three OSA Fellows who won the 2005 Nobel Prize in Physics were the celebrities of the 89th annual meeting. Throughout the conference, all eyes turned to Roy Glauber of Harvard University, John L. "Jan" Hall of JILA and Theodor Hänsch of the Max Planck Institute for Quantum Optics.

In a "meet-the-Nobelists" portion of the conference plenary session, OSA 2005 President Susan Houde-Walter asked the three prizewinners how they got their start in science.

"I was an experimentalist long before I was a theorist," said Glauber. At age 11 he ground several telescope mirrors and played around with viewing cellophane tape in polarized light. He began to study mathematics seriously in high school, after having become concerned, at 12, that astronomy might have no future.

Hänsch grew up on a street named for German chemist Robert Bunsen, who introduced the Bunsen burner in 1855. He became intrigued by the sciences after asking his father what Bunsen had done to earn that honor. He was also fascinated with light and optics as a boy, and recalled hooking up a gas light in his kitchen in Heidelberg.

As a youth, Hall was interested in electricity and his crystal-set radio, from which he listened to Bob Hope on his radio ear-phones. "I came in on the low-frequency end," he said.

Where were you when ...

On October 4, 2005, the day the Nobel notifications were made, Glauber was awakened by a 5:30 a.m. phone call, which he initially thought was from either a family member with an emergency or a colleague in New Zealand who had miscalculated the time difference. He was delighted to learn that the call was from the Royal Swedish Academy of Sciences.

Hänsch was at his desk at the university when he got the call from Stockholm. "I was unable to call anybody in my family because as soon as I put the phone down, it rang again."

Meanwhile, in Colorado, Hall's wife Lindy answered the phone. At first, she thought that the heavily accented person at the other end of the line was a telemarketer, and promptly hung up the phone. Fortunately, on his second attempt, the caller insisted, "This is really important!" and got through to Hall.

Giving back

All three laureates want to use their new status to attract more young people to study science and technology. Hall said he remembers the many times that his wife, a longtime teacher, brought her eighth-graders to visit his laboratory.

Last summer Hänsch worked with a Stony Brook University undergraduate, Melissa Friedman, under the auspices of the Center for Research and Education in Optics and Lasers. He was present for Friedman's talk at the FiO/LS Undergraduate Research Symposium. Friedman later won a Marshall Scholarship to study physics at Oxford University.

Glauber, who was also spotted in the audience at the undergraduate symposium, spent 10 years teaching a Harvard Extension School night class on waves and particles—on the condition that high school students and teachers would be admitted free of charge. He still teaches a freshman survey course at Harvard.

Hänsch has been an OSA Fellow since 1973. Hall said that he spent a couple of years on the OSA board under Anthony J. DeMaria, whom he called "one of the absolute giants of the early days of high-powered lasers."

OSA 2004 President Peter L. Knight described Glauber as "the doyen of theorists in quantum optics." Of Hall and Hänsch he said, "Their work has been absolutely critical for a whole generation of people working with lasers."

— Patricia Daukantas



then championed by Einstein) to the explosion of experimental work over the last decade.

Insight into Saturn's moon

Martin Tomasko, research professor of planetary sciences at the University of Arizona, reviewed the successes and failures of the Descent Imager/Spectral Radiometer (DISR) instrument aboard the *Huygens* spacecraft, which landed on Titan—one of Saturn's moons—in January 2005.

Titan has a dense atmosphere composed primarily of nitrogen and methane. It is also likely to contain complex organic molecules that could be precursors to life. "Titan represents a kind of primitive Earth that's been locked away in a deep freeze for the length of the solar system's life," Tomasko said.

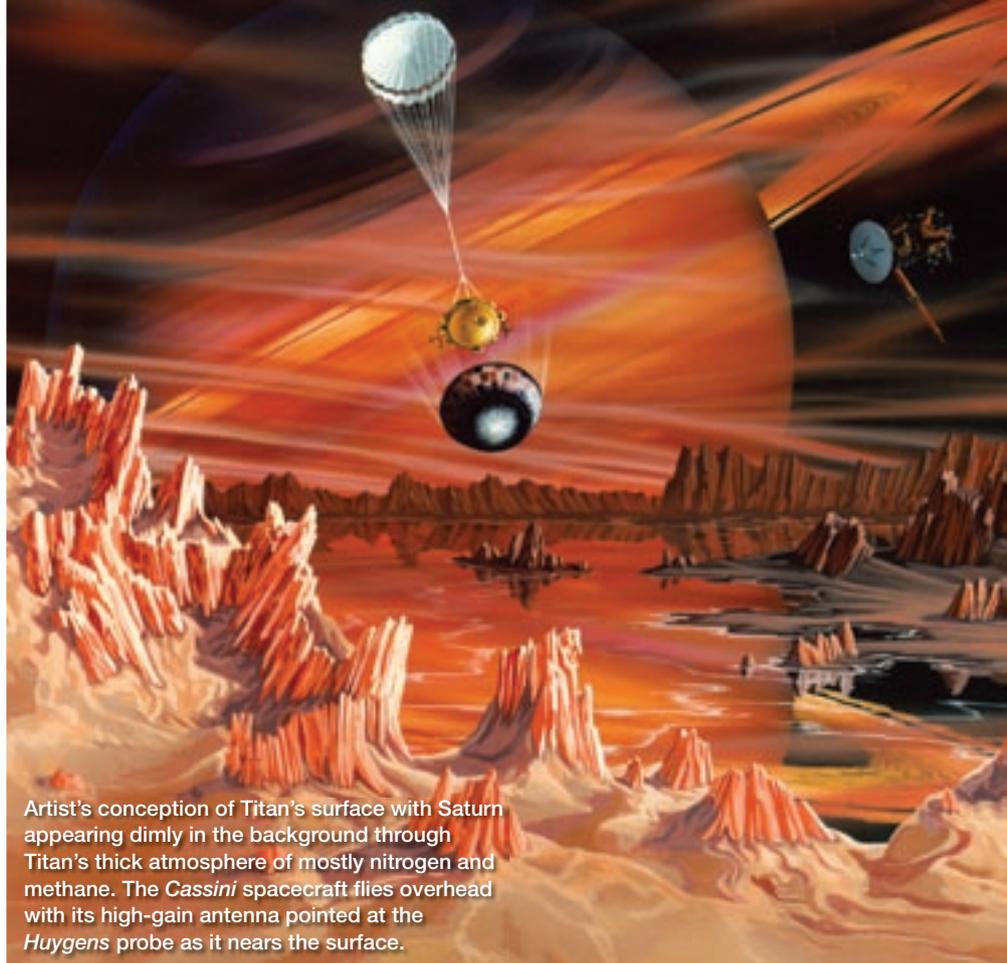
DISR, the only optical package aboard the descent probe, was designed in 1990 with the imaging technology of that era. Its goal was to capture panoramic views of the surface of Saturn's largest moon. "We didn't want to come down near the Grand Canyon of Titan and not know it was there," Tomasko said.

Tomasko's team had hoped to see the surface from an altitude of 70 to 80 km, but above 40 km the probe was still in a soupy haze. Nevertheless, the panoramic images revealed evidence of past fluid flow on Titan's surface, as well as creek-type channels that are evidence of methane rain. Scientists are still analyzing the *Huygens* data to glean more clues to the composition of the huge moon.

Organic optoelectronics and thin films

The symposia on Organic Optoelectronics and Organic Thin Films for Photonic Applications (OOE/OTF) paralleled the FiO/LS programming tracks. Organic optoelectronics was a new symposium topic for 2005. Many speakers expressed hope that these technologies will lead to exciting applications such as flexible displays and low-cost solar cells.

Toshinori Matsushima of the Chitose Institute of Science and Technology in Japan spoke about extremely high-density



Artist's conception of Titan's surface with Saturn appearing dimly in the background through Titan's thick atmosphere of mostly nitrogen and methane. The *Cassini* spacecraft flies overhead with its high-gain antenna pointed at the *Huygens* probe as it nears the surface.

Craig Attebery, NASA

carrier injection and transport into organic thin films. He and his colleagues reported a maximum current density of 12.2 kA/cm^2 in a copper-phthalocyanine device for a fraction of a second.

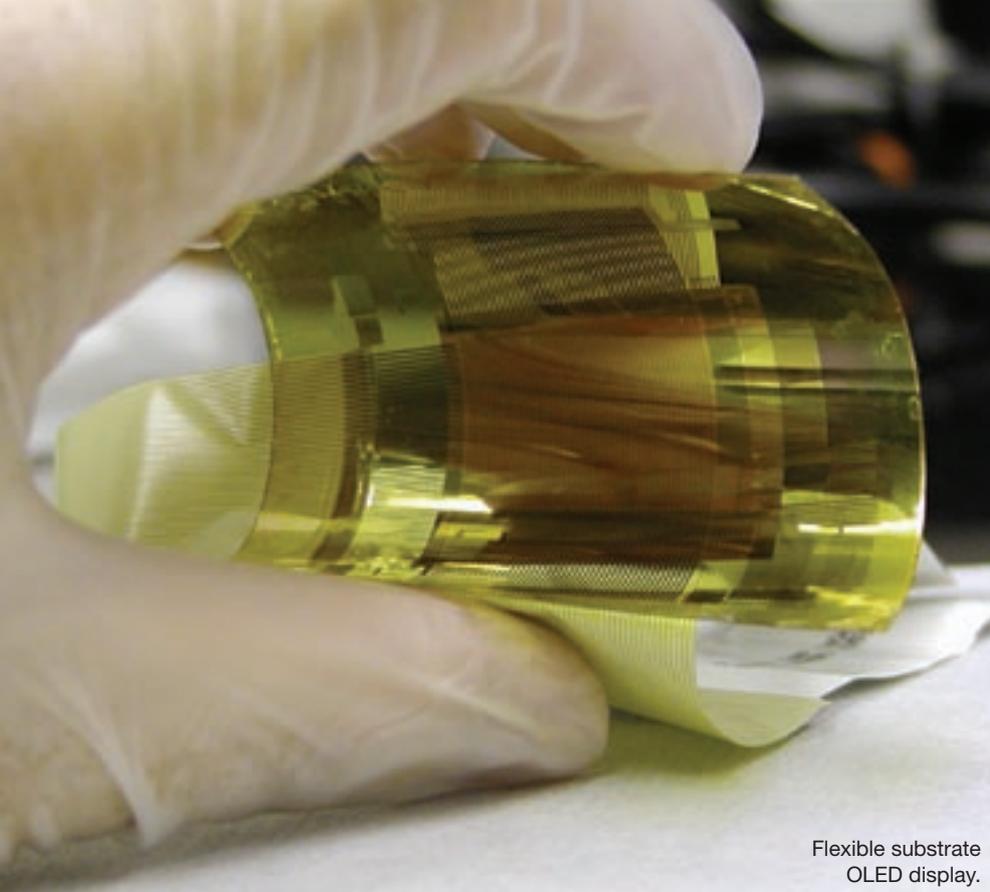
Tunable ultraviolet lasers could find uses in fluorescence spectroscopy, gene expression in biotechnology, photodynamic therapy in medicine and cancer diagnosis and therapy. Thomas Riedl of the Technical University of

Braunschweig said he and his German colleagues have demonstrated an organic semiconductor laser with tunable emission between 361.9 and 395 nm. So far, spiro-linked terphenyl has worked best as the active material because of its low lasing threshold.

C. Daniel Frisbie of the University of Minnesota talked about organic thin-film transistors from a materials engineering perspective. His research group studies crystalline organic materials such as tetracene, pentacene and perylene, which are all narrow-band semiconductors with bandwidths of about 0.5 eV. Thanks to transverse-shear-force microscopy and Kelvin probe force microscopy, materials scientists can now visualize defects in crystals of these substances and analyze how they affect the performance of organic transistors.

Thomas N. Jackson of Pennsylvania State University talked about vapor- and solution-deposited organic thin-film transistors (OTFTs). Potentially, OTFTs could cost less to manufacture than thin-film transistors on other substrates, but they need to be uniformly reproducible.

Tunable ultraviolet lasers could find uses in fluorescence spectroscopy, gene expression in biotechnology, photodynamic therapy in medicine and cancer diagnosis and therapy.



Flexible substrate
OLED display.

Penn State

Jackson said that he and his colleagues have been studying pentacene, which has extremely strong self-ordering tendencies. He has also been investigating the integration of vapor-deposited OTFTs with organic light-emitting diodes.

Optics and the life sciences

Imaging techniques have been important tools in biomedicine for decades. Some of the most exciting sessions at FiO/LS came out of the linkage between optics and the life sciences.

According to Anthony J. Durkin, chair of OSA's Optics in Biology and Medicine Division, emerging areas of interest include nonlinear optical microscopy of biological systems; nanophotonics and novel optical reporters; optical methods in small animal research; optical methods for diagnosis, monitoring and guided intervention; and trends in biomedical imaging and spectroscopy.

Lida P. Hariri and her colleagues at the University of Arizona assessed different imaging technologies for their effectiveness in detecting colon cancer in mice. They compared optical coherence tomography (OCT), laser-induced fluorescence (LIF) and laser scanning

confocal microscopy (LSCM). The study demonstrated the benefits of multimodal imaging, as the OCT and LIF images guided the LSCM imaging, while LIF helped identify the adenomas in otherwise ambiguous OCT images.

Young L. Kim and his Northwestern University colleagues studied another imaging method that could provide a new way to screen humans for early-stage colon cancer—low-coherence enhanced

More than 50 million Americans over the age of 50 need periodic screening for colon cancer, and low-coherence enhanced backscattering could represent a less invasive and expensive alternative for diagnostic screening.

backscattering (LEBS). This technique is not limited to single-wavelength measurements in biological tissue, as is conventional enhanced backscattering. More than 50 million Americans over the age of 50 need periodic screening for colon cancer, and LEBS could represent a less invasive and expensive alternative for diagnostic screening.

Alzheimer's disease is another health concern for millions of Americans, and one of the challenges of treating the condition is diagnosing it before the patient dies. Lee E. Goldstein of Harvard Medical School has been studying whether the disease can be detected by identifying a type of eye cataract that may result from the same process that causes Alzheimer's to form in the brain. The challenge is to distinguish Alzheimer's-related cataracts from age-related ones, which are far more common.

Federal research funding tips

At a two-hour symposium for FiO/LS attendees, officials from many agencies that provide federal funding for science described their programs and the hot topics for which researchers have been winning grants.

Dan Litynski, physics program director in the Division for Undergraduate Education at the National Science Foundation (NSF), said that optics is typically the largest proposal group for physics under the Course Curriculum and Laboratory Improvement (CCLI) program. CCLI seeks to improve college-level teaching of science, engineering and mathematics, especially through development of new course materials and teaching strategies.

Larry Goldberg, senior engineering adviser in the Electrical and Communications Systems Division at the NSF, said his division is planning for a fiscal 2006 solicitation on novel concepts for communications networks under extreme or emergency conditions. The National Nanotechnology Initiative has requested \$344 million for fiscal year 2006 and has two program solicitations, \$42 million for active nanostructures and nanosys-

tems and \$3 million for undergraduate education in nanotechnology.

Goldberg listed several research needs inspired by Hurricane Katrina. Small grants are available for assessing the damage to the power infrastructure, researching power and telecommunications system failure modes and methods of robotically surveying faults in underground cable systems.

Goldberg also mentioned the Photonics Technology Access Program (PTAP), jointly sponsored by NSF and the Defense Advanced Projects Research Agency (DARPA), and administered by the Optoelectronic Industry Development Association (OIDA). PTAP aims to help photonics researchers by building bridges between industry and universities and giving faculty members access to prototype (pre-commercial) photonics technologies. See www.oida.org/PTAP for more information.

Henry O. Everitt, senior scientist with the Army Aviation and Missile Research, Development and Engineering Center in Huntsville, Ala., discussed the growing importance of quantum information science (QIS) to the U.S. government. QIS funding took off in the 1990s but has leveled off in the current decade, Everitt said. Nevertheless, many interesting challenges remain in the field of quantum computing, from developing quantum error correction algorithms to building robust quantum memory devices.

According to Everitt, the government's research investment strategy has changed from supporting work designed to ascertain whether a quantum computer can be built to that which can discern the most promising approaches.

Howard Schlossberg, a program manager with the Air Force Office of Scientific Research, said his agency funds several large multi-investigator research programs. Among the topics receiving support are high-energy lasers and the application of lasers and imaging techniques to military medicine.

Optical interconnects

Two sessions examined the possibilities for using optical interconnects to replace

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much of the silicon and copper inside high-performance computers of the future. As the innards of computers get ever smaller and faster, they need to dissipate waste heat more efficiently. Optical interconnects could allow components to be spaced farther apart for improved cooling airflow.

According to the FiO speakers, optical interconnects will probably appear first on the backplane: the circuit board that connects a computer's major internal components. Researchers have further to go until they can make good optical interconnects directly between processors or between the tiny devices inside a computer chip.

Polymer passive waveguides are attractive for integrating computer components on the backplane because they have relatively high reliability and low cost, said Nan Marie Jokerst of Duke University. She has been working on heterogeneous integration of small optoelectronic devices onto a common substrate.

Jerry Bautista, a researcher for microprocessor manufacturer Intel Corp., listed some of the trends driving computers' rapidly growing needs for internal bandwidth. With increasing microprocessor clock speeds, the chips are pushing more data in and out of short-term memory and long-term storage. The largest computers need to move multiple trillions of bits every second. By 2010, interconnects will need to handle data

rates above 15 Gbps per channel while consuming less than 20 mW per Gbps.

Today's copper-based technologies may well coexist with their optical interconnects without a full transition to optoelectronics, Bautista said. Likewise, Ashok V. Krishnamoorthy of Sun Microsystems Inc., one of Intel's rivals in the microprocessor market, said his company is working to integrate photonic devices with complementary metal-oxide semiconductor (CMOS) technology. The potential benefit of CMOS-enabled photonics is the opportunity to break the \$1-per-Gbps price barrier, Krishnamoorthy said.

Tribute to Nicolaas Bloembergen

A special FiO symposium honored Nicolaas Bloembergen, professor emeritus at Harvard University and visiting professor at the University of Arizona. Bloembergen shared the 1981 Nobel Prize in Physics for his contributions to the development of laser spectroscopy.

Eric Mazur of Harvard University saluted Bloembergen by talking about his research group's work on silica nanowires in the context of nonlinear optics. Y. Ron Shen of the University of California at Berkeley and Eli Yablonovitch of the University of California at Los Angeles also paid tribute to Bloembergen with discussions of surface nonlinear optical spectroscopy and inverse design problems in photonics.

See you in Rochester

The 2006 Frontiers in Optics conference and exhibit will take place at the Rochester Riverside Convention Center in Rochester, N.Y., on October 8–12. This gathering will coincide with OSA's 90th anniversary.

To learn more about this year's meeting, or to locate topics of interest, see the archived program information online at www.osa.org/meetings/archives/2005/annual/program/ or check the conference proceedings. ▲

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