PHOTONICS spectra

Military Imaging • Polymer Optics • Crystals

Apr/10

PHOTONICS spectra

April / 2010

Advances in Polymer Optics

Care and Handling of Quantum Dots

A Visual Advantage: Military Imaging Systems

PHOTONICS
The LASER at 50

Inside this issue, starting opposite page 82

See us at SPIE Defense, Security & Sensing, Booth #725

NEW www.Photonics.com

Measure Temperature · Log Data · Drive Heaters

Temperature Control ... at your fingertips

PTC10 Programmable Temperature Controller

- ***Touchscreen graphical display***
- ***Temperature data logging***
- ***1 mK resolution***
- ***Thermocouple and RTD inputs***
- ***AC and DC outputs for heaters***
- ***PID control with auto-tuning***
- ***Ethernet, RS-232 and GPIB interfaces***

The PTC10 makes temperature measurement and control easy. With simply the touch of your finger, you can zoom in and pan through your data, quickly change measurement parameters, and instantly switch between a variety of different displays.

The system measures up to 16 channels of temperature data and drives industrial heaters. PID feedback with auto-tuning is provided for each channel.

Controlling the PTC10 from your computer couldn't be easier. Ethernet, GPIB and RS-232 interfaces are all available. A USB port delivers unlimited data storage capacity.

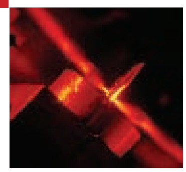
We've even added a digital I/O port, analog DACs/ADCs, relays, and system alarms for process control applications.

SRS Stanford Research Systems
1290-D Reamwood Ave., Sunnyvale, CA 94089

Phone: (408) 744-9040
www.thinkSRS.com

PHOTONICS spectra
April | 2010

TABLE OF CONTENTS



NEWS & ANALYSIS

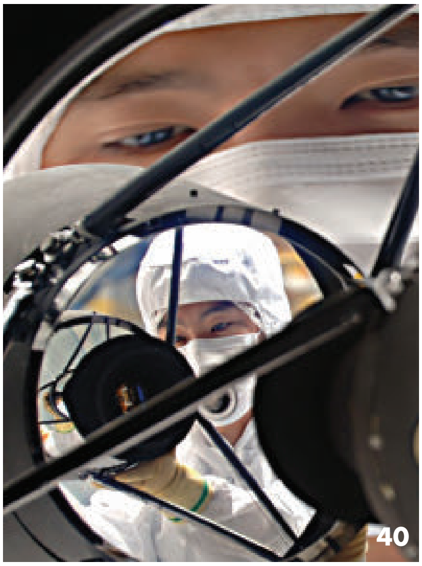

14

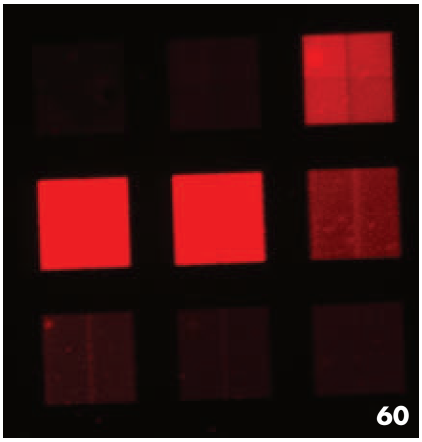
DEPARTMENTS

THE COVER
US Air Force First Lieutenant "Sqwirll," an F-16 Fighting Falcon pilot with the Vermont Air National Guard, peers out of his cockpit through night-vision goggles (US Air Force photo by Master Sergeant Rob Trubia). Military imaging is covered in an article beginning on page 40. The cover was designed by Senior Art Director, Lisa N. Comstock.

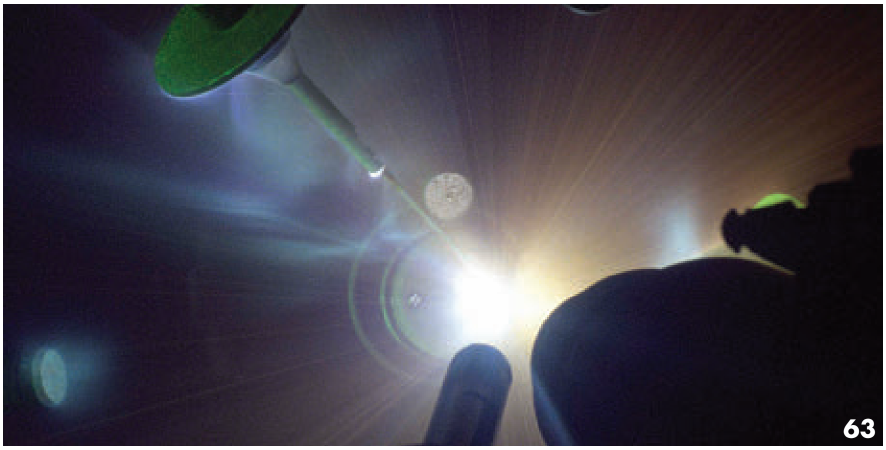

82

FEATURES


40


60


54


63

PHOTONICS SPECTRA (USPS 448870) IS PUBLISHED MONTHLY BY Laurin Publishing Co. Inc., Berkshire Common, PO Box 4949, Pittsfield, MA 01202, +1 (413) 499-0514; fax: +1 (413) 442-3180; e-mail: photonics@laurin.com. ISSN-0731-1230. TITLE reg. in US Library of Congress. Copyright ® 2010 by Laurin Publishing Co. Inc. All rights reserved. Copies of Photonics Spectra on microfilm are available from University Microfilm, 300 North Zeeb Road, Ann Arbor, MI 48103. Photonics Spectra articles are indexed in the Engineering Index. POSTMASTER: Send form 3579 to Photonics Spectra, Berkshire Common, PO Box 4949, Pittsfield, MA 01202. Periodicals postage paid at Pittsfield, MA, and at additional mailing offices. **CIRCULATION POLICY:** Photonics Spectra is distributed without charge to qualified scientists, engineers, technicians, and management personnel. Eligibility requests must be returned with your business card or organization's letterhead. Rates for others as follows: $122 per year, prepaid. Overseas postage: $28 surface mail, $108 airmail per year. Inquire for multiyear subscription rates. Publisher reserves the right to refuse nonqualified subscriptions. **ARTICLES FOR PUBLICATION:** Scientists, engineers, educators, technical executives and technical writers are invited to contribute articles on the optical, laser, fiber optic, electro-optical, imaging, optoelectronics and related fields. Communications regarding the editorial content of Photonics Spectra should be addressed to the managing editor. Contributed statements and opinions expressed in Photonics Spectra are those of the contributors – the publisher assumes no responsibility for them.

PHOTONICS spectra

Editorial Staff

Managing Editor	Laura S. Marshall
Senior Editors	Charles T. Troy, Melinda A. Rose
Features Editor	Lynn M. Savage
News Editor	Caren B. Les
Departments Editor	Ashley N. Paddock
Copy Editors	Judith E. Storie, Patricia A. Vincent, Margaret W. Bushee
Contributing Editors	Hank Hogan, Krista D. Zanolli, Gary Boas, Marie Freebody, Dr. Jörg Schwartz, Anne L. Fischer

Electronic Media Staff

.NET Developers	Brian L. LeMire Alan W. Shepherd

Creative Staff

Senior Art Director	Lisa N. Comstock
BioPhotonics Art Director	Suzanne L. Schmidt
EuroPhotonics Art Director	Juliana T. Willey
Designer	Janice R. Tynan

Editorial Offices

2 South Street, PO Box 4949, Pittsfield, MA 01202-4949
+1 (413) 499-0514; fax: +1 (413) 442-3180; www.photonics.com

Laurin Publishing has additional editorial offices throughout the world. News releases should be directed to our main office. If you would like an editor to contact you, please notify us at the main office and we will put you in touch with the editorial office nearest you.

Editorial E-mail: editorial@photonics.com
Ad Sales E-mail: advertising@photonics.com

More Than 100,000 Distributed Internationally

Editorial Advisory Board

BPA WORLDWIDE
ABP Association of Business Publishers

www.photonics.com


Brighter Fiber Solutions
At Nufern our efforts bring you the brightest in:
• Specialty optical fibers
• Industrial fiber lasers
• Sub-assemblies
• Military fiber lasers and amplifiers
• Scientific fiber lasers and amplifiers
Find intelligent fiber, laser and amplifier solutions at www.nufern.com
NUFERN®
FIBER LASERS - SUB-ASSEMBLIES - OPTICAL FIBERS
866.466.0214 | www.nufern.com

PHOTONICS spectra

Corporate Staff

Chairman/CEO	Teddi C. Laurin
President	Thomas F. Laurin
Director of Sales	Robert J. Briere
Controller	Mollie M. Armstrong
Accounting Manager	Lynne M. Lemanski
Accounts Receivable Manager	Mary C. Gniadek
Business Manager	Elaine M. Filiault
Human Resources Coordinator	Carol J. Atwater

Business Staff

Marketing & Research Manager	William Hoelzel
Advertising Production Coordinator	Tracy L. Reynolds
Trade Show Coordinator	Allison M. Mikaniewicz
Computer Systems Manager	Deborah J. Lindsey
Computer Assistant	Angel L. Martinez
Circulation Manager	Heidi L. Miller
Assistant Circulation Manager	Melissa J. Liebenow
Circulation Assistants	Alice M. White, Kimberly M. LaFleur, Theresa A. Horn
Subscriptions	Janice L. Butler
Distribution Manager	George A. Houghtlin
Traffic Manager	Daniel P. Weslowski

Advertising Offices

Main Office
Robert J. Briere
2 South Street, PO Box 4949
Pittsfield, MA 01202-4949
+1 (413) 499-0514, Ext. 101
Fax: +1 (413) 443-0472
bob.briere@photonics.com

United Kingdom
Penny Pretty
Whitehouse, 134 Templewood, Walters Ash
High Wycombe, Bucks HP14 4UF UK
+44 1494 564411
Fax: +44 1494 461198
penny.pretty@photonics.com

Japan
Scott Shibasaki
The Optronics Co. Ltd.
Sanken Bldg., 5-5 Shin Ogawamachi
Shinjuku-ku, Tokyo 162-0814, Japan
+81 3 5225 6614
Fax: +81 3 5229 7253
s_shiba@optronics.co.jp

China
Hans Zhong/Hai Yan Qin
Shenzhen Fortune Technologies Ltd.
3-7E, Di Jing Feng, Moi City, Buji
Shenzhen, China 518112
+ 86 755 2157 3066
Fax: +86 755 2872 6973
hans.zhong@yahoo.com.cn

For individual advertising contacts' information, view listings next to advertiser index.

www.photonics.com

Discretionary spending

With its proposed Department of Defense budget for 2011, the Obama administration explicitly states that it wants to reform how the US agency operates – how it takes care of its people, how it enhances capabilities for current and future conflicts, how it supports troops in the field and how it does business.

And because the department deals with a wide range of photonics technologies and companies, just how the DoD does business – how it buys, what it buys and how it supports research and development – has a strong impact on our industry.

The overall figure for the 2011 DoD budget is $708.2 billion, with $548.9 billion intended for the base budget and $159.3 billion for overseas contingency operations; these are the ongoing operations in Afghanistan and Iraq. The base budget amount for 2011 is $18.2 billion higher than the 2010 enacted amount, which was $530.7 billion. So the 2011 base budget reflects a 3.4 percent increase, or 1.8 percent after adjustment for inflation.

That base budget covers not only personnel, family housing, military operations and construction, but also the photonics industry's interests: technology procurement, R&D, testing and maintenance.

At $137.48 billion, the 2011 procurement budget is up, just barely, over that of 2010, which was $136.06 billion. Although this is only a 1.05 percent increase, it's better than the cuts that can be seen in the 2011 R&D, evaluation and testing (RDT&E) budget. In that proposal, spending will be down to $76.77 billion, 5.13 percent less than 2010's $80.92 billion.

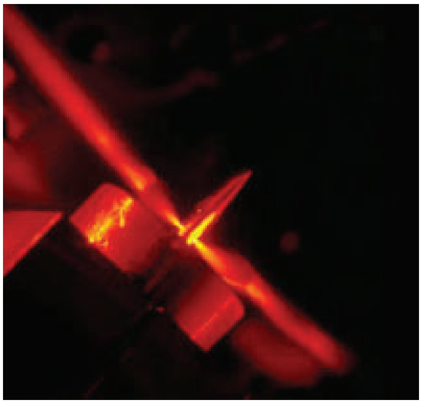
For the military's combined procurement and RDT&E budget for communications, telecom, electronics and intelligence technologies, a total of $17.45 billion has been set aside, an increase of 3.2 percent over 2010's amount, which was $16.9 billion as enacted by Congress.

One program that has kept its funding is the Airborne Laser (ABL), which is transitioning to the Missile Defense Agency's Directed Energy Research Program. The ABL aircraft will be used for the National Laser Test Program (NLTP), according to the proposed budget, and the NLTP will provide a venue for demonstration of other integrated laser weapons systems.

Those are a lot of numbers to ponder, but the upshot is that, although cuts have been proposed for the DoD's tech budget, there also are increases. The increases might not be as large as our industry needs, but they will help to encourage some growth in photonics. And the cuts are not as severe as some had predicted or feared.

On page 40 of this month's issue, editor Hank Hogan looks at some recent innovations in sensors, displays, digital processing and more that will allow military imaging systems to not only catch but also display critical information that cannot be captured or revealed with today's technology.

Developing attosecond spectroscopy for lasers with longer pulse durations



Over the past decade, researchers have developed technology with which to record electron processes occurring on the timescale of attoseconds, including subfemtosecond laser pulses. Shown is the first source of light pulses shorter than 1 fs, generated by exposing neon atoms to 0.3-mJ, 5-fs, near-infrared laser pulses. The fluorescence emission originates from ionizing neon atoms streaming from the interaction volume (thin metal tube). Photonics Institute, Vienna University of Technology, courtesy of Dr. Gabriel Tempea. Used with permission of attoworld.de.

MANHATTAN, Kan. – The development of high-speed photography in the 19th century demonstrated to equestrians and other interested parties that all four of a horse's hooves leave the ground when it runs, presumably settling bar bets from Saratoga, N.Y., to Louisville, Ky. Similarly, in the 1980s, the emergence of laser pulses lasting only a few femtoseconds (10^{-15} s), enabled researchers to record the motion of atoms in molecules – with the ultrafast pulses acting like the shutter of a camera.

Questions remained, however, with respect to the motion of electrons in atoms as well as in molecules and solids. Electron processes occur not just on a much smaller spatial scale than molecular dynamics but on a considerably faster timescale: from tens to hundreds of attoseconds (10^{-18} s). Much shorter laser pulses therefore were needed.

The first isolated attosecond laser pulses were reported in 2001. They proved too dim, however, to be used as both the "pump" and the "probe" in time-resolved spectroscopy of processes occurring on the attosecond scale. To address this, investigators developed an approach that uses a few-cycle infrared laser pulse with a well-controlled electric-field waveform instead of the attosecond probe pulse. Practical attosecond spectroscopy thus became a reality.

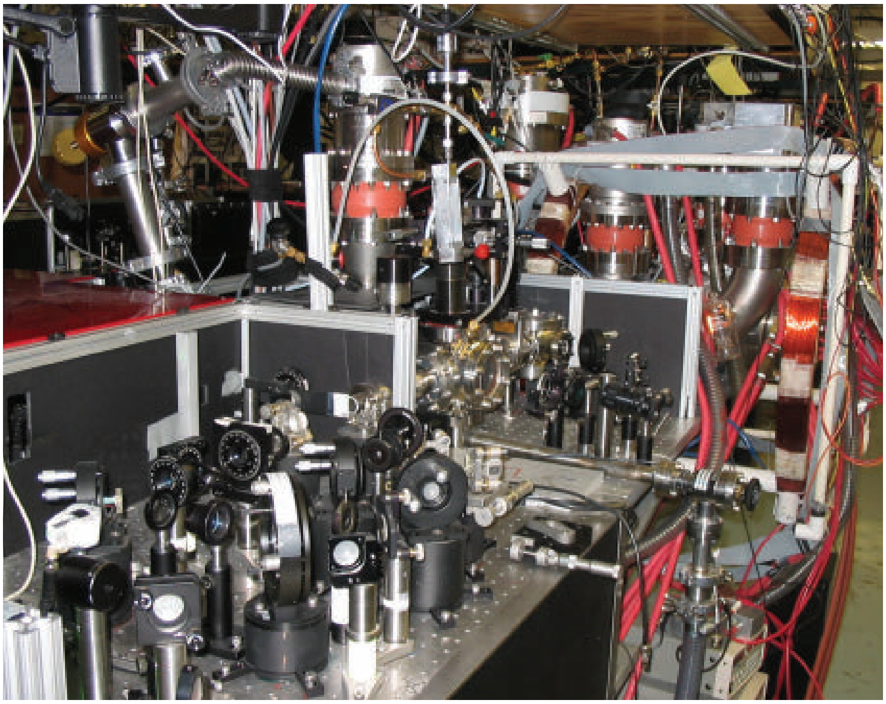
To date, researchers have demonstrated pulses as short as 80 attoseconds, and, using these, have achieved temporal resolution of close to 24 attoseconds, the atomic unit of time.

Attosecond spectroscopy holds considerable promise for a wide range of applications – from probing the microscopic origins of disease to developing electronic circuits in which currents can be switched on and off with the electric field of light – but the technology used to perform the measurements often is both fragile and complex, calling for spectral lasers that only a few labs know how to build and that require a significant amount of skill and training to operate.

The next step in developing the method, therefore, may be to make the technology accessible to a larger user base. "In order for attosecond lasers to be effective as a tool outside a few specialized laboratories," said Zenghu Chang, an investigator at Kansas State University, "turnkey sources of strong attosecond pulses need to be developed."

In the Oct. 30, 2009, issue of *Physical Review Letters*, Chang and colleagues reported a generalized double optical gating technique with which to produce single attosecond pulses with 20- to 28-fs lasers. They previously had described double optical gating for generating single pulses with approximately 10-fs lasers, combining two-color and polarization gating, but there was an upper limit on how long the input laser pulse could be.

The single attosecond pulse is generated within one of 10 cycles of the femtosecond laser pulse used, Chang said. "The difficulty is to avoid complete ion-



Researchers have reported a method called generalized double optical gating that enables attosecond spectroscopy with lasers with longer pulse durations than were previously used with the technique.

ization of the target atom by the laser field of the cycles before the attosecond pulse is produced. In the generalized double optical gating method, the unwanted ionization is suppressed by transforming the field before the generation cycle into elliptical polarization." The researchers demonstrated this method by producing single isolated pulses of 260 attoseconds with 20-fs laser pulses from a hollow-core fiber and pulses of 148 attoseconds with 28-fs amplifier pulses.

Being able to use lasers with longer pulse durations could open up the field to a much larger number of research groups. Many labs already have 25-fs lasers, for example; 5-fs lasers can be difficult to construct – and difficult to operate, even if they are available. Also, optical components such as waveplates and mirrors are considerably less expensive for 25-fs lasers, helping to drive down the overall costs of systems used for attosecond spectroscopy.

Gary Boas
gary.boas@photonics.com

"Totally new physics" yields first germanium laser

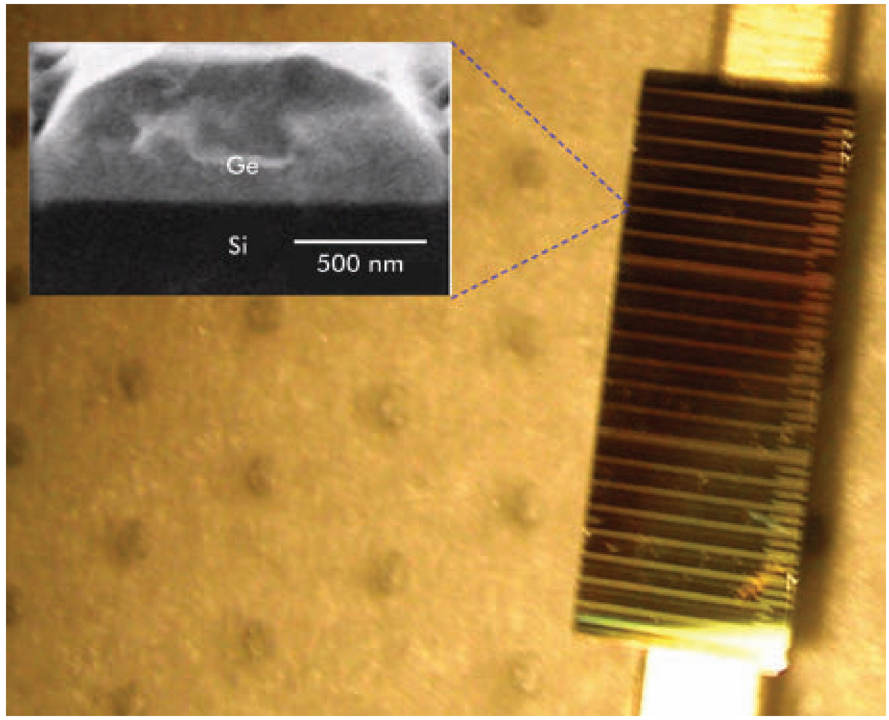
BOSTON – It's the very first germanium laser capable of emitting wavelengths useful for optical communications. It's also the first operable at room temperature. And this new laser not only holds promise for optical computing but also proves that indirect-bandgap semiconductors can yield practical lasers.

"The laser is just totally new physics," said Lionel C. Kimerling of MIT, whose Electronic Materials Research Group developed the germanium laser. Kimerling is the Thomas Lord professor of materials science and engineering. The research team published its results online in *Optics Letters* in January.

Previously, it was believed that indirect-bandgap semiconductors could not be used for practical lasers. Within semiconductor crystals, an excited electron will free itself and enter the conduction band so it can move freely around the crystal. But that excited electron will be in one of two states: In the first, it releases extra energy as a photon; in the second, the extra energy is released another way – heat, for example.

In direct-bandgap materials, the first, photon-emitting state is a state of lower energy than the second state; in indirect-bandgap materials, the reverse is true. And because an excited electron will occupy the lowest-energy state available, they tend to go into the photon-emitting state in direct-bandgap materials such as gallium arsenide but not in indirect-bandgap materials such as germanium.

"In indirect gap semiconductors, there is a mismatch in momentum between the electrons in the indirect conduction valleys and the holes in the valence band," said lead author Jifeng Liu, a postdoctoral associate who co-authored the article with Kimerling, Jurgen Michel, the group's principal research investigator,



A germanium laser chip and a cross-sectional scanning electron microscope picture of the Ge waveguide are shown here. The patterns that appear on the laser chip are the result of the scattering of light by the Ge waveguides. Courtesy of Jifeng Liu, MIT.

and graduate students Xiaochen Sun and Rodolfo Camacho-Aguilera.

"Since any transition needs to conserve the momentum, light emission cannot happen in indirect-bandgap semiconductors unless the electrons happen to obtain an adequate amount of momentum from the waves of atomic vibrations in the material, known as 'phonons,' to compensate this mismatch," Liu said.

"It is similar to the situation of penguins waiting to catch the right sea wave in order to hop onto an iceberg. Therefore, the light emission in indirect-gap semiconductors is very inefficient, so these materials are considered unsuitable for practical lasers. Historically, scientists simply avoid using indirect-gap materials for light-emitting devices," he said.

For the new laser, Liu and colleagues forced excited germanium electrons into the photon-emitting state – the higher-energy state – using two strategies common to chip manufacturing.

In the first approach, the group doped the germanium with phosphorous, which has five outer electrons; germanium has only four. That extra electron filled the lower-energy state in the conduction band, causing excited electrons to "spill over" into the higher-energy state and emit photons.

In the second strategy, the team "strained" the germanium, prying its atoms slightly farther apart than they naturally would be. To do this, they grew the germanium directly atop a layer of silicon, which lowered the energy difference between the two states, enabling excited electrons to spill over into the photon-emitting state instead of releasing their extra energy in another way.

Thus, they lured the electrons into the photon-emitting state and produced a practical laser with indirect-bandgap semiconductors.

For optical computing, it is essential to develop cheap, practical ways to integrate optical and electronic components onto silicon chips. Lasers used today for communications systems must be built separately from expensive materials such as gallium arsenide and then grafted onto silicon chips, a process that takes more time and is more costly than if they were constructed directly on the silicon itself.

Germanium, it should be noted – unlike typical laser materials – is easy to use in existing silicon-chip manufacturing processes. Liu said that germanium and silicon are in the same group in the periodic table and have the same crystal structure and number of valence electrons. "Therefore, introducing germanium directly onto silicon chips does not induce any dopant contamination to existing silicon transistor devices as typical laser materials such as GaAs do."

"There are two major steps in further development of this technology," he said. "First, we will develop germanium laser diodes that are directly powered by electrical current. In fact, we demonstrated the first germanium light-emitting diode on silicon last year, so we believe that an electrically pumped laser diode can be achieved with improved device design. Second, we will further increase the doping level in germanium to enhance its efficiency. We have found some good approaches to achieve this goal, but I cannot disclose it yet due to proprietary issues."

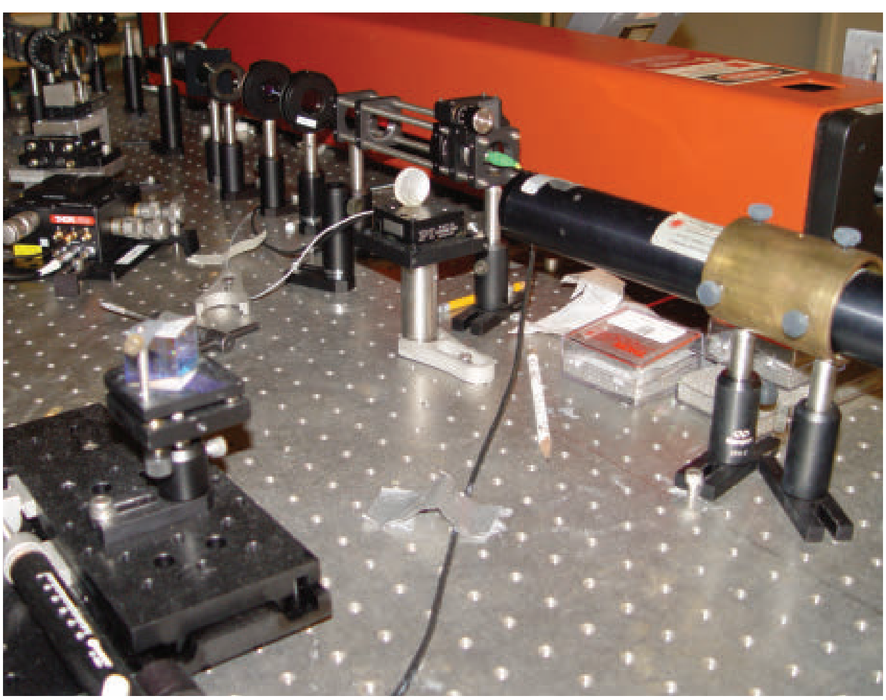
Laura S. Marshall
laura.marshall@photonics.com

Time shifts with faster-than-light photons

GAITHERSBURG, Md. – Experiments with faster-than-light photons are highlighting the weird world of quantum tunneling. Researchers at the Joint Quantum Institute (JQI) have boosted single photons to seemingly faster-than-light speeds through a stack of materials by adding a single, strategically placed layer.

"For the first time, we experimentally show a strange effect when an increase of the overall structure length leads to a decrease in traversal time," said Natalia Borjemscaia, a researcher at JQI, a collaboration of the National Institute of Standards and Technology and the University of Maryland. "Our work offers insight into developing nanostructures with tailored optical properties, particularly with regards to engineering temporal delays and dispersion."

Intuition would have us believe that light achieves its maximum speed in a vacuum and slows down appreciably when it travels through materials such as glass or water. We would expect the same to be true for light traveling through a stack of dielectric materials, but this is not necessarily so. A quantum object or particle – such as a photon of light – can appear to traverse barriers of one thickness in less time than it would take to traverse a barrier that is less thick.



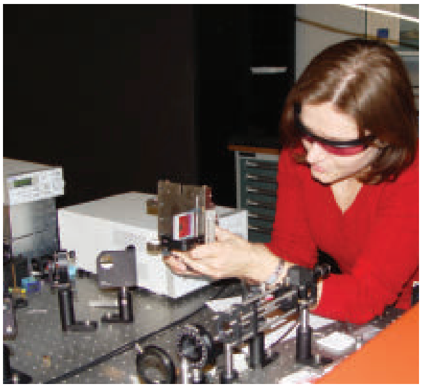
This is the experimental setup used to determine propagation delays of photons traversing dielectric stack structures. Courtesy of the Joint Quantum Institute.

"We investigate how subtle rearrangements of quarter-wave optical stack layers affect the traversal times of single photons," Borjemscaia said. "We show that slight rearrangements of layers can significantly change the traversal time – by many times what one would expect from the change in thickness of the structure alone."

In the experiment, which was published in the February 2010 issue of *Optics Express*, a pair of photons is generated using parametric down-conversion, a process in which one photon from the pump laser is converted into two identical ones of lower energy with twice the wavelength of the pump.

One photon is sent through one of four sample stacks made with alternating layers of two materials with different refractive indices: high (H) and low (L). The other photon is sent through a calibrated delay line.

The JQI team found that traversal times strongly depend on which layer terminates the structure; in particular, when the group added an H layer to a structure that initially terminated with two L layers (one on each end), the structure's thickness increased and the traversal time significantly decreased.



Natalia Borjemscaia inspects the dielectric stack structure stage. Each sample contains bare regions used for reference and four regions with different combinations of starting and ending dielectric stack layers deposited on top of the substrate.

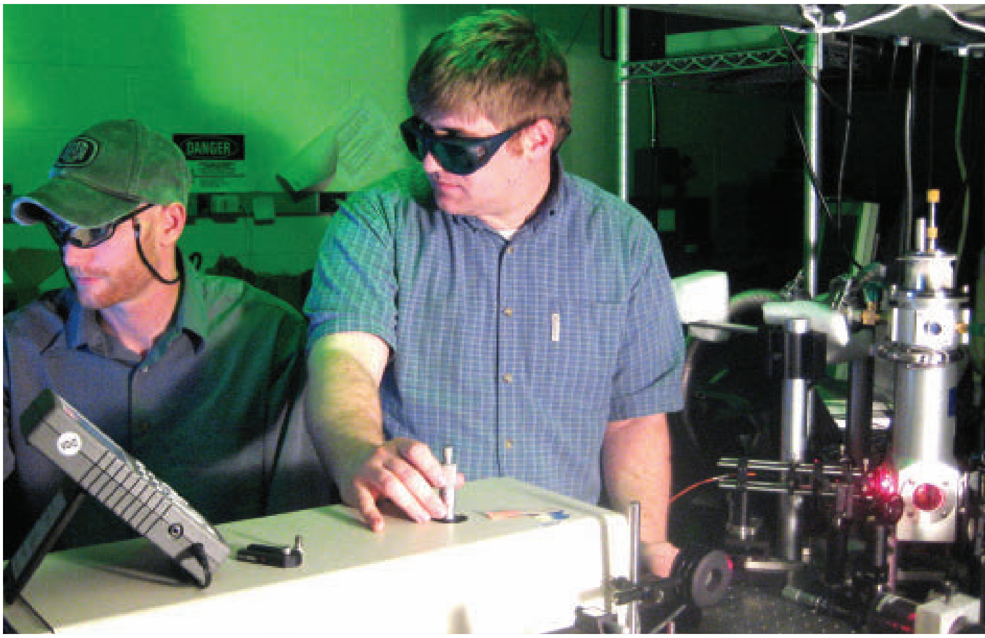
This seemingly superluminal, or faster-than-light, speed can be explained by the wave properties of light. When a photon hits a boundary between the layers of a material, it creates waves at each surface. The waves interfere with each other so that very little light makes it out of the other side of the stack of layers but, provided that the H and L layers are arranged in just the right way, the photons that do make it to the other side emerge early.

Now that Borjemscaia and colleagues have demonstrated the temporal effects with dielectric stacks, which was one system suggested as a model of the quantum barrier, they hope to continue their experiments with a different optical barrier.

"We are actively pursuing measurements of traversal times through another optical 'analogue' of the quantum mechanical potential barrier – a narrow gap between two blocks of glass," Borjemscaia said. "This arrangement is one that better approximates the quantum mechanical barrier and will fill an experimental void in the direct measurement of tunneling times."

Marie Freebody
marie.freebody@photonics.com

Cooling goes cryogenic


Graduate students Seth Melgaard (left) and Denis Seletskiy (right), members of Mansoor Sheik-Bahae's research group at the University of New Mexico, are conducting a spectroscopic study of cooling efficiency of the ytterbium-doped YLF crystal. Photo courtesy of Mansoor Sheik-Bahae.

ALBUQUERQUE, N.M. – All-solid-state laser cooling, or "optical refrigeration," a technique that can be applied to airborne and space-borne sensors, has been demonstrated by a team at the University of New Mexico under the direction of Mansoor Sheik-Bahae, a professor in the physics and astronomy department.

"Currently, standard multistage thermoelectric (Peltier) coolers are capable of cooling a device (i.e., a detector) only to 170 K with diminishing efficiency and cooling power. We have broken this barrier by laser cooling [an ytterbium-doped $LiYF_4$ crystal] to 155 K and 90 mW of heat lift under nonoptimal conditions," Sheik-Bahae said. In laser cooling of solids, heat is removed through the annihilation of lattice vibrations in the process of anti-Stokes fluorescence.

"Based on our ongoing modeling efforts and supporting spectroscopic measurements, cooling to near liquid nitrogen (77 K) temperatures should be possible once optimum conditions and reasonable improvements in material purity have been implemented," added Denis Seletskiy, lead author, senior graduate student and major contributor to the research.

Infrared photon detectors and focal plane arrays must be cooled to become highly sensitive (low dark current), Sheik-Bahae explained. He added that many such detectors currently use mechanical cryocoolers (e.g., Stirling coolers), which are relatively bulky and introduce microphonic noise due to vibrations. Solid-state optical cryocoolers will be compact and vibration-free and have long lifetimes with very low thermal jitter, he said. The lightweight requirement makes such cryocoolers specifically suited for space-based and airborne applications.

Seletskiy noted that they have started working on proof-of-principle experiments where they are aiming to demonstrate cooling of the detectors. "We have already demonstrated an ytterbium-based cryocooler to lower a temperature of 5 micrograms of gallium arsenide semiconductor heterostructure to 165 K," he said.

"The key insight was to exploit the sharp Stark manifold resonances in an ytterbium-doped YLF crystal (crystal field splitting)," Sheik-Bahae said. Seletskiy added that, unlike in glass hosts previously used in laser cooling, ytterbium resonances are preserved due to long-range order of the host crystal. "By tuning the excitation laser to the lowest-energy resonance, we were able to utilize maximum cooling efficiency of the process and thus achieve cryogenic operation," he said. In addition, cavity enhancement of the pump absorption and careful thermal management played important roles in the advance.

To minimize parasitic heat load from the environment, the researchers conducted cooling experiments in high vacuum and used a sample chamber with coating designed to minimize radiative (blackbody) load on the sample. They also designed and implemented a noncontact temperature measurement technique.

"Another essential factor in reaching this milestone was the high quality of the crystal that was grown by collaborators at the University of Pisa in Italy under professor Mauro Tonelli," Sheik-Bahae said. "They managed to grow relatively high-concentration Yb-doped crystals with extreme purity and essential requirements for low-temperature operation in laser cooling," he added.

The researchers said they will be addressing challenges such as the need for higher-quality (purity) material synthesis in rare-earth doped crystals as well as semiconductors with high quantum efficiency and low parasitic absorption. "Our modeling predicts that factor-of-four improvement in purity of rare-earth doped crystals can lead to cooling below 100 K," Seletskiy said. Possible applications of solid-state laser cryocooling include superconducting electronics, solid-state spintronics and, eventually, quantum computing.

The researchers will also be working on integration with photovoltaic devices to recycle waste fluorescence to improve overall efficiency and on development of compact, efficient (diode-based) pump laser sources.

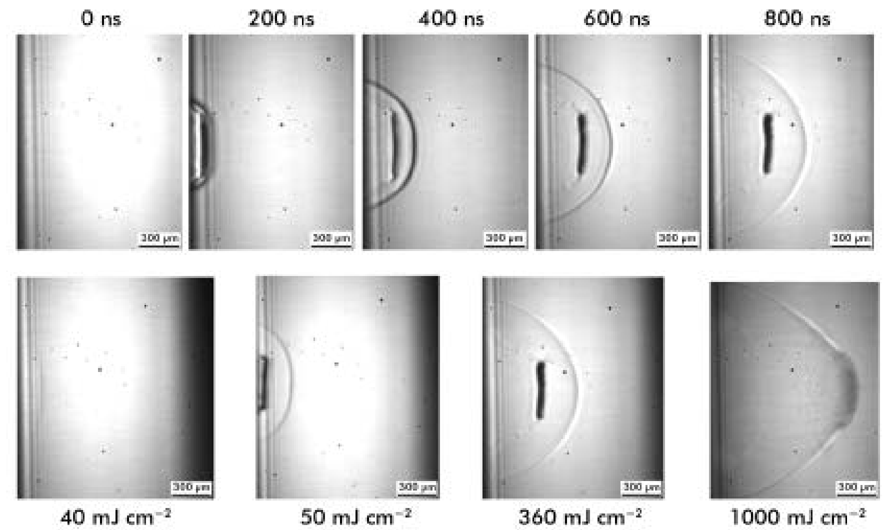
The team, which included researchers from the Los Alamos National Laboratory in New Mexico, conducted its investigation under a multi-university grant from the U.S. Air Force Office of Scientific Research, based in Arlington, Va. The study was published online in *Nature Photonics* on Jan. 17, 2010.

Caren B. Les
caren.les@photonics.com

Giving a lift to thin films

VILLIGEN, Switzerland – If you have ever played with one of those desk ornaments with the suspended metal balls called a Newton's cradle, you know that when you pull back and release one or more balls on one side, an identical number of balls on the other side moves in reaction to this force. A newly developed technique that mimics this process holds the promise of changing the way that thin films are deposited.

Researchers at the Paul Scherrer Institute and Empa are working with a method called laser-induced forward transfer (LIFT). In LIFT, a layer on a transparent substrate is ablated by an excimer laser,



The upper row shadowgraphy microimages show the time-resolved development of the shock wave and flyer ejection for a laser fluence of 360 mJ/cm^2. The flyer consists of a layer of 80-nm aluminum coated on top of a 350-nm-thick triazene photopolymer. The flyer stays stable over quite a long distance of more than 0.3 mm. In the bottom row, the forward-ejection of the same model system was studied to investigate the fluence dependence of the generated thrust. Images were taken at a constant delay time of 800 ns after the laser pulse. Flyer velocity and shock wave shape depend on the applied laser fluence. The bar in the images corresponds to 300 μm. Courtesy of Thomas Lippert.

passed through the substrate and collected on a second substrate. In the process, the laser moves from spot to spot, producing a patterned thin film.

"The laser defines the material to be transferred [or] deposited. If we use a 500 by 500-micron beam, we deposit that size, or if we use a round beam, we deposit a round pattern," said Thomas Lippert, head of the materials group at the institute.

Shadowgraphy

Here's how it works: A sacrificial layer of triazene polymer is placed between the substrate and the transfer layer, which converts the laser energy into mechanical energy while at the same time protecting the transfer layer from radiation. During the process, films made of a stack of triazene polymer, metal and, optionally, an electroluminescent polymer are irradiated from the back side by a pulsed XeCl excimer laser operating at 308 nm with a pulse duration of 30 ns. The evolving "ablation" generates a laser-triggered pressure jet, which then punches out and catapults the overlying transfer materials, called flyers, integrally toward the receiver substrate.

The ablation process was imaged by lateral time-resolved shadowgraphy. "Shadowgraphy," Lippert explained, "is more or less microphotography with backlighting. The difference is that the flash is a few nanoseconds, and we can see solid objects and changes in the refractive index."

Since the sacrificial polymer release layer protects the transfer layer from the incident UV irradiation, even highly sensitive biomaterials can be transferred and deposited. An international research collaboration has demonstrated that the modified LIFT process can transfer not only sensitive materials but also living mammalian neuroblast cells. With the aid of an approximately 100-nm-thick aryltriazene photopolymer film, the cells were deposited precisely onto a biological substrate, gently enough that the functionality was not impaired, and the cells started reproducing instantly.

Lippert said that the lasers employed are from Lambda Physik and Quantel.

The group has started a European Union project called E-LIFT to test applications for the technology that include organic field-effect transistors/organic LEDs, sensors/bioprinting, and energy harvestors (piezoelectric and thermoelectric)/smart radio-frequency ID tags.

The researchers published a paper on their findings in the Jan. 6, 2010, online issue of *Journal of Physical Chemistry C*.

Charles T. Troy
charlie.troy@photonics.com

Dialing up the laser power

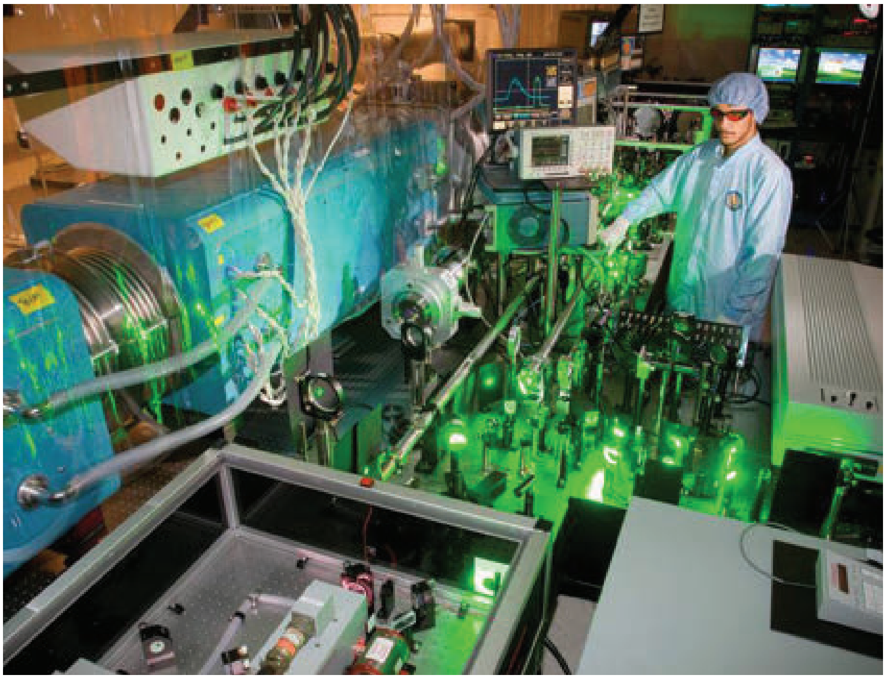
AUSTIN, Texas – Over the past 20 years, physicists have been steadily stepping up the power of lasers from the previously impressive terawatt level to the recently realized petawatt level. Now, researchers at the University of Texas are working toward building the first exawatt laser, which will be the most powerful laser in the world.

"Every leap in power made by the laser community has led to dramatic and unexpected applications," said professor Todd Ditmire, who heads up the Texas Petawatt project. "The leap in power by a factor of 1000 that an exawatt laser would provide will no doubt lead to new applications."

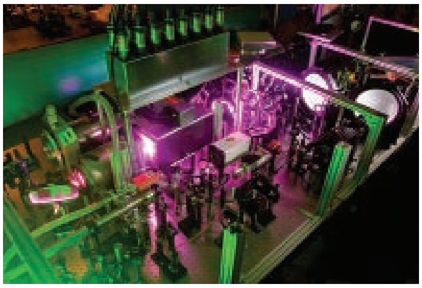
Current research uses for the Texas Petawatt Laser include producing thermonuclear fusion, a process that many engineers would like to harness for the commercial generation of electricity. Other applications include the study of hot, dense plasmas.

Reaching exawatt levels should push these studies to new extremes and likely reveal new applications. So convinced are they about the coming applications that Ditmire and colleagues have formed their own company, National Energetics, to commercialize their work.

"An exawatt laser might be used to accelerate particles to a very high energy. We might imagine accelerating electrons to energies of up to one teraelectronvolt, which is 10 times higher than the energy produced by the Stanford Linear Accelerator Center in California," Ditmire said. "It might also be used to create a small amount of matter in the lab that has a relativistic temperature. Such temperatures



This shows the amplifier bay of the Texas Petawatt Laser. Images courtesy of the Texas Petawatt project.



Shown is the large silicate glass rod that is used in the amplifier chain.

Pictured is a view down the axis of the large 31-cm glass disk amplifiers.

are thought to exist near black holes and are very exotic states of matter."

While a number of petawatt lasers already exist around the world, the Texas Petawatt Laser uses a new mixed glass approach to amplify pulses with durations down to nearly 100 fs.

The method is based on chirped pulse amplification, which involves stretching a femtosecond pulse to make it safe for amplification. After the pulse's energy is boosted, the pulse is recompressed in time to create a high-peak-power pulse.

"We start with a very low energy femtosecond oscillator to produce broadband pulses, which are stretched using diffraction gratings in order to spread the colors of the pulse out in time," Ditmire explained. "Then, the pulse is amplified with nonlinear optical crystals followed by large mixed glass amplifiers. Finally, the pulse transits two more gratings, which compress the colors back to a pulse duration near that of the initial seed pulse."

The Texas team hopes that, by developing new kinds of glass for use in the mixed glass amplifier, it will be able to make a laser with energies exceeding 100,000 joules and a pulse duration of less than 100 fs.

"The next steps involve working with German glassmaker Schott Glass to develop the new kinds of laser glass we will need for an exawatt laser," Ditmire said. "In parallel, we are commercializing the mixed glass architecture."

Marie Freebody
marie.freebody@photonics.com

LEDs lead to change for some silver

OTTAWA – Adding a touch of silver can improve several photonic endeavors, such as surface-enhanced Raman scattering, surface-enhanced fluorescence and surface plasmon resonance spectroscopy. The metal amplifies the otherwise minute emissions that must be recorded in Raman and plasmonic studies.

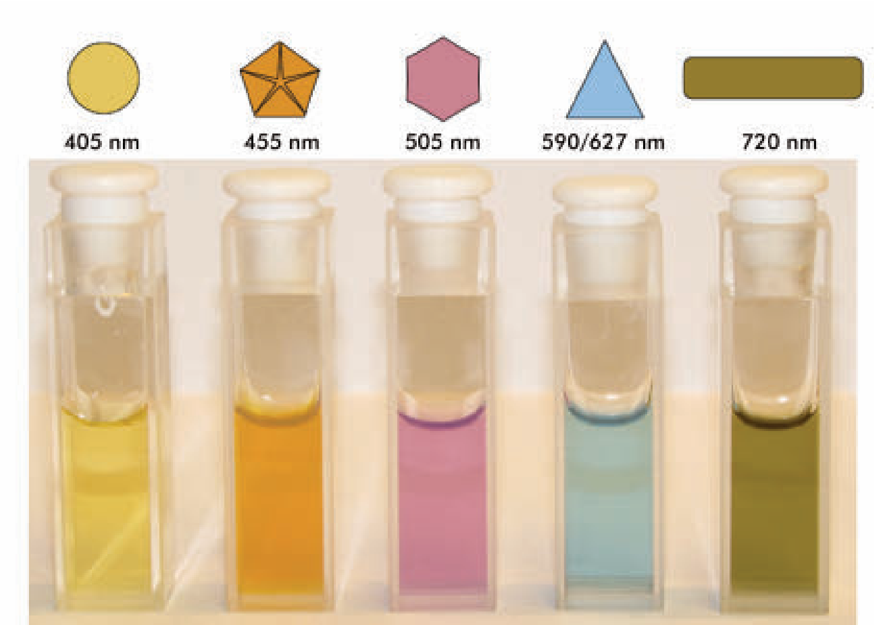
Initial studies focused on solid substrates made of silver, which were used to increase the signal of particles laid atop them. Later research broke up these metal films into smaller and smaller segments. Eventually, nanoscale silver particles became the target of interest, brought into proximity with materials that needed a localized push into higher emissions.

The optical properties of silver nanoparticles determine their functionality and applicability to whatever task may be required of them but, in turn, these properties depend largely on their size and shape.

There are a number of thermochemical ways to synthesize silver nanoparticles of various shapes, but the reducing agents and high heat they often require can be too environmentally harsh for some. Photochemical methods also exist – and are better for the environment – but they don't offer much control over the final size of the nanoparticles. Now, Juan C. Scaiano and his colleague Kevin G. Stamplecoskie, of the University of Ottawa, have devised a nearly all-photonic method of creating a variety of shapes and sizes of silver nanoparticles using nothing but LEDs.

Scaiano and Stamplecoskie started by photochemically synthesizing "seed" particles and growing them to about 3 nm. They irradiated batches of the seed in solution with LEDs of specific emission wavelengths and found that a dose of 405-nm radiation caused the seed particles to grow and aggregate. Using 455-nm light, they found, formed dodecahedral masses; 505-nm light, hexagonal platelets interspersed with a few dodecahedral particles; 590-nm or 627-nm light, roughly triangular platelets; and 720-nm light, rods with an aspect ratio of about 2:1 or 3:1. Each change in shape corresponded with a change in the absorption spectra of the amassed particles.

The scientists similarly tested the seed particles using a laser and a xenon lamp. The lamp took far longer to provide



Researchers at the University of Ottawa have devised an LED-based approach to growing and controlling the shape of silver nanoparticles. The various shapes result in different emission wavelengths. Courtesy of the American Chemical Society.

results (longer than one week versus 1 to 48 h for the LEDs). Also, Scaiano said, the resulting products "were more of a distribution of shapes that were aggregated more if they formed at all."

A pulsed laser gave no result in changing particle size, and although a high-power continuous-wave laser might work – if its beam were made divergent – it would be too costly in comparison with the LEDs.

According to the investigators, the LED wavelength and the localized electromagnetic field that surrounds the seed particles as they are irradiated are the driving forces for changes in the nanoparticles' final shape.

Next, the team will be working to implement the various particle shapes into applications in catalysis and spectroscopy, while examining how each shape and exposed crystal facet affects results.

"The biggest advantage [of the LED-based technique] is that you can obtain many different sizes and shapes that all have similar surface functionalization," Scaiano said. "Therefore, when doing something like catalysis, these particles do not have different ligands on the surface, which is commonly the case and which can adversely affect the catalysis."

Scaiano and Stamplecoskie report their work in the Feb. 17, 2010, issue of the *Journal of the American Chemical Society*.

Lynn Savage
lynn.savage@photonics.com

Hitting the light switch for magnetic manipulation

WEST BENGAL, India – Reversing the magnetic properties of materials is the underlying reality behind computer hard drives, audiotape and other recording media. For these purposes, changing the magnetic state of macroscale particles suffices, but efforts are under way to exploit the spins and magnetic moments of electrons, which could lead to smaller electromagnetic devices than currently exist.

Using the inorganic materials typically chosen for their ferromagnetic properties limits the amount of time an electronic spin state lasts, however. Organic chemicals have garnered interest in the nascent field of spintronics because they can hold spins longer and therefore are more suitable for use in electromagnetic solid-state devices.

Altering a magnetic field commonly is performed with other, more highly magnetic fields or with radio-frequency devices, but using photons generally is easier and would seem well-suited for spintronics. Unfortunately, little to no work has been done on matching photoinduced magnetization switching techniques with organic chemicals.

Now, Anirban Misra and his colleague Suranjan Shil of the University of North

Bengal in Siliguri, India, have completed a study of the magnetic properties of several azobenzene molecules.

Using imino nitroxide, nitronyl nitroxide and verdazyl – three highly stable forms of azobenzene – the researchers delved into the molecules' ferromagnetic properties in their natural *trans* isomeric forms. In the *trans* form, each azobenzene is antiferromagnetic, or not susceptible to magnetic fields at all. However, after exposure to UV radiation in the 340- to 380-nm range, the molecules converted into their *cis* forms, which proved to be ferromagnetic.

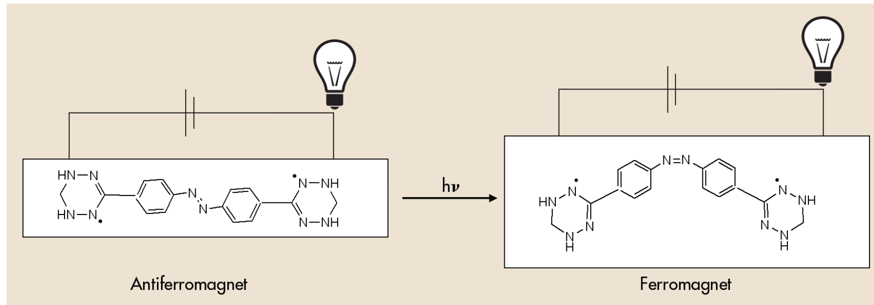
Importantly for potential solid-state data manipulation, this photoisomerization process takes place at the nanosecond scale, enabling ultraquick on-off digital data processing. In addition, the ferromagnetic *cis* forms of the molecules had highly polarized electron spins, whereas the *trans* forms did not, indicating a possible role for *cis* azobenzenes as spin valves in electromagnetic read heads or in magnetic field detectors.

The investigators also measured the coupling constant (*J*) of each organic molecule, determining that the *cis* form of verdazyl has the highest *J*, which they measured to be 79 inverse centimeters. Nitronyl nitroxide had a *J* of 64 cm^{-1} and imino nitroxide the lowest, 15 cm^{-1}. According to Misra, the larger the *J* value, the more suitable the molecule would be for potential applications. They reported their findings in the Feb. 4, 2010, issue of the *Journal of Physical Chemistry A*.

The scientists are now focused on further quantifying spintronic behavior in organic molecules as well as on evaluating the properties of "magnetically interesting" organic and inorganic systems.

"This is the first report of magnetization reversal in the systems of organic origin," Misra said. "In organic systems, spins can be preserved for longer timescales than conventional inorganic materials. This may eventually lead to the application of photoinduced spintronics, photomagnetic switches, spin valves and so on."

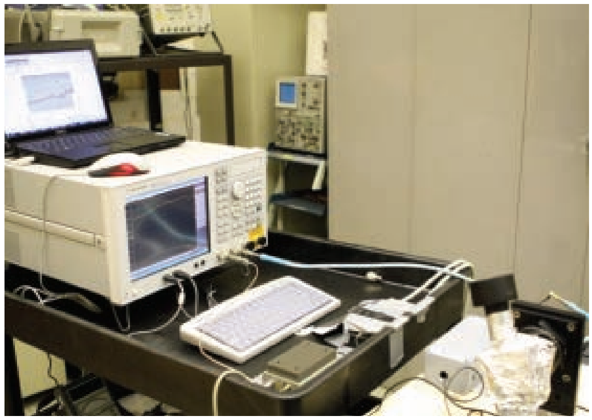
Lynn Savage
lynn.savage@photonics.com



When exposed to UV radiation, molecules in the azobenzene family change isomeric shape, which also changes them from antiferromagnetic to ferromagnetic. Courtesy of Anirban Misra, University of North Bengal.

Optical WLAN is fast, secure and green

UNIVERSITY PARK, Pa. – Researchers at Pennsylvania State University have demonstrated optical wireless transmission using a diffused light setup with speeds exceeding 1 Gb/s, opening the door for bandwidth-hungry applications such as high-resolution video to go wireless. And the optical implementation comes with the benefit of being intrinsically safe.


Pennsylvania State University researchers have developed a diffused light setup for optical wireless transmission with speeds exceeding 1 Gb/s.

Indoor optical wireless communication was proposed as early as 1979, when scientists at IBM Research in Zürich, Switzerland, developed the first prototype. At the time, there was no Internet and little need for widespread use of such technology. The researchers used a diffuse implementation, which requires high-power transmitters and/or highly sensitive receivers.

However, these tend to be expensive, and multiple light paths using room reflections can cause echoes, degrading the performance. The alternative would be a transmitter and a receiver pointing directly at each other, but such a "line of sight" configuration is not practical because it is prone to "shadowing" and does not tolerate any movement of the user in the room without readjusting the link.

The Penn State researchers, Mohsen Kavehrad and Jarir M. Fadlullah, found a promising compromise, however, which they presented in a paper at SPIE Photonics West 2010 in San Francisco in January. They use a multi-input multi-output architecture, in which a multielement transmitter sends several copies of the signal to the room ceiling, where it is reflected, and a multibranch receiver collects the returned signals. A holographic beam former disperses light in various directions, generating the transmitted light grid, and a receiver, fitted with a similar "fly eye" holographic optic, collects all replies.

"Sending and receiving several copies of the signal offers better performance, minimizes echoes and lets the user move around freely," Kavehrad said.

The researchers demonstrated data rates well beyond 1 Gb/s – "a bandwidth very difficult to achieve at safe radiation levels with radio waves, even millimeter waves," Kavehrad noted. But he sees many further benefits, one being increased security. "Applying security at the physical layer is the safest" because light cannot leave rooms as easily as radio waves. Also, light does not interfere, and the same frequencies can be used in adjacent rooms.

The researchers compared wireless technologies with respect to their energy-per-bit-per-meter range performance and found that optical free-space solutions, despite still being in their infancy, are much "greener" than today's radio technologies, including IEEE 802.11g, 3G or Bluetooth.

Beyond that, there is another forward-looking angle being worked on by Kavehrad's team and other groups, including Boston University's Smart Lighting Engineering Research Center. The investigators propose replacing existing lighting with low-power, high-efficiency white LEDs – using the light sources as wireless transmitters rather than having the signal sent up and reflected by the ceiling. Where infrastructure exists, such as light fixtures, power lines or network cabling, these could be reused; otherwise, the technology could be combined with power-line broadband, delivering not only electricity but also broadband all the way to the end user.

Asked what is needed for this technology to advance, Kavehrad said: "Wake up the industry."

Dr. Jörg Schwartz
joerg.schwartz@photonics.com

3-D: Coming soon to a TV near you?

AUSTIN, Texas – The development of 3-D television has become an area of intense interest to manufacturers, according to market analysis firm DisplaySearch in its *Quarterly TV Design and Features Report*. The company notes that the manufacturers are seeking to retain consumer interest in the sets, for which average selling prices are expected to fall for the first time since the beginning of the flat panel model transition.

The report indicates that LED backlighting and 240-Hz LCDs will enable development of new features in TVs, particularly 3-D. The company forecasts that the number of 3-D-ready TVs will reach 64 million in 2018, up from 0.2 million units in 2009. It predicts that 15.6 million 3-D-capable TVs will be shipped in 2013, up from an estimated 1.2 million shipments in 2010.

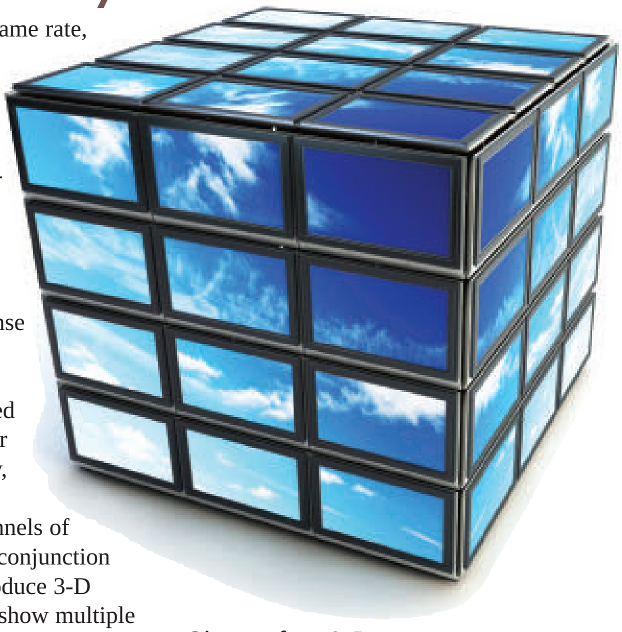
"The main reason for this positive projection is the convergence of 3-D content, in terms of movies, games and, soon, broadcast content, and in hardware, in terms of good-quality 3-D displays and Blu-ray Disc players," said Paul Semenza, senior vice president of DisplaySearch. High-density optical Blu-ray Disc technology, designed to replace the standard DVD format, is a key platform for movie content, and movies are the leading area of development for 3-D, he said.

"Furthermore, the high bandwidth required for high-definition 3-D movies will limit distribution – or make it expensive – via cable and satellite. So Blu-ray is a key link in the chain of delivering 3-D content to 3-D TVs. Agreement on a standard should help speed implementation of 3-D as a regular feature in Blu-ray players," Semenza said.

The Blu-ray Disc Association released a Blu-ray specification in December 2009 that will leverage the advantage of the Blu-ray Disc format to deliver high picture quality as well as uniformity and compatibility across the full range of Blu-ray 3-D products, both hardware and software. The technology, which uses a 405-nm blue-violet laser, enables almost 10 times more data storage than a DVD.

Semenza noted that any multiple of a 60-Hz – or 50 in Europe – frame rate, including 120 Hz, 240 or higher, enables higher video performance. Specific to LCDs, the higher frame rate enables some compensation for the relatively slow switching time of the liquid crystal material, he said.

He explained that, in large screen sizes, this slow response can cause artifacts such as image blur, in which a fast-moving object appears blurred or skips across the frame. For any type of flat panel display, the higher frame rate can be used to display multiple channels of video, which can be used in conjunction with switching glasses to produce 3-D video, or it could be used to show multiple video streams simultaneously on the same display.



"The benefits of LED backlighting include wider color gamut, faster switching time, thinner-depth sets and the ability to have 'local dimming,' which increases contrast ratio and decreases power consumption. LED has only an indirect impact on 3-D – the fast switching of LEDs helps to enable the high frame rates needed to produce full high-definition 3-D video," Semenza said.

From *Avatar* to awareness

"Awareness – despite the success of the film *Avatar* – is an industry challenge," Semenza said. He noted that consumer surveys by the Port Washington, N.Y.-based NPD Group Inc. market research firm (of which DisplaySearch is a part) indicate that there is relatively low awareness of 3-D technology. The surveys also showed that consumers are not willing to pay a high premium for 3-D capability and that they would like a large amount of the content they watch to be available in 3-D.

"Finally, there are questions about usage modes – how much will consumers want to see in 3-D – sitcoms? local news? – and are there any health concerns with prolonged 3-D viewing," Semenza said.

Glasses-free 3-D

"The key issue at present is interoperability of the glasses from different set makers; it is not clear, for example, if glasses produced for a Samsung TV will work with a Sony, or vice versa. It is probably not a difficult issue; it just needs to be resolved," he said.

Perhaps the ultimate implementation of 3-D TV is glasses-free, autostereoscopic display. To achieve this type of display without any degradation in resolution or brightness, optical or other component technology must be added or integrated into the display.

"In the long term, a mix of 3-D offerings, including movies, live sports and gaming, will be needed to make the 3-D feature in TVs desirable to consumers. Active – shutter – glasses are required now and will be for the next several years, until the high-quality autostereoscopic displays are developed. These active glasses are heavier and more expensive than the passive – polarizer – glasses being used in cinemas; passive glasses are enabled through the use of two projectors that run simultaneously, something that would not be feasible in the home," Semenza said.

Caren B. Les
caren.les@photonics.com

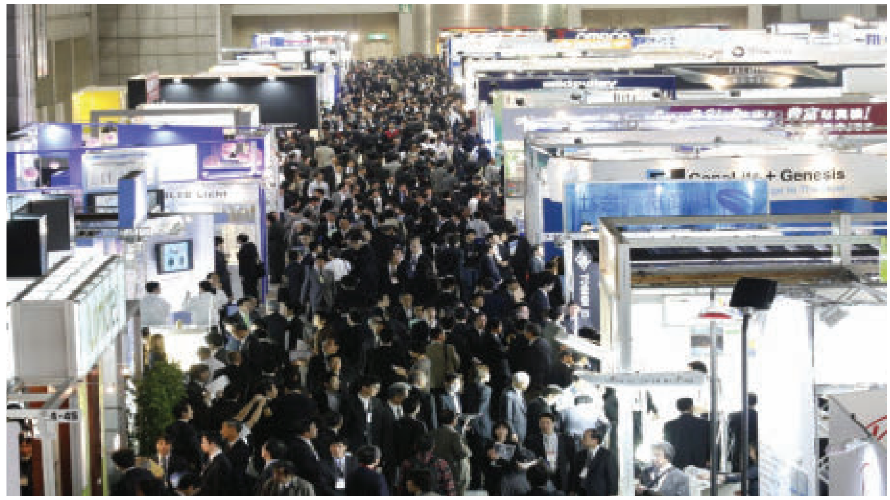
Eco-friendly lighting will shine at show

TOKYO – Green lighting technologies will be featured at the second LED/OLED Lighting Technology Expo – also known as Lighting Japan 2010 – which will be held at Tokyo Big Sight, the nickname for the Tokyo International Exhibition Center.

Organizers from Reed Exhibitions Japan Ltd. say the show is a crucial part of a company's global business and network expansion strategy. During last year's show, 16,395 visitors and 218 exhibitors attended, many from Taiwan, South Korea and mainland China. This year, 25,000 visitors and 400 exhibitors from around the world are expected to participate.

Lighting Japan will be held concurrently with Finetech Japan 2010, which will include the second International Touch Panel Technology Expo, known as Touch Panel Japan. Other concurrent events include two newly launched exhibitions, the Nanoimprint Technology Fair and the Highly-functional Film Technology Expo. A total of 1,100 exhibitors and 88,000 visitors are expected to take part in all the events.

Industrial events – from technical seminars to a VIP party – are planned for exhibitors and visitors. The seminar and conference program will cover a number of areas. One Lighting Japan keynote session, "National Policies upon Next-Generation Lighting Development," will focus on expectations for LED lighting as well as on Japan's efforts to realize a low-carbon society. Nobumori Otani, parliamentary secretary of the environment and a member of the House of Representatives, will give the lecture.



With an eye on green lighting, the second LED/OLED Lighting Technology Expo, Lighting Japan, will feature eco-friendly LED and OLED technologies. Image courtesy of Lighting Japan.

The second keynote talk, "National Policies of China on the SSL Industry," will be given by Wu Ling, general secretary of the China Solid State Lighting Alliance. She will highlight Chinese government efforts in promoting the solid-state lighting (SSL) industry.

The full program schedule, with information on keynote and technical seminar and conference sessions, is available online at www.lightingjapan.jp. For more information about Lighting Japan 2010, contact Reed Exhibitions Japan Ltd. at +81 3 3349 8568 or at light@reedexpo.co.jp.

Laura S. Marshall
laura.marshall@photonics.com

Fiber Distribution 3SAE Technologies Inc. of Franklin, Tenn., a manufacturer of large-diameter fiber fusion splicing and preparation technologies, has signed a consulting and distribution agreement with DPM Photonics of Vernon, Conn., a fiber optics consulting service, to make its products available to high-power fiber laser manufacturers, military, aerospace and industrial medical markets throughout the US. The two companies have worked together since 2003, combining optical components and fiber-based device experience.

Distribution Agreement Fremont, Calif.-based Solyndra Inc., a cylindrical photovoltaic systems manufacturer, has signed a distribution agreement with Advanced Green Technologies of Fort Lauderdale, Fla., a renewable energy solutions and building-integrated solar energy products provider. The agreement has provided the California company with comprehensive support capabilities suitable for its North American distribution network.

Headquarters Relocated FiconTec Service GmbH has moved its corporate headquarters to Achim, Germany, because of the increased demand for automated photonic assembly projects solutions. The new facility offers sufficient capacity to address the boost from the introduction of the company's latest microassembly platform. FiconTec supplies semiautomatic and fully automated production and testing systems for the optical, laser diode, optoelectronics, medical, security, military engineering and telecommunications industries.

Solar Purchase Zhejiang Hongchen Photovoltaic Energy Co. Ltd. of Zhuji City, China, has purchased additional PV1200 photovoltaic metallization lines from DEK Solar, a screen printing specialist based in Zurich, Switzerland. As part of the former's drive to increase cell production through 2010, the lines were selected for their ability to offer productivity, cost and lead-time advantages. The PV1200 delivers 1200 wafers per hour for repeatable solar cell production.

Prosilica Renamed Prosilica Inc. of Burnaby, British Columbia, Canada, is now fully integrated into the Allied Vision Technologies group and has been renamed Allied Vision Technologies Canada Inc. Acquired in July 2008, the Canadian camera manufacturer's GigE Vision product lineup and sales channels have been fully integrated into the group's camera range.

Solar Contract Singulus Technologies AG of Kahl, Germany, has received a €19 million contract from a European solar cell manufacturer to produce a new generation of thin-film solar cells. The company's new processing system for thin-film solar technology is now available, extending its product offerings to include photovoltaic systems.

$5M Metrology Order Rudolph Technologies Inc. of Flanders, N.J., a process characterization equipment and software provider, has received $5 million worth of orders from a long-standing customer for its S3000A and MetaPulse III thin-film metrology systems. Expected to ship to multiple fabs in the first half of 2010, the systems will be used in copper metrology applications, including copper seed/barrier, electrochemical deposition and chemical mechanical polishing. The MetaPulse III can directly measure thickness and other metrology parameters on product wafers in the active device regions for accurate process control.

NAVAIR Contract In Chelmsford, Mass., McPherson Inc., a manufacturer of dispersive spectrometers, has been contracted by Naval Air Systems Command (NAVAIR) for design and production of a spectral test, calibration and light delivery system. The Spectral Test System (STS) delivers near-contiguous wavelength coverage from the ultraviolet to the long-wave infrared. The system helps to characterize and document the response of sensors to specific wavelengths of light to calibrate their response and to acquire useful data when the spectral sensors are airborne. The STS will help NAVAIR to characterize sensors for the SPIKE program, a precision-guided technology using high-tech imaging and electro-optical sensors.

Certification Awarded High-performance thin-film optical coatings manufacturer Reynard Corp. of San Clemente, Calif., has been awarded ISO9001:2008 quality management system certification from QAS International. The company said that the certification provides evidence to customers, suppliers and employees of its commitment to improve customer satisfaction.

Blue LED Order Aixtron AG of Aachen, Germany, has announced that Formosa Epitaxy Inc. of Lung-Tan, Taoyuan, Taiwan, has ordered multiple metallorganic chemical vapor deposition (MOCVD) reactors to be used in the production of ultrahigh-brightness InGaN-based blue LEDs. Composed of Crius close-coupled showerhead systems and AIX 2800G4 HT planetary reactor systems, the MOCVD tool order will be shipped in the course of 2010 and will be installed alongside Formosa's high-throughput Aixtron MOCVD systems.

Large Order Installation In Dresden, Germany, AIS Automation Dresden (AIS) received a large order to install its manufacturing execution system (VPC-MES) for the factory currently under construction in Arnstadt. To be used for manufacturing crystalline solar cells, the factory will extend the production capacities of Bosch Solar Energy AG by ~400 megawatt-peak. The system is already successfully used in four factories run by Bosch.

US Office Expansion Specialised Imaging Ltd. of Tring, UK, has announced the opening of its North American partner company, Specialised Imaging Inc., in Simi Valley, Calif. After five years of representation in North America by IMC/Photo-Sonics Inc. of Burbank, Calif., the new office will expand and develop support for the company's ultrahigh-speed imaging systems and components from its California facility.

PV Cell Facility Launched Solar energy systems provider Kyocera Corp. of Kyoto, Japan, has finished construction of its solar cell manufacturing plant in Yasu City, Shiga Prefecture. The facility will be the core production site for the company's newly enhanced photovoltaic cell with a conversion efficiency of 16.9 percent. The plant will further the company's production target of 1 GW annually by March 2013, a production volume that is two and a half times the current 400-MW capacity.

Solar Plant Built Mitsubishi Electric Corp. of Tokyo has announced that PV (Photovoltaic) Cell Plant #2 has been built at its Nakatsugawa Works Iida Factory in Nagano Prefecture. By March 2011, the company will raise its annual PV module production capacity by 50 to 270 MW with a longer-term annual goal of 600 MW. In addition to its current polycrystalline silicon PV modules, Mitsubishi plans to manufacture monocrystalline silicon PV cells, starting production by March 2011.

European Distribution Avo Photonics Inc. and AMS Technologies AG have entered into a distribution agreement that entitles the latter to represent the former's capabilities in the European market. Avo, of Horsham, Pa., provides advanced contract design, prototyping and manufacturing services for customers in the military, aerospace, medical, communications and industrial markets. AMS will distribute the services to its European electro-optics clientele.

Wafer Bonding Shipment Wafer bonding and lithography equipment supplier EV Group of St. Florian, Austria, has shipped two wafer bonding systems to the University of Michigan's Lurie Nanofabrication Facility, a center for microelectromechanical systems (MEMS) and microsystems research and a member of the National Nanotechnology Infrastructure Network. The new systems will provide high-force wafer bonding capabilities to increase the level of the university's MEMS research efforts.

Insight Acquired L-3 Communications of New York, a supplier of products and services for the aerospace and defense industries, has unveiled that it has entered into an agreement to purchase Insight Technology Inc. of Londonderry, N.H., a night-vision and electro-optical equipment manufacturer. With an undisclosed purchase price to be funded with cash, the acquisition is anticipated to be completed in the second quarter of 2010, subject to customary closing conditions and regulatory approvals. It will be structured as an asset purchase.

New Company Formed Innovation Photonics of Verona, N.J., has been established by Don Wilson, founder of Special Optics and of Optics for Research. The new company, nicknamed innpho, is engaged in optical components, engineering, design and manufacturing, with an emphasis on innovative products. Products available include mid-infrared focusing objectives designed for laser-to-fiber coupling, output collimators, laser-mountable input couplers, and mid-infrared polarizers and fiber pigtails.

Solar inspection mixes sound with imaging

BY ANNE L. FISCHER
CONTRIBUTING EDITOR

Solar manufacturers have a few technologies at their disposal that can detect cracks in cells and modules. In an industry where energy efficiency is the name of the game, manufacturers want to reduce or eliminate cracks to improve yield, reduce waste and avoid putting faulty modules into solar panels. Defects are detected with various types of imaging (see "Camera makers find a niche in the solar market," page 43, May 2009), but some companies prefer to begin with resonance ultrasonic vibration (RUV) technology.

The process known as RUV was invented and developed by Dr. Sergei Ostapenko, who conducted his research at the University of South Florida in Tampa. Initially, his projects focused on measuring stress in silicon wafers for microelectronics. But with a personal interest in photovoltaics (PVs) and an involvement in numerous PV projects at the university, his research moved quickly in that direction.

His team found that resonance vibration modes in wafers could be measured while they were running along the production line. The group also developed data analysis software; both technologies became the basis for the launch of Ultrasonic Technologies Inc., a startup based in Tampa, Fla.

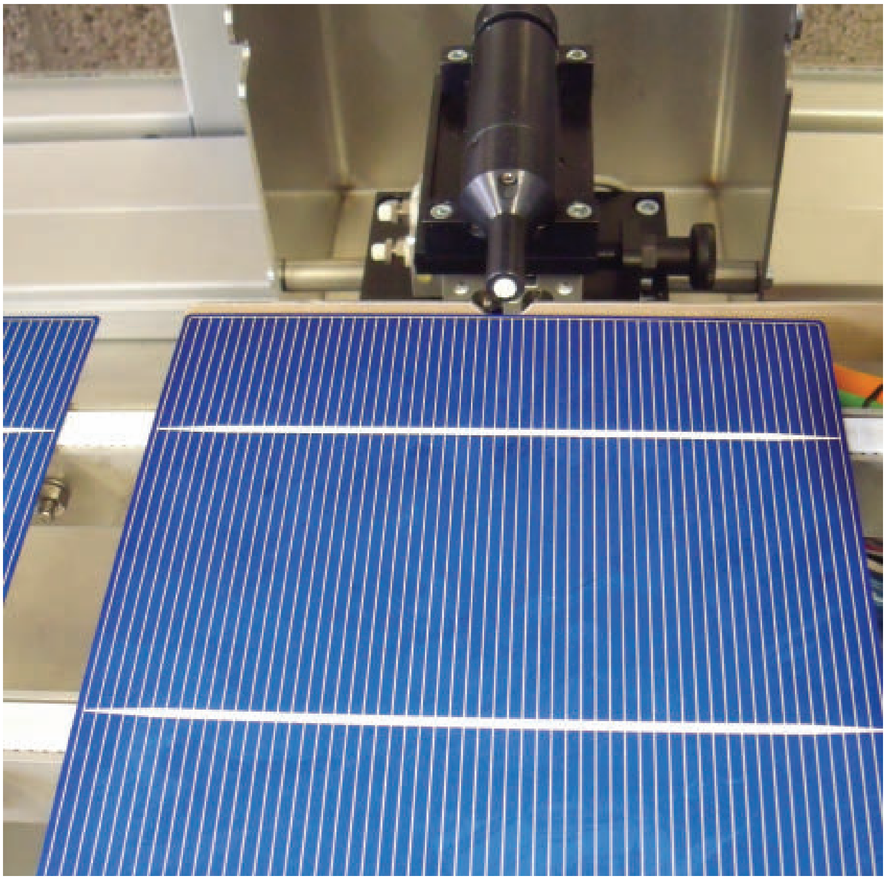
The way it works, according to Ostapenko, is basically akin to tapping on several identical new wine glasses. A glass with a crack in it will sound different from an undamaged one. "Ultrasonic testing does the same thing with silicon wafers and solar cells, but at a frequency range above what you can hear with your ear, which ultimately increases crack detection sensitivity and accuracy," Ostapenko explained. On the production line, RUV also allows fast real-time crack inspection, matching throughput of solar cell wafers and modules at a few seconds per unit.

Optical testing an option

Yield and quality are directly related to finding and rejecting unstable wafers or cells while they are still on the assembly line, manufacturers find. This can be achieved with RUV, so the technique can eliminate the need for optical testing. However, if discarding defective units is not the sole goal and locating the crack is essential, optical testing off-line can perform this function.

The main difference between RUV and optical methods is that RUV is "listening" to the cracks rather than seeing them. Manufacturers can use both techniques first by listening to the cells and then, as a backup, using infrared or electroluminescent (EL) inspection on any wafers or cells that are rejected or questionable.

A clear strength of optical testing, said Ostapenko, is its ability to get a visualization of the full wafer. However, the drawbacks of using optical testing alone include its inability to see tiny, sealed cracks, or to distinguish between a surface scratch and a true crack. Furthermore, he



Resonance ultrasonic vibration is used to inspect solar cells on the assembly line. Photo courtesy of RUV Systems.

added, EL imaging can be applied only to finished cells and cannot be used on wafers, which don't yet have electrical contacts to which the bias voltage needed for EL would be applied. Similarly, infrared transmission imaging can be used exclusively on bare wafers and cannot be applied to processed material with a nontransparent back contact. The RUV method, on the other hand, is applicable to the entire silicon cell production process, from wafers to finished cells.

When RUV is used in conjunction with optical inspection, the two technologies complement and reinforce one another. Rimas Systems BV is a Dutch manufacturer of solar module manufacturing equipment. At RUV Systems, a company partially owned by Rimas, RUV technology is being implemented in inline production equipment for module, cell and wafer manufacturing. RUV Systems, in cooperation with Ostapenko, also studies RUV in conjunction with optical imaging.

According to Michel van Dooren, plant manager at RUV Systems, RUV technology is "the most reliable for detecting cracks in an in-line situation." He added that optical imaging is best for analyzing the rejects off-line, where there is more time to make the image. Using the two technologies in conjunction helps to reject faulty product from the assembly line and then validate the problem with an image.

anne.fischer@photonics.com

LED market: Looking good

High-brightness LEDs are everywhere. From general lighting to outdoor displays and signage, notebook and television displays, automotive applications and industrial lighting, it's no wonder that the market for them is booming.

According to the 178-page *Quarterly GaN LED Supply Report* released in January by IMS Research of Austin, Texas, demand is likely to grow by 61 percent this year, creating a supply shortage that will not abate until 2013. The report forecasts major growth areas, including display backlights in TVs, notebooks and lighting.

Barry Young, report author, IMS Research senior consultant and founder/managing director of the OLED Association, said, "We're seeing conversion much faster than anyone had anticipated of LCD TVs that used cold cathode fluorescent [CCFL]) backlighting to those that use LEDs." It is this conversion that is driving demand, Young stated.

The report outlines the number of LED dies produced on a quarterly basis, listed by manufacturer. Also included are revenue projections from die makers, a demand forecast, a supply-and-demand forecast and analysis, and a listing of metallorganic chemical vapor deposition (MOCVD) equipment manufacturers. (For more on MOCVD manufacturing, see

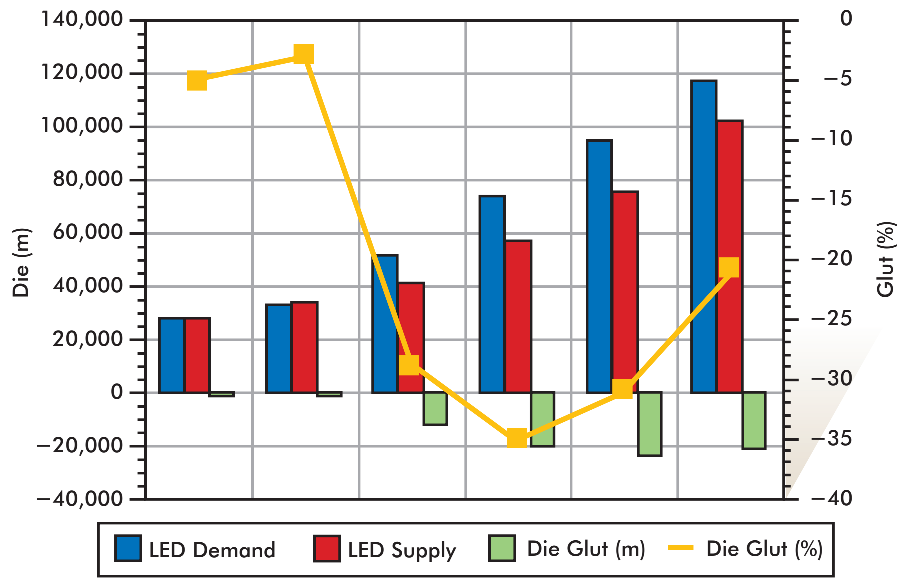
"MOCVD Systems Meet LED Backlight Demand," page 40, March issue.)

On the revenue side, major manufacturers such as Nichia Corp. of Tokushima, Japan, hold a leadership in white LEDs and a 42 percent share of that market. Durham, N.C.-based Cree Inc.'s specialty is general lighting, and its share could grow from 10.6 percent in 2009 to "between 15 and 18 percent," Young said. "We can estimate this because we know Cree will increase capacity two to three times in the next year."

Nichia is the biggest supplier and controls more than 40 percent in terms of revenue, he said. Epistar Corp. of Hsinchu, Taiwan, which was No. 2, traded places with Samsung LED Co. of Suwon, South Korea, formerly No. 3, because of Samsung's strong role in the TV market.

Regional LED production also is listed, with Taiwan at the top, and Japan, Korea, the US, Europe and China holding the next spots, respectively. Although it seems surprising that the US and Europe produce more than China, Young said the reason is that China has more capacity but that production is less efficient. "The yields are significantly lower," he added.

The forecasted LED supply shortage spells opportunity for new manufacturers and toolmakers. What we also are beginning to see, Young noted, is that LCD manufacturers such as Samsung, LG, Sharp and others will become more self-



The shortage of 12 billion to 14 billion binned die is projected to continue into 2013. This will stimulate the MOCVD reactor market, which has a projected demand for nearly 600 reactors this year.

sufficient and will buy less from other suppliers. "They'll have notable second sources but will rely on their own production facilities," he said, adding that the lighting market will begin to mature.

"I would think that, after this sort of change in control in terms of who builds what, we'd start to see a lot more attention given to lighting, and that that area will try to grow." He said it is possible that the market "may exceed our forecasts, supply might be greater, and the excess demand might be met in a different way."

anne.fischer@photonics.com

From tobacco to energy

Tobacco farmers, faced with fewer traditional buyers for their crops, are looking to the solar industry for income. Plants such as tobacco are sunlight collectors with many similarities to solar cells. Now, a group of scientists is trying to take advantage of that collection system to produce inexpensive and biodegradable solar cells.

In a study reported in the January 2010 issue of *Nano Letters*, investigators from the University of California, Berkeley, demonstrated how to program tobacco plants to enhance their sunlight collection system. They genetically engineered a virus called the tobacco mosaic virus and sprayed it over the tobacco plants. This forced the plants to artificially produce lots of chromophores, which form the basis of the collection system and convert photons from sunlight into electrons.

The trick, the scientists found, is that the chromophores must be spaced at a fairly precise distance of about 2 or 3 nm from one another. If the chromophores deviate from this spacing, the electric current is halted, or the electrons are more difficult to harvest. Fortunately, tobacco plant cells are very good at lining up chromophores at this exact distance from each other in a long spiral measuring hundreds of nanometers long. The team was able to exploit this plant structure to grow strands of chromophores.

The researchers were able to extract the chromophore structures when they harvested the plants. After dissolving the structures in a liquid solution, they sprayed the new solution on a glass or plastic substrate to create a solar cell.

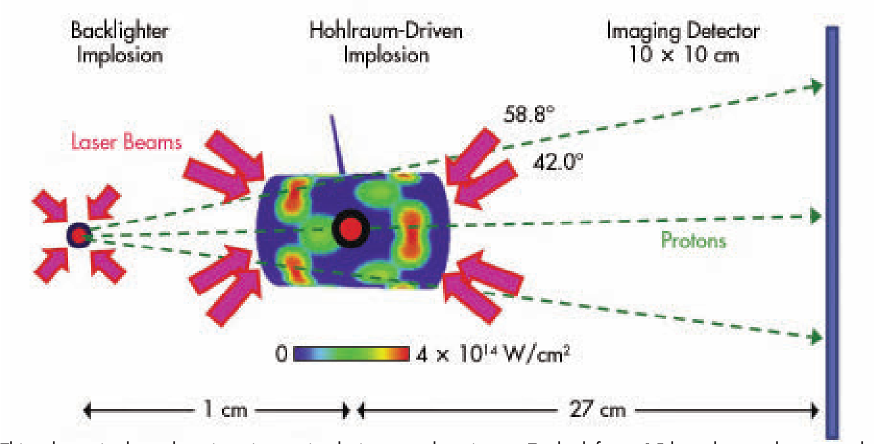
The next step in their work will be to demonstrate that the resulting solar cells can turn light into electrical energy. They also demonstrated how to manipulate *E. coli* bacteria to produce chromophore structures. In this case, instead of using a virus, they modified the bacteria directly.

Compared with traditional solar cells, those made from plants or bacteria have several potential pluses. For instance, they don't require the use of toxic chemicals, they're biodegradable, and they're inexpensive to produce. The downside is that bio-based solar cells likely have a shorter lifetime than silicon ones.

anne.fischer@photonics.com

Scientists from the University of California, Berkeley, demonstrated how to program tobacco plants to make use of their sunlight collection system.

Backlighting fusion



This schematic shows how imaging an implosion was done in test. To the left are 15 laser beams that entered each end of the hohlraum. The proton backlighter was driven by 30 laser beams. As the backlighting protons passed through the laser-driven hohlraum, the plasma conditions and capsule implosions were sampled at various times.

Harnessing fusion energy requires achieving the milestone of fusion ignition in the laboratory. At Lawrence Livermore National Laboratory's National Ignition Facility in Livermore, Calif., researchers are attempting indirect drive inertial fusion, involving a tiny capsule of heavy hydrogen fuel centered inside a hohlraum cavity.

Beams from 192 lasers with nearly 2 million joules of ultraviolet energy in a billionth-of-a-second pulse are directed to the inside walls of the hohlraum, which is heated, generating x-rays that implode the capsule to ignition conditions. Fusing atoms at the center of the capsule cause surrounding atoms to fuse, leading to ignition, a nuclear energy release greater than the laser energy required for the implosion. To achieve ignition, diagnostic tools are needed to see what happens inside the imploding capsule.

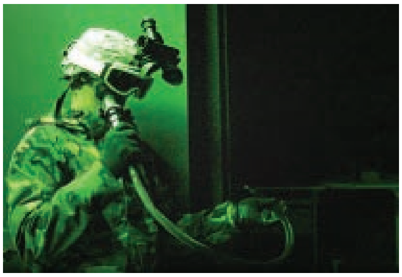
The capsule, containing deuterium-tritium, must be imploded with nearly perfectly spherical symmetry. Theoretical designs constrain the level of symmetry that must be achieved, and researchers are developing a variety of techniques to measure it. A challenge in achieving ignition is that the reactions take place inside a fuel capsule with an initial 2-mm diameter that has been compressed to such a degree that its temperature and pressure become much greater than those at the center of the sun.

A team led by Richard Petrasso, a scientist at MIT's Plasma Science and Fusion Center, developed a fusion backlighting method using charged particles generated in a secondary implosion to probe the hohlraum and capsule dynamics. This technique was tested on the Omega Laser System at the Laboratory for Laser Energetics at the University of Rochester in New York. A capsule filled with deuterium and helium-3 was imploded, producing large numbers of energetic protons with energies of 14.7 and 3.0 MeV.

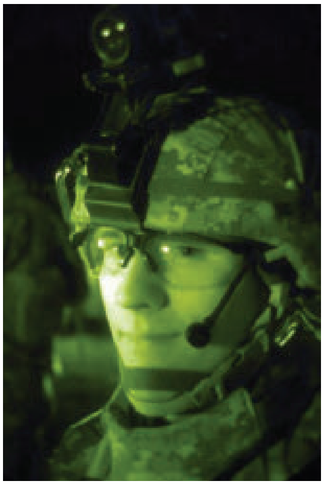
Collaborators from Lawrence Livermore National Laboratory, the Plasma Science and Fusion Center at MIT, the Laboratory for Laser Energetics and General Atomics in San Diego observed an asterisklike pattern in the electric fields within the hohlraum. In the experiment, 30 laser beams with a wavelength of 0.351 µm produced the radiation field in the hohlraum, while another 30 imploded the deuterium and helium gas-filled capsule used for the radiograph. A nuclear track detector recorded the proton images, determining the spatial distribution of the number of protons and their energy. Distribution is affected by the electric and magnetic fields within the capsule, while energy is determined by the amount of material they pass through. By taking an image and changing the timing of the proton sampling (the time when the backlighting protons start to pass through the target), the time evolution of the hohlraum conditions are probed (making a movie). The pattern recorded in the image results from the positioning of the incoming laser beams, but it will require further analysis to fully understand the implications regarding fusion.

anne.fischer@photonics.com

Night-vision light-enhanced photography showing US Army Sgt. 1st Class Arnold Stone, 1st Platoon, Bravo Company, 2nd Battalion, 108th New York Army National Guard, wearing his AN/PSV-7D night-vision goggles while using a handheld radio to call for a situation report. (US Air Force photo by Tech. Sgt. Steve Faulisi, Balad Air Base)



Schott's NightViper optical scope, introduced by the company's Fiber Optics Defense Division in 2008, allows soldiers on night operations to see what's around corners, under doors, in vehicles or through holes in buildings before entering. NightViper, a flexible wound fiber optic bundle 2 to 6 ft long, attaches to standard 18-mm night-vision goggles. (Photo courtesy of Schott)



A close-up night-vision view of a US Army soldier, 1st Battalion, 30th Infantry Regiment, 2nd Brigade Combat Team, 3rd Infantry Division, wearing a Kevlar helmet with night-vision goggles attached. (US Army photo by Spec. Olanrewaju Akinwunmi)

WITH BETTER EYES IN THE SKY AND ON THE GROUND, SOLDIERS SOON WILL SEE THE BATTLEFIELD MORE CLEARLY THAN EVER. THANKS TO SENSOR INNOVATIONS, SCREEN IMPROVEMENTS, FASTER DIGITAL PROCESSING AND OTHER ADVANCES, MILITARY IMAGING SYSTEMS WILL CAPTURE AND REVEAL CRITICAL INFORMATION THAT CANNOT BE CAUGHT OR DISPLAYED TODAY.

BY HANK HOGAN
CONTRIBUTING EDITOR

A US Army soldier from Alpha Company, 1st Battalion, 15th Infantry Regiment, 3rd Heavy Brigade Combat Team, 3rd Infantry Division, uses night-vision goggles to scan for enemy personnel during a nighttime air assault operation in Sayafiya, Iraq, in 2007. (US Army photo by Sgt. Timothy Kingston)

US Army Staff Sgt. Abraham Bitolas, of the 1st Squadron, 2nd Stryker Cavalry Regiment, uses night-vision goggles to provide security at an Iraqi army checkpoint in Ur, Iraq, in 2008. (US Air Force photo by Tech. Sgt. Adrian Cadiz)

US Army Sgt. Jason Weaver from Echo Company, 1st Battalion, 125th Infantry Regiment, Michigan National Guard, scans his sector for insurgents during a night patrol using his night-vision goggles, PVS-14, monocular night-vision device. (US Army photo by Staff Sgt. Bronco Suzuki)

SEEING BETTER TO SHOOT BETTER

An engineer adjusts the Advanced Responsive Tactically Effective Military Imaging Spectrometer, or ARTEMIS, hyperspectral imaging sensor prior to launch aboard the US Air Force's TacSat-3 satellite. Courtesy of Raytheon Co.

Shown below is an artist's rendering of the TacSat-3 satellite, relaying hyperspectral imaging and other data to ground forces for tactical use. Courtesy of US Air Force.

A BETTER EYE IN THE SKY

For military imaging, a space-borne perch offers an overwhelming advantage, said John Silny of Raytheon Co. "You have the highest vantage point, the ultimate high ground, to view from."

Imaging from orbit is changing, as can be seen in the Advanced Responsive Tactically Effective Military Imaging Spectrometer, or ARTEMIS, which was researched and developed by Raytheon's El Segundo-based Space and Airborne Systems Div. Silny is technical director of the project, which currently is flying in a satellite roughly 200 miles above the Earth and which is in the process of moving into an operational phase.

Unlike other space-borne military sensors, ARTEMIS is a hyperspectral imager, capturing 400 bands in the visible through short-wave infrared. This creates a data cube, with ground location forming X and Y, while the spectral response is the third dimension.

This approach trades spatial resolution for spectral detail. Identification of objects is done by looking for a spectral fingerprint. Captured data is compared with results gathered in a lab, with corrections for atmospheric effects.

The technique works, said Lesley Foster, program director for Tier 2 mission solutions at Raytheon. For example, ARTEMIS detected that a field thought to be natural grass was in fact covered by the artificial variety, determining this based upon its spectral signature.

ARTEMIS is intended to supply tactical information, such as the existence of camouflage, disturbed earth or other signs of enemy activity. To do this, it carries an onboard digital signal processor that allows it to deliver data, such as highlighted areas of suspicious activity, within 10 minutes of acquisition.

When, and if, the hyperspectral imager goes into operation, there may be some changes. For one thing, its field of view may be enlarged for a tenfold increase in coverage area. For another, it may be flown with other sensors on a constellation of satellites. Having multiple sensors, some operating at different wavelengths,

A digital night-vision goggle, such as this BAE Systems-developed prototype, will fuse data from various thermal and low-light sensors to improve situational awareness. Courtesy of BAE Systems.

will provide additional imaging opportunities at varying times and from different perspectives. Together, these can allow more information to be extracted.

This, of course, means that the separate data sets will have to be precisely stacked atop one another. That won't be a problem because the image location on the ground is accurately known, Foster said. "As long as your geolocation accuracy is there, then you've got the knowledge you need to fuse the information."

Building a better sight

Just as important as seeing from the high ground is seeing what's right in front of you, particularly if an adversary can't. That's the motivation behind the development of the US Army's next-generation night-vision goggles and weapon sights. It also drives efforts funded by DARPA.

An example of a future goggle comes from global defense firm BAE Systems. The company's prototypes digitally combine video imagery from a low-light-level visible sensor and an uncooled long-wave infrared sensor into a single color display mounted in front of the eye.

Fusing the output of two separate sensors offers advantages, said Scott Tarbox, the Lexington, Mass.-based manager of BAE's Enhanced Night Vision Goggle program. Thermal imaging improves the ability to detect objects hotter than the background, such as people, and makes it possible to see through smoke and other obscurants. Low-light technology enables soldiers to see clearly at night, complementing the lower-resolution thermal image. Using a digital approach allows the signal to be processed for optimal image quality and eliminates the need to combine image streams optically.

Future designs could incorporate higher resolution sensors, but that enhancement must be weighed against size and weight limits. There also could be issues with other constraints, Tarbox said. "When you get larger resolution systems, there is a trade-off with the processing. The more processing you have to do, the more battery life you consume."

Prototypes of the new goggles will be tested this year. Production, which will come as a result of a government Request for Proposal, could start in 2013.

DARPA funds far-out, potentially very advantageous technology that will not go into production for years, if ever. One such program is the Super-Resolution Vision System, portions of which have reportedly been in field tests. The goal is to develop sighting systems that offer better than diffraction-limited imaging in a field device carried by a soldier.

One way this could be accomplished depends upon atmospheric microlensing. Although total images are blurred by turbulence, that same turbulence causes a varying set of individual pixels in every captured image to provide a sharp view. With high-speed imaging and enough processing power, those pixels can be picked out and assembled to yield a clearer image than is otherwise possible.

The hope is that this super vision technology will extend target identification distance, a potentially decisive advantage. Such a capability could reduce friendly-fire incidents and collateral damage.

Microdisplays, which use a chip near the eye to create the virtual image of a much larger screen farther away, are used in military applications to fuse sensors and make the invisible visible. The technology is found in devices worn by soldiers (top right, bottom left) as well as in consumer products (camera and glasses, lower right). Courtesy of Kopin Corp.

Rewritable holograms, such as these, could allow three-dimensional rendering of battlefields and other military command-and-control applications. Courtesy of Nasser Peyghambarian group, University of Arizona.

The eye of the beholder

No matter how advanced the sensor technology, what is captured ultimately must go through the eye. Researchers are working on ways to present increasingly complex information without burdening soldiers unduly.

Nasser Peyghambarian, a professor of optics at the University of Arizona in Tucson, published results a few years ago (see "Coming Attractions: Holographic Movies," *Photonics Spectra*, April 2008, p. 94) about holographic technology that allows scenes to be presented in three dimensions, without the need for special glasses. At the time, it took several minutes to record a scene.

That is too slow for an application such as the depiction of a battlefield or other command-and-control applications, Peyghambarian said. "Video rates may not be needed, but it needs to be pretty fast."

He reported that his group had been working on the problem and should have new results out soon. Although he declined to give exact figures, he did say that these would show fast update times, perhaps fast enough to be useful.

Finally, there are microdisplays that use tiny chips near the eye to create a virtual image with the effect of a regular screen some distance away. In this way, a soldier can effectively carry a high-resolution screen in something the size of a postage stamp.

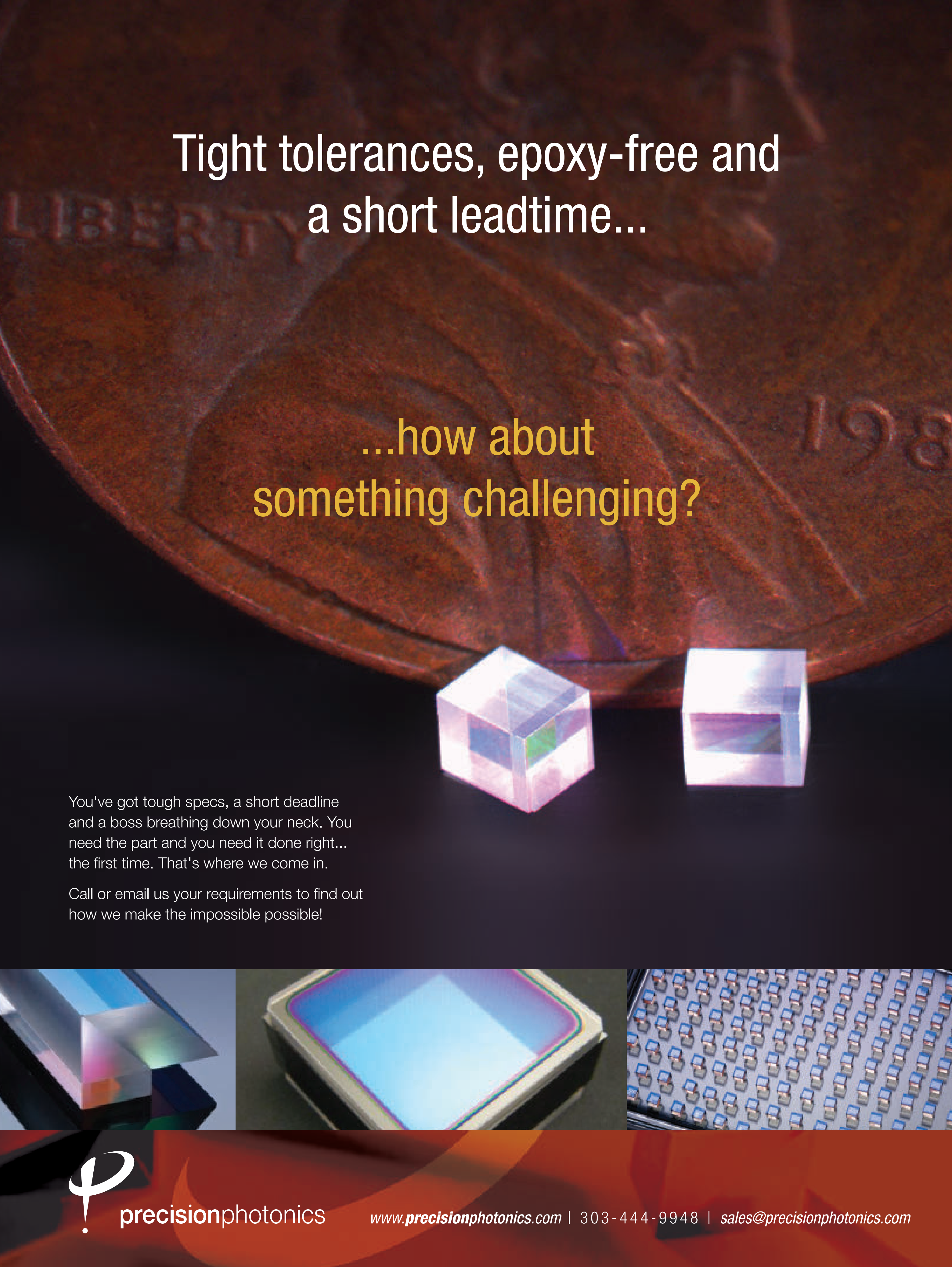
Kopin Corp. of Taunton, Mass., is developing a 2048 × 2048-pixel device for the US military, said to be the world's highest-resolution microdisplay. Antonio V. "Tony" Bacarella, director of business development for the company's visual products group, noted that military applications demand higher imaging system performance than commercial ones. They typically require fewer cosmetic defects, higher contrast and more brightness uniformity.

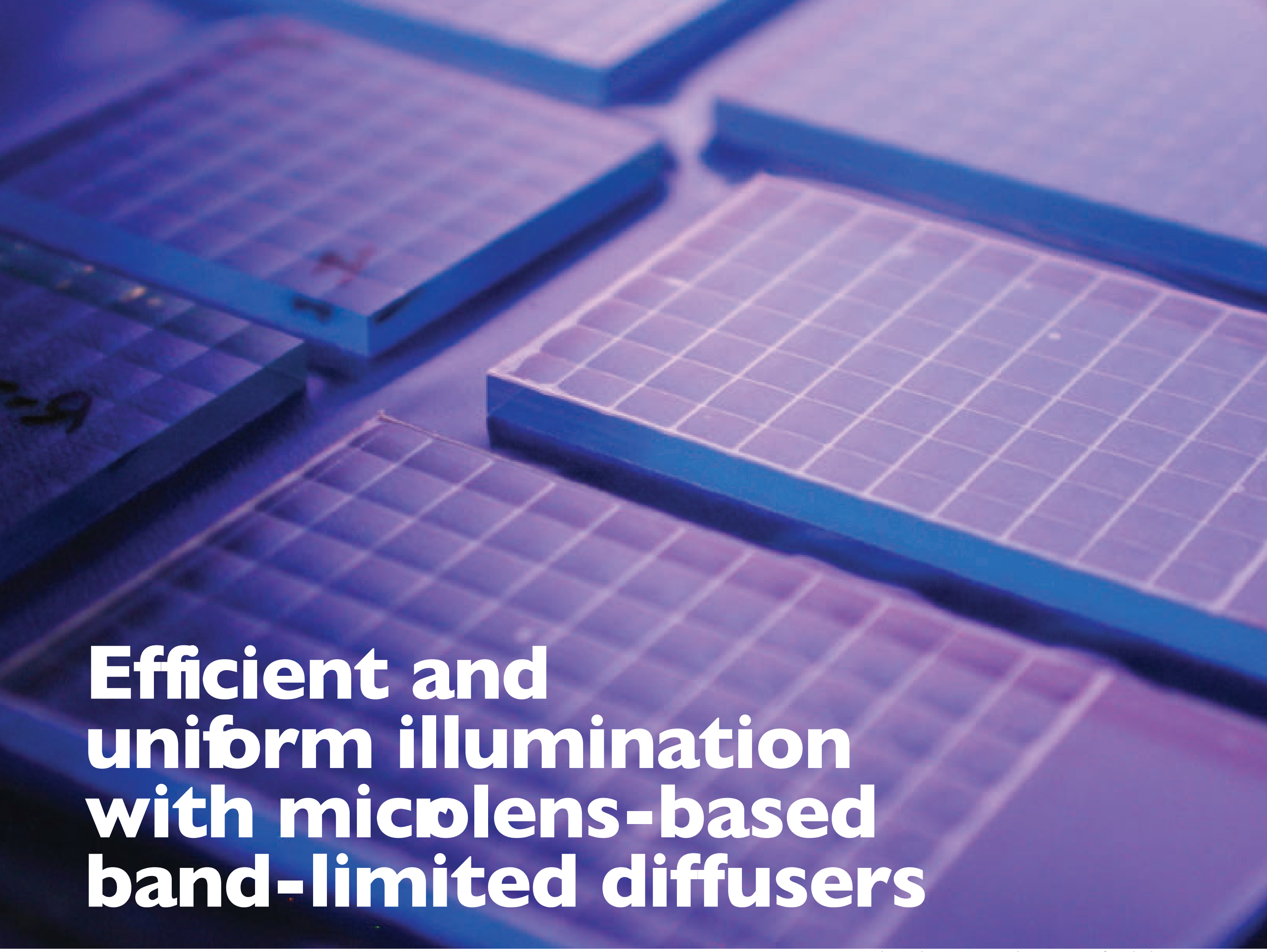
They also must work in extreme cold. For that reason, Kopin uses three methods in its devices to maintain operation at very low temperatures. Two of the techniques, which were developed for commercial digital cameras, are integrated in the display backplane, allowing near-instant-on operation, despite the cold.

As can be seen, the company's military and consumer products do share some technology. Another example is found in the high-resolution microdisplay under development. Its increase in pixel count has been accomplished by a decrease in pixel size, and those smaller pixels are showing up in some commercial products.

Bacarella declined to give specifics about the new technology but did offer a comparison to older products that shows where things are headed. In talking about pixel size, he said, "When you go back a couple of years, the standard was fifteen microns. Now you're looking at pixels that are subnine microns."

hank.hogan@photonics.com


Tight tolerances, epoxy-free and
a short leadtime...
...how about
something challenging?
You've got tough specs, a short deadline and a boss breathing down your neck. You need the part and you need it done right... the first time. That's where we come in.
Call or email us your requirements to find out how we make the impossible possible!
precisionphotonics
www.precisionphotonics.com | 303-444-9948 | sales@precisionphotonics.com



Efficient and uniform illumination with microlens-based band-limited diffusers

Shown here is a microlens array in fused silica.

BY TASSO R.M. SALES
RPC PHOTONICS INC.

Uniform illumination over a certain target area is a common requirement in many applications, and oftentimes schemes must be devised to ensure that this requirement is achieved. In display systems, for example, light that illuminates a viewing interface such as a screen must appear uniform and devoid of any distracting image artifacts. Depending on the particularities of the system, different approaches must be developed to provide uniform illumination without sacrificing efficiency.

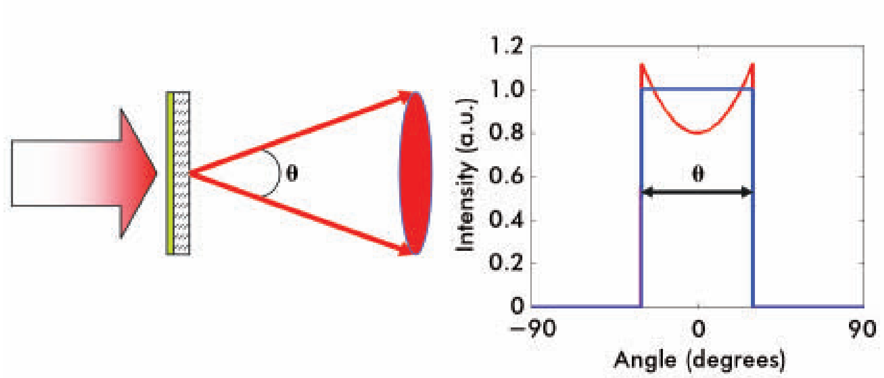
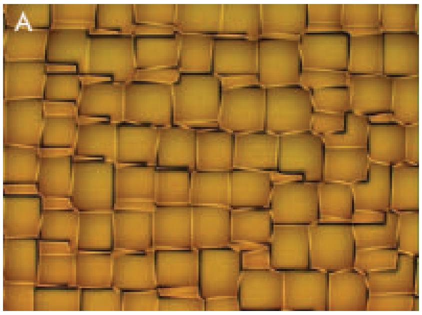


Figure 1. In an ideal band-limited diffuser, all light is scattered within a certain angular range, θ.

Side-illuminated backlit displays use painted dots and microstructures to extract guided light in a controlled fashion so that the display is visually uniform; lithographic illumination systems often use fly's eye microlens arrays to generate uniform illumination, sometimes in combination with additional diffusers and/or motion to minimize the diffraction artifacts induced by the periodic lens arrays; laser displays make use of optical diffusers for shaping and uniform light distribution as well as speckle management; general lighting has routinely relied on simple diffusers and prismatic films that, although not the most efficient or aesthetically pleasing, are inexpensive and commonly found in light fixtures.

A frequent approach to uniformly illuminating a target uses a diffusing element in the optical path to spread and homogenize the incident illumination and provide the desired degree of uniformity. The requirements for the diffuser, or diffusers, depend upon a number of factors, such as the source properties (primarily spectrum, divergence and coherence), as well as on the performance goals, which depend



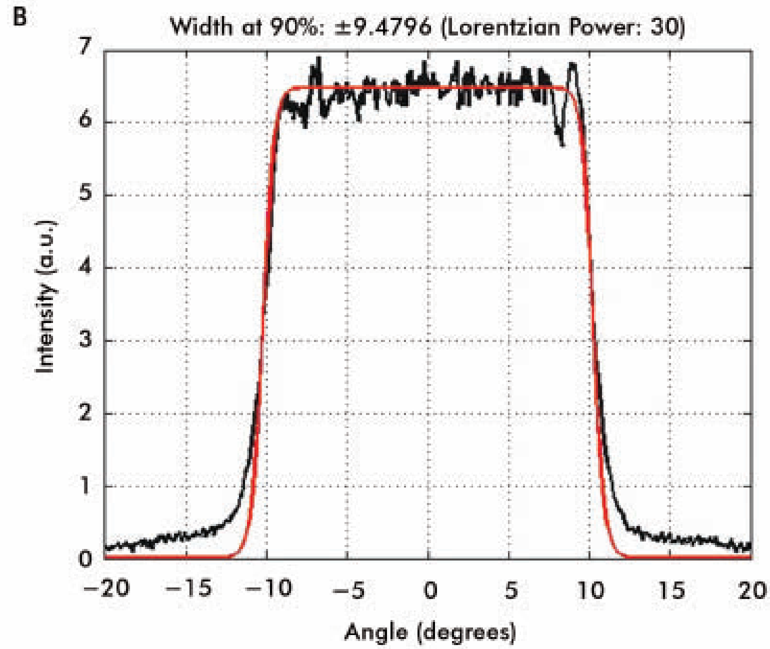


Figure 2. Shown is the surface pattern of a diffuser that generates a square pattern (A) and its measured intensity profile (B).

strongly upon the application. We are particularly concerned with applications that require some sort of light shaping, either in intensity or distribution. For this type of application, optical performance is critical, and only a handful of diffuser technologies can be brought to bear.

Among the available options, band-limited diffusers are unique because of their highly desirable qualities and good performance. Band-limited diffusers are defined as diffusers that scatter light within a well-defined angular range, usually – but not necessarily – with uniform intensity. An ideal band-limited diffuser attains 100 percent of the diffuse light within its band limit; in practice, however, it has been difficult to come close to this goal for a variety of reasons. Here we will review issues related to common diffuser technologies, typical performance associated with the technology and its precision in comparison with the band-limited ideal. We will also discuss recent advancements in microlens diffusers engineered to attain nearly band-limited performance.

Band-limited diffusers

The concept of a band-limited function is best known in the framework of linear systems theory, particularly with regard to signal recovery from sampled data[1] where band-limited functions have interesting properties. A band-limited function has nonzero values only within a finite domain. Outside of this domain, the function is identically zero. In the context of diffusers, the concept applies directly so that in the far field, or at the focal plane of a lens, the diffuse light is confined to a certain angular range with little or, ideally, no energy outside of that range.

Figure 1 illustrates an ideal band-limited diffuser in the geometrical optics limit where all of the incident illumination is contained within a cone angle θ. Both blue and red curves represent band-limited diffusers. The case of uniform illumination

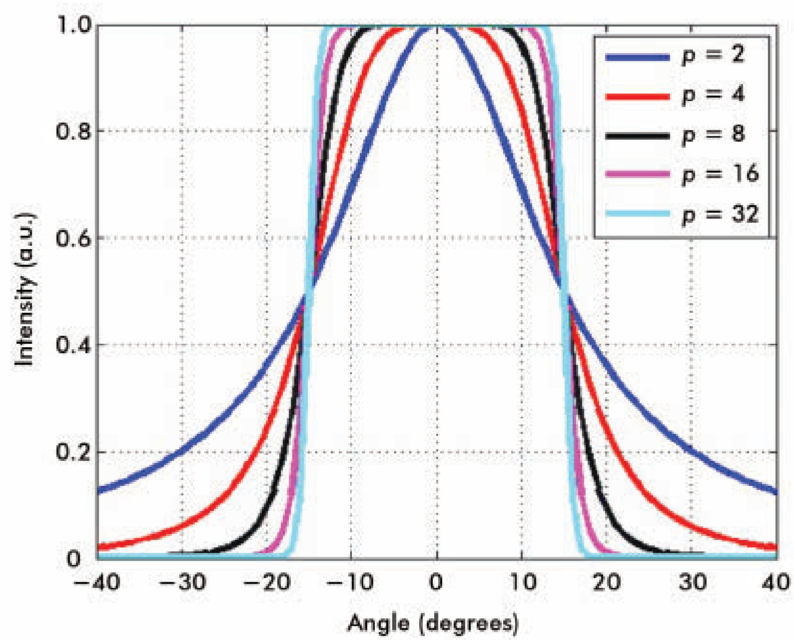


Figure 3. Shown are super-Lorentzian curves for $\theta_0 = 15°$ and various power values.

(blue curve), however, plays a particularly important role in many applications, and for this reason, we will focus on uniform band-limited diffusers.

Evidently, the geometrical limit is only an approximation, and, because of diffraction, the intensity fall-off at the edges of the intensity profile always has a finite extent. This depends on the nature of the surface features that define the diffuser, assuming that the incident illumination is collimated. In any case, the concept of a band-limited diffuser is simply extended to include the intensity fall-off so that, in the best possible scenario, the fall-off is limited only by diffraction.

Given the importance of uniform illumination, it is no surprise that band-limited diffusers have been the focus of continual, if sporadic, investigation. Significant

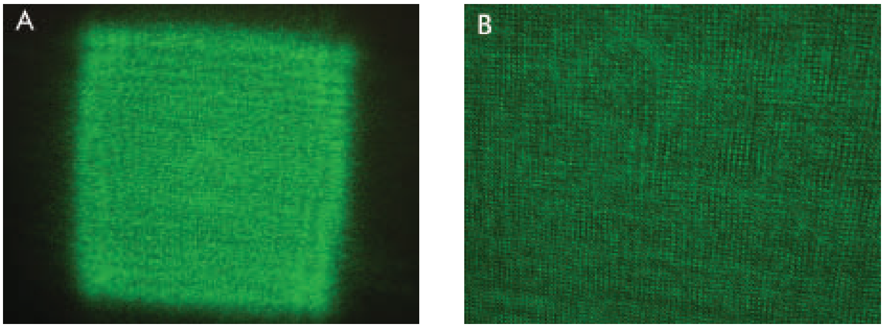


Figure 4. The scatter pattern from a diffuser that shapes a laser beam into a square pattern is pictured. The diffuser surface has some underlying periodicity that shows up as diffracting artifacts such as lines (A) and, on a finer scale, dots (B) with apparent local periodicity.

advances in the understanding of the fundamental properties of band-limited diffusers seem to have started in the early 1970s, and research continues to this day. During this period, however, the goal of producing a band-limited diffuser has remained elusive.

Existing solutions

One of the earliest attempts at implementing a band-limited diffuser was the diffractive diffuser, which can create very uniform diffuse patterns with general distributions. However, it is intrinsic to diffractive elements that a certain fraction of the incident illumination spills into diffraction orders beyond the target region of interest. In the case of binary elements, at least 20 percent of the light is lost to higher diffraction orders. If the diffuser is produced with a continuous-phase function, the losses become much lower, but even in this case, typically at least 5 to 10 percent is lost to higher diffraction orders (Note that these figures do not include Fresnel losses). We can therefore say that, although a diffractive diffuser can provide uniform illumination, it is not band-limited, with the continuous-phase element coming very close.

A limiting issue with diffractive diffusers, however, is that they are often restricted to monochromatic illumination and relatively small spread angles, unless one can deal with a strong zero order, a bright center spot collinear with the incident illumination. Because of deviation from the design wavelength or fabrication errors, diffractive elements commonly display the presence of a zero diffraction order that is much stronger than any other order in the diffraction pattern, and may or may not be eliminated in practice.

Refractive diffusers, on the other hand, are fundamentally free of the intrinsic losses associated with high-order diffraction and zero order, and are thus the best candidates for band-limited behavior. Simple examples of refractive diffusers include ground glass and holographic diffusers created by exposing photosensitive materials to laser speckle. These diffusers have been around for quite some time but generate Gaussian scatter and therefore do not have a uniform scatter region or well-defined cutoff for the diffuse light and are thus not band-limited. Just a few decades ago, researchers at Kodak would comment[2] that "no known random phase diffuser is band-limited." This includes diffractive diffusers, which, strictly speaking, are not random, and holographic diffusers, which are obviously not band-limited.

Since the early work at Kodak and elsewhere, not much had happened until recently, when microlens-based diffusers became commercially available.[3] Alternative concepts also have been proposed[4] such as a distribution of linear facets that are randomly combined to spread light over a specific angular range. Each facet scatters into a specific direction; by imposing an upper limit to the slope angles in the ensemble, one can theoretically guarantee band-limited behavior. By further ensuring the appropriate distribution of facets over the angular range of interest, one can produce uniform illumination.

The approach does provide, at least in principle, band-limited behavior, and some experimental demonstration can be found in the literature.[5] However, because each linear facet corresponds to a specific angular direction, this type of diffuser would seem to require a large input beam size to sample a sufficiently large number of facets so that uniform illumination could result over some specified angular range. Making the linear facets small minimizes the requirements for a large beam but runs into manufacturing issues.

Microlens-based engineered diffusers

Microlens arrays are used in a great

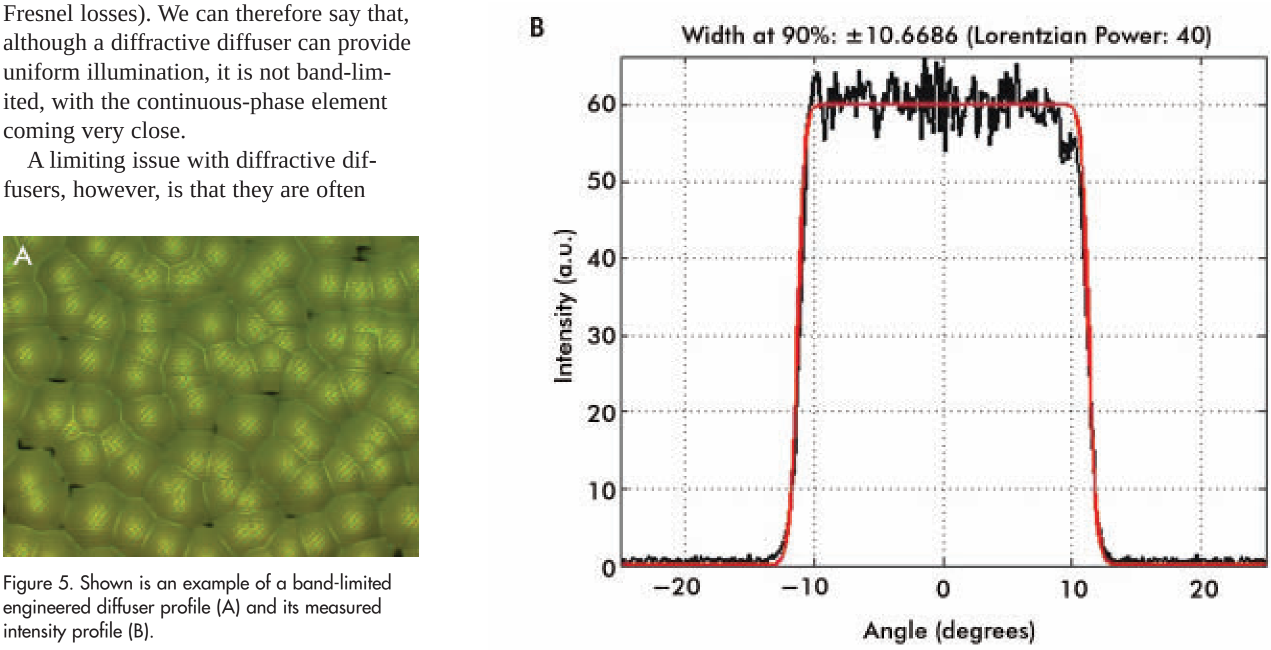


Figure 5. Shown is an example of a band-limited engineered diffuser profile (A) and its measured intensity profile (B).

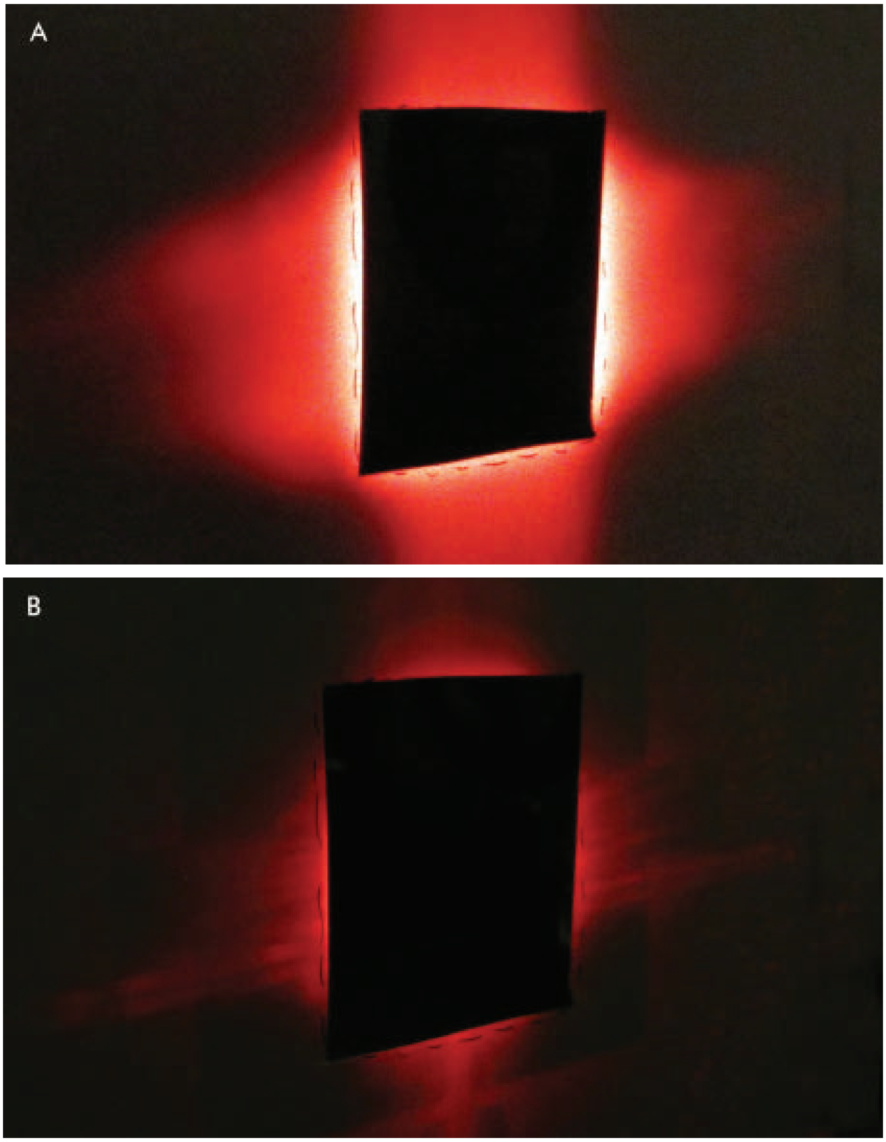


Figure 6. A typical engineered diffuser produces a square pattern (A), whereas a band-limited engineered diffuser shows considerably less light loss outside the square pattern (B).

number of applications, and in certain instances, they are also used for beam shaping and diffusion. However, because microlens arrays are periodic, there is a limitation in the achievable shaping capabilities as well as in the diffraction effects that result from the regular arrangement of the microlenses. The microlens element itself, however, provides a basic component from which general band-limited diffusers can be built.

In recent years, we have introduced a class of microlens-based diffusers[3] – also referred to as engineered diffusers – that provide not only homogenization but also general shaping capabilities. Each microlens unit in an engineered diffuser is defined by a certain number of parameters, such as a radius of curvature and a conic constant that are randomized to create the diffuser. Unlike common diffusers, however, engineered diffusers are created deterministically, such that each microlens element is individually designed and fabricated to produce a certain scatter pattern with a controlled intensity profile.

The design concept behind engineered diffusers can be described in simple terms. The prescription for the set of lenses that comprise the diffuser is defined, including feature sizes and slope angles based on the scatter requirements. These parameters are typically defined in terms of probability distribution functions that specify the likelihood that a certain lens will assume a specific prescription. The next step is the spatial distribution of the microlenses to create the diffuser surface structure according to probability distribution functions. An example of a commercially available engineered diffuser that shapes an incident beam into a 20° square pattern is shown in Figure 2.

The intensity profile (Figure 2B,) was measured in the far field with a detector large enough to average enough speckles and reveal the envelope of the intensity distribution. The intensity profile can be described by a Lorentzian profile – the red curve in Figure 2B – given by

$$I(\theta) = \frac{I_0}{1 + \left(\frac{\theta}{\theta_0}\right)^p}$$

where I_0 is a constant, $2\theta_0$ is the full width half maximum, and p is a number directly related to the flatness of the intensity profile. For the plot shown in Figure 2, $p = 30$ and $\theta_0 = 11.5°$. For $p = 2$, one finds the usual Lorentzian function. For $p > 2$, the function is sometimes referred to as a "super-Lorentzian" with power p. The parameter p provides an indication of the flatness, or uniformity, of the super-Lorentzian intensity profile, Figure 2. The larger the parameter p, the flatter will be the intensity profile and the narrower the fall-off region. For uniform diffusers, the steepness of the fall-off depends directly on the microlens feature size. For the diffuser shown in Figure 2, the lens feature sizes are ≤160 µm.

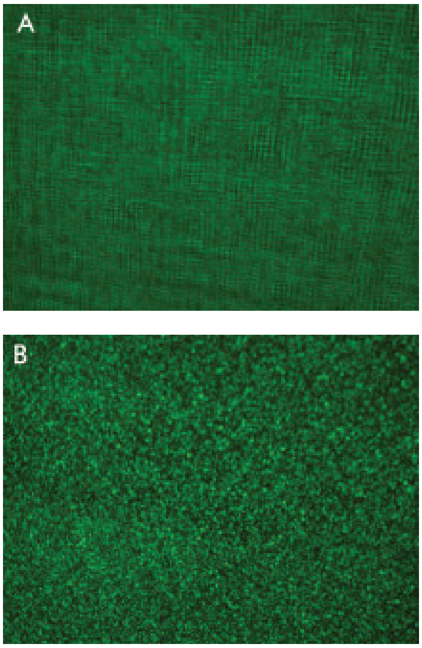


Figure 7. Shown is a speckle comparison of a standard (A) and a band-limited (B) engineered diffuser.

Two items are readily noticeable from Figure 2. First, although the surface pattern on Figure 2B is clearly not regular, an underlying grid pattern seems apparent. Secondly, the super-Lorentzian fit matches nicely the flat portion of the intensity profile but not the bottom portion, toward wider angles. The effect of an underlying grid in the diffuser surface reveals itself in the diffuse pattern as diffraction artifacts that are particularly obvious with coherent sources such as lasers. A small illuminating beam size further emphasizes the nonuniformity. Examples of these artifacts are seen in Figure 4. As the beam size increases, the visibility of these artifacts is reduced but not completely eliminated.

The mismatch in the wide-angle fit, Figure 2B, is caused by scatter losses due to light falling outside the target. These losses originate from steep slopes between adjoining lenses. Each lens has a unique surface prescription that is generally distinct from another lens.

Consequently, the boundary between lenses generally contains discontinuities that spread light into wide angles outside the target and lead to the observed deviation from the super-Lorentzian fit. It clearly also reduces the system efficiency.

Estimates place the amount of lost light to wide-angle scatter at approximately 10 to 15 percent, depending on the diffuser design, feature sizes and conditions of fabrication.

Band-limited engineered diffusers

Recent improvements in design and fabrication techniques have led us to develop a diffuser concept that considerably advances the state of the art in the production of microlens-based diffusers. At the root of these improvements is the effort to eliminate any underlying periodicity in the spatial distribution of the microlenses and to eliminate lens mismatches that lead to wide-angle scatter, thus maximizing the use of available light.

The measured performance of this new class of diffusers comes much closer to the band-limited ideal without the presence of diffraction or image artifacts, which should be particularly significant not only for coherent illumination but also for incoherent illumination such as LEDs, because of the higher efficiency. An illustration of the surface structure of this band-limited engineered diffuser is shown in Figure 5.

The intensity profile shown in Figure 5B indicates much improved super-Lorentzian behavior over the entire range of angles with $p = 40$ and lens feature sizes $\leq$160 µm. To further illustrate the higher efficiency of the band-limited engineered diffuser, Figure 6 shows a visual comparison of the light scattered outside of the target, where it seems clear that the new generation of diffusers significantly increases the utilization of light.

Finally, the careful randomization of the diffuser surface structure also creates a scatter distribution that is devoid of artifacts. In the case of coherent illumination, it gives rise to the typical uniformly random speckle pattern expected from random diffusers, as illustrated in Figure 7. For reference and side-by-side comparison, 4B is repeated in 7B.

It is now nearly half a century since the first significant efforts started in the understanding and fabrication of band-limited diffusers. Since then, we have developed a better understanding of the theoretical requirements for band-limited diffusers. The relatively recent introduction of microlens-based diffusers, in the form of engineered diffusers, came a step closer to the band-limited ideal, although they are not perfect.

The new generation of microlens diffusers that is now being unveiled, as described here, brings the band-limited diffuser idea from a purely conceptual realm into the real world.

Meet the author

Tasso R.M. Sales is chief technology officer at RPC Photonics Inc. in Rochester, N.Y. He can be reached at tasso@rpcphotonics.com.

References

1. J.W. Goodman (1996). *Introduction to Fourier Optics*, 2nd ed. McGraw-Hill, New York.
2. C.N. Kurtz, H.O. Hoadley and J.J. DePalma (1973). Design and synthesis of random phase diffusers. *J Opt Soc Am*, pp. 1080-1092.
3. www.rpcphotonics.com and www.thorlabs.com.
4. E.R. Méndez et al (2004). Design of two-dimensional random surfaces with specified scattering properties. *Opt Lett*, pp. 2917-2919.
5. E.R. Méndez et al (2001). Photofabrication of random achromatic optical diffusers for uniform illumination. *Appl Opt*, pp. 1098-1108.

Advantages of Polymer and Hybrid Glass-Polymer Optics

Figure 1. Qioptiq Polymer Inc. offers a variety of precision polymer optical components. Images courtesy of Qioptiq Polymer Inc.

BY VALENTINA DOUSHKINA
QIOPTIQ POLYMER INC.

Polymer materials with optical properties are being thrust into the design forefront for new, sophisticated electro-optical applications, enabling commercial markets and applications including medical disposables, bar-code scan/recognition, security and fingerprint scanners, motion and presence sensors, CCD cameras and laser collimation. Current advancements in polymer technology and injection molding capabilities have increased the manufacturability and precision of polymer optics.

Designing and manufacturing optics and optical systems using polymers alone or hybrid polymer-glass applications provide complete custom capability and offer new optical and optomechanical solutions for a variety of applications. Integrated mounting provides configuration flexibility, design freedom, and simplified optical alignment, mechanical design, assembly and packaging. A system can be assembled and aligned in a single manufacturing step.[1]

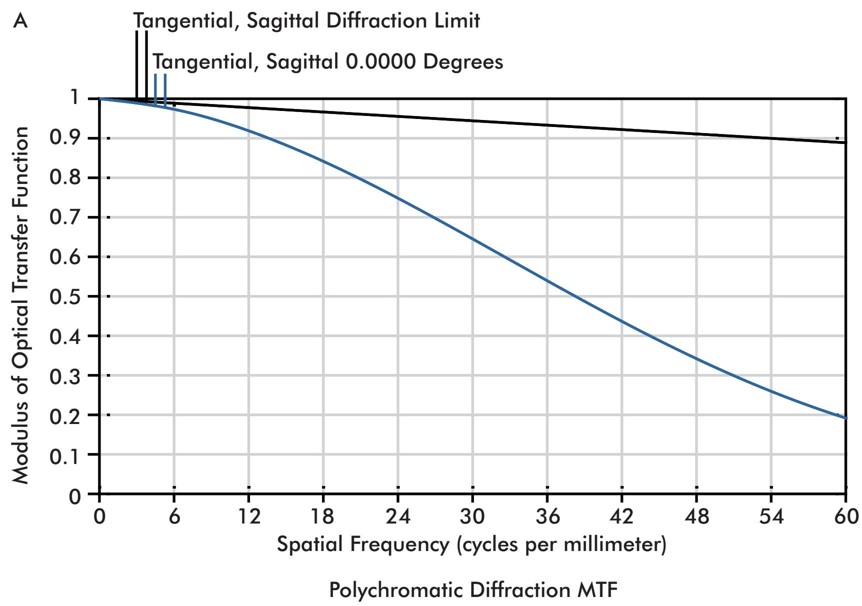
Polymer optics: Why and where

In many optical products and applications, traditional optical glass has been successfully replaced with optical-grade polymers. The main reasons that polymer optics are chosen for a variety of devices, applications and markets are the low cost of materials and the fabrication techniques, which offer high production volume with high precision and fast repeatability.

Among other advantages is high impact resistance: Polymers do not split like glass, making this type of optics highly useful in terms of durability and cost efficiency in applications such as head-up displays, goggles, and medical and biomedical disposable optics. The modern days of nanotechnology are known for our fascination with compact customer products; e.g., mobile phones, cameras and microprojectors that can be about the size of a credit card, offering low weight, affordability, multifunctionality and long-lasting battery charge.

Thanks to their low density or low weight by volume, polymers are well adapted for making cutting-edge-technology products lighter and smaller. Polymers are between two and a half and five times lighter than comparable glass products[2] and are suitable for difficult and sophisticated refractive, reflective and diffractive substrates with spherical, aspherical and cylindrical prescriptions, thus reducing the number of optical components needed in a given optical system. Molding is the most repeatable, consistent and economical way to produce complex-shaped optics in large volume or to integrate them onto a common substrate. Optical-grade polymers exhibit high light transmittance and are comparable to high-grade crown glasses. The optical-grade polymer market is growing rapidly; new polymers with low birefringence as well as higher and more stable refractive indices are available, offering design flexibility not possible with glass optics on their own.

Grinding and polishing of glass optics is costly and time-consuming, whereas injection or compression molding of precision polymer optics is inexpensive and offers design capability and flexibility. Mounting features can be integrated with optical components, simplifying the assembly and resulting in a compact product and reduced price. A comparison of the design requirements, manufacturing lead time, tolerances of finished products and production cost between glass and equivalent



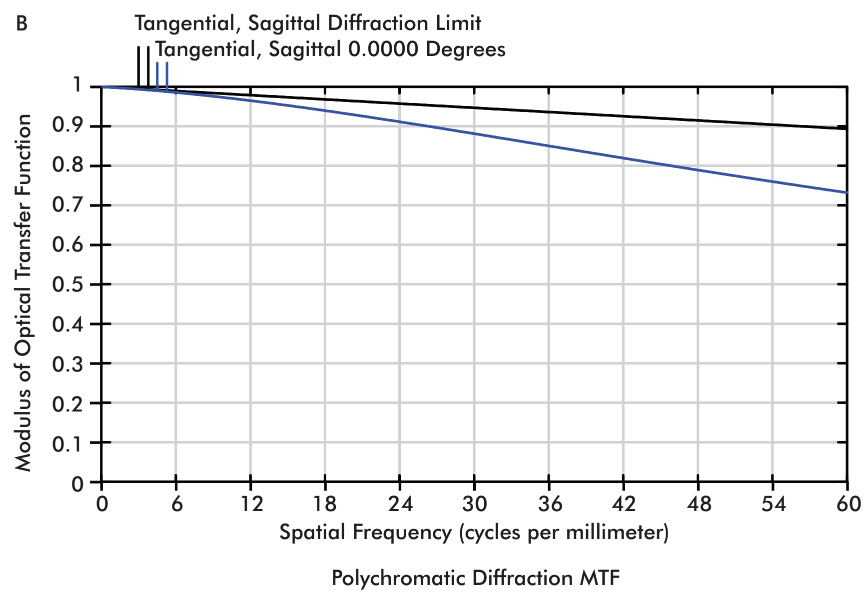


Figure 2. The off-the-shelf glass doublet was analyzed via modeling for thermal stability. Image (A) shows the polychromatic diffraction MTF of the glass doublet at 0 °C, and (B) shows the same glass doublet at 70 °C.

polymers in many applications shows the superiority of polymers.

To utilize polymers, the optical designer must have a solid understanding of the injection molding process and know how to design optics with polymers. Having the molding manufacturing company involved in product design at an early stage is beneficial for cost-effective manufacturing of high-performance optics.

Several diamond-turned and/or injection-molded precision polymer optical components manufactured at Qioptiq Polymer Inc. are shown in Figure 1.

Advantages of hybrid optics

In glass-polymer hybrids, a fairly thin layer of asupherized optical polymer is added to a conventional spherical glass lens. Most optical-grade polymers have great transmission – comparable to crown glass – so the overall transmission of the hybrid is comparable to that of glass optics. The advantage of hybrids is the freedom of glass selection because the glass component is manufactured conventionally.

Glass-polymer hybrids are widely used in advanced optical systems, making some applications feasible by reducing component weight, lowering production cost and enhancing the safety and appeal of products. Applications range from consumer photographic zoom lenses to professional fast-zoom lenses.

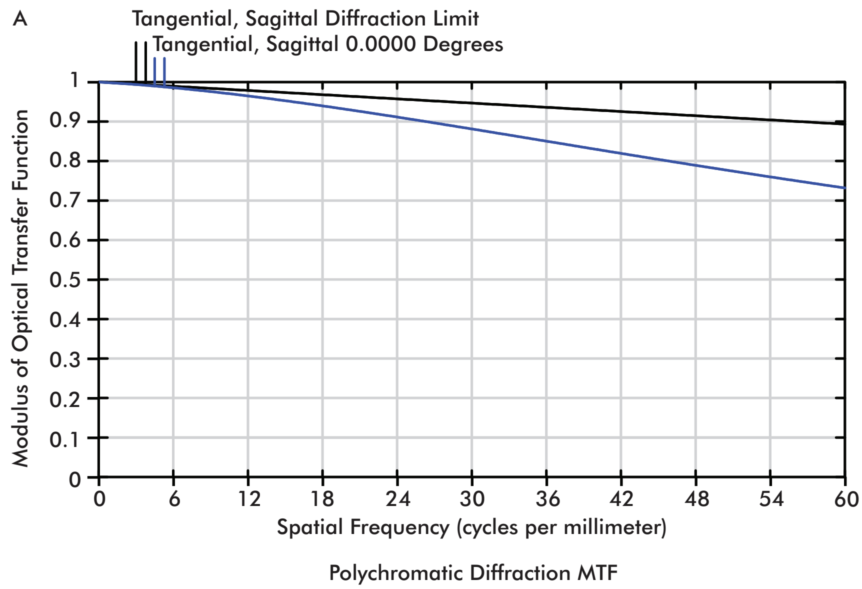
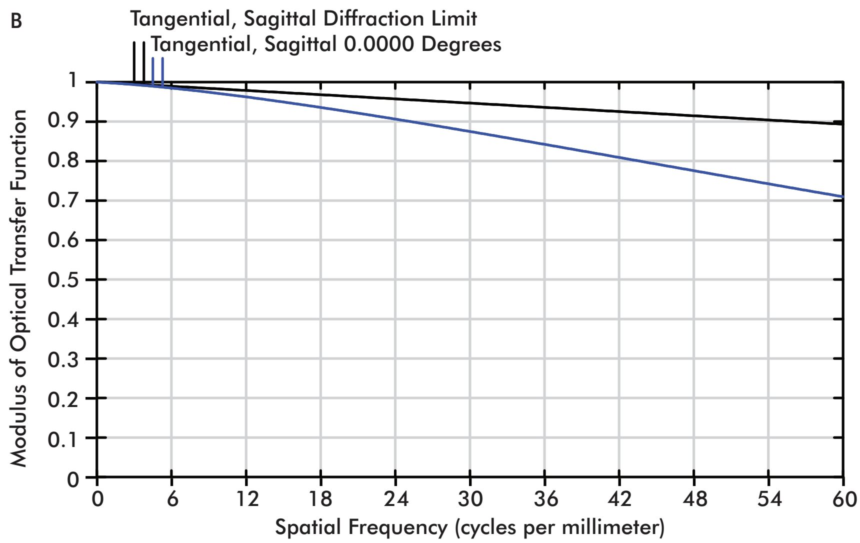


Figure 3. The polychromatic diffraction MTF of the hybrid was analyzed at 0 °C and (b) at 70 °C.

The properties of glass and polymers complement one other; for example, a nonhydroscopic glass component facing the outer environment protects the inner asupherized polymer component of a hybrid, while the latter offers a large numeri-



Polychromatic Diffraction MTF

cal aperture, wide-field angles, a diffraction-limited highly resolved image and a compact design with a minimal number of optical components.

Another advantage is that they have the thermal stability of glass and the low manufacturing cost of polymer-molded optics. When the glass component carries the optical power and the thin layer of the aspherized polymer component corrects for aberrations, the thermal behavior of the hybrids is as stable as that of glass optics – or even better: Optical glass has a positive dn/dt, while the optical polymers have a negative dn/dt, enhancing the thermal stability of a glass-polymer hybrid. The refractive index of optical glass or polymer changes with the temperature; dn/dt is the temperature coefficient of the refractive index defined from the curve showing the relationship between glass temperature and refractive index. The temperature coefficient of refractive index (for light of a given wavelength) changes with wavelength and temperature.[3]

An off-the-shelf catalog lens was modeled as an aspherized glass-polymer hybrid and analyzed for image quality and thermal stability. The sharpness of an imaging system or of a component of the system is characterized by a parameter called modulation transfer function (MTF), or spatial frequency response. The polychromatic diffraction MTF of the glass doublet alone is shown in Figure 2a and is 20 percent for 60 cycles per millimeter, while the aspherized hybrid shown exhibits 82 percent MTF for 60 cycles per millimeter (Figure 2B). This is an economical way to create a high-performance diffraction-limited lens.

The off-the-shelf glass doublet was analyzed via modeling for thermal stability; the results are shown in Figures 3A and B. The polychromatic diffraction MTF variation within the temperature range from 0 to 70 °C is about 10 percent.

The modeled aspherized glass-polymer hybrid also was analyzed for thermal stability. The polychromatic diffraction MTF of the hybrid is shown in Figures 4A and B. The variation of the MTF within the temperature range from 0 to 70 °C is only 1 percent, compared with that of the glass doublet, which was 10 percent.

Typical optical polymers

Acrylic (polymethylmethacrylate, or PMMA) is the most commonly used polymer. It has good clarity and high transmittance in the visible, whereas polystyrene is a good achromatic pair with acrylic. Polycarbonate is similar to polystyrene and has high impact strength and good performance over broad temperatures – up to 120 °C. Polymers have a tendency to absorb water, which can significantly alter some of their key properties. Those containing only hydrogen and carbon (polyethylene and polystyrene) are nonhydroscopic (highly water resistant), whereas polymers having oxygen or oxyhydrogen groups are hydroscopic.

Zeonex/Zeonor – cyclo olefin polymer – has much lower water absorption, high transparency and purity, good moldability, low birefringence (one-third of polycarbonate), high heat resistance – 100 to 160 °C – and good chemical resistance to acids, bases, alcohols and fragrances.

Ultem PolyEtherImide, an amber transparent high-performance polymer, combines high strength and rigidity at elevated temperatures with long-term heat resistance. It excels in reusable medical applications requiring repeated sterilization and is available in FDA-compliant colors. OKP4 has a high refractive index of 1.6 or more and has extremely low birefringence and high fluidity.[2]

Innovative hybrid glass-polymer optical solutions on a component or module level offer the thermal stability of glass with the low manufacturing cost of polymers as well as enhanced optical performance and a reduced number of components. The latter characteristics are not achievable when polymer or glass optics are used on their own.

Meet the author

Valentina Doushkina, MSc, is director of engineering at Qioptiq Polymer Inc. in La Verne, Calif.; e-mail: valentina.doushkina@ca.qioptiq.com.

References

1. V. Doushkina and E. Fleming (2009). Optical and mechanical design advantages using polymer optics, *Proc SPIE*, Vol. 7424, 74240Q.
2. IDES Prospector. http://www.ides.com.
3. http://www.oharacorp.com.

Quantum Dots

Are Finding Their Place in the World

BY LYNN SAVAGE, FEATURES EDITOR

There has been a panoply of research into the next big thing in quantum dots – those semiconducting artificial atoms that are ubiquitous in fluorescence imaging, biological and chemical sensing, and display applications. Quantum dots of more (or less) exotic materials and with more (or less) interesting shapes are demonstrated on almost a weekly basis. It is the heyday for the field. But getting less attention are the practical issues of handling quantum dots in such a way that their functionality can be maximized and their use more broadly commercialized.

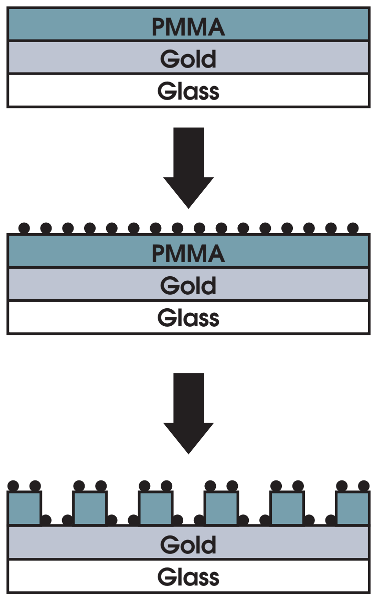
What follows is a look at some important steps in that direction.

Dropping through the grate

Negative-refractive-index materials, superlenses and Raman scattering-based spectroscopy are just a few applications that have come about – or that have been improved – through research developments involving surface plasmons. Quasiparticles analogous to photons, surface plasmons are the faint residue of electronic oscillations that occur naturally at the interface between metal and dielectric materials, such as silver and air, respectively. Integrate photons into the situation, and you obtain surface plasmon polaritons, another form of energetic quasiparticle that moves across the metal surface until reabsorbed or radiated away.

One way to improve the signal quality in a sensor is to use surface plasmon polaritons to enhance the fluorescence signal of nearby dye particles. For example, using a metallic surface rather than glass can improve the emission intensity of a fluorescent dye by as much as 20 times, perhaps more. Furthermore, if the metal surface is grated, more enhancement can be coaxed from the system because the coupling of photons to surface plasmons is boosted.

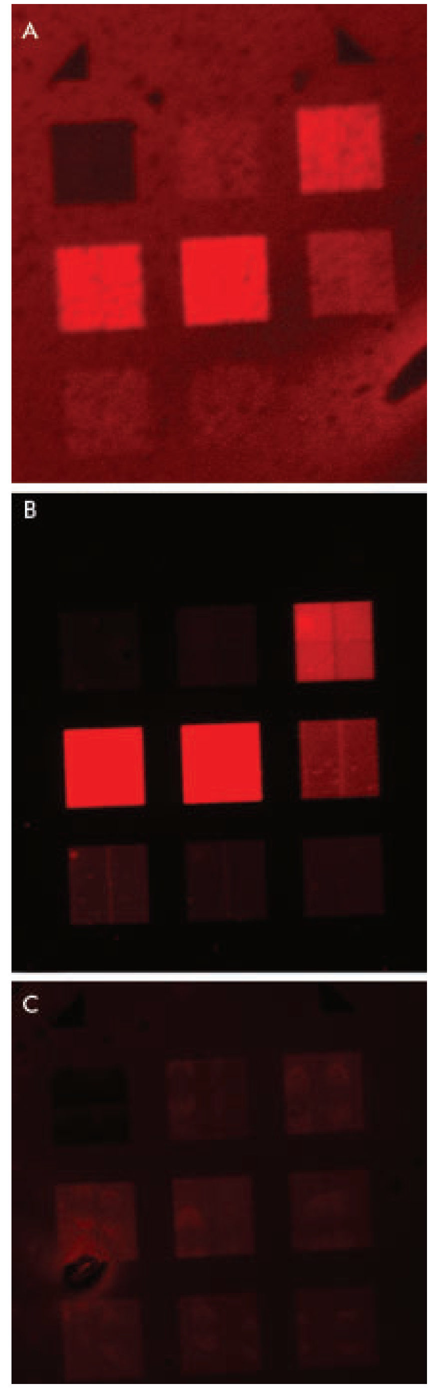
To further increase the applicability of fluorescence enhancement to sensor technology is to use quantum dots instead of dyes. Quantum dots have several advantages over fluorescent dyes, including size-dependent emission spectra, wide absorption bands, insusceptibility to photobleaching and higher quantum yields.



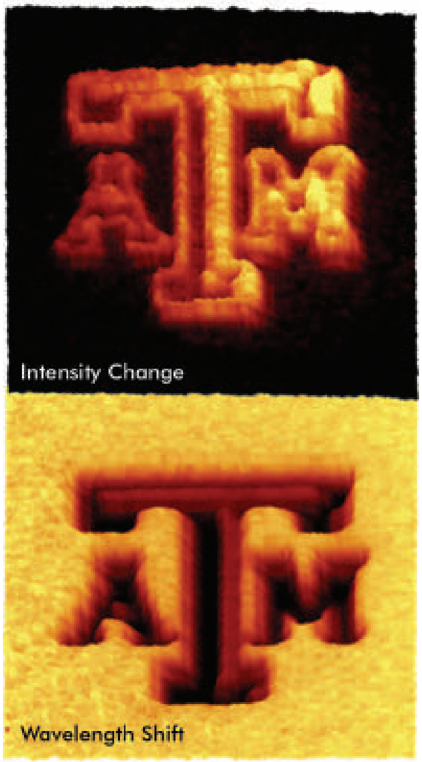
Coating a PMMA-gold-glass system with quantum dots before etching a grating pattern into the PMMA material makes possible novel ways to increase the sensitivity of biosensors based on the interactions of surface plasmon and light. Reprinted with permission of the American Chemical Society.

"In our work, we were able to take advantage of several of the special properties of quantum dots relative to traditional fluorescent dyes," said Ehren Hwang of the University of Maryland, College Park. "The broadband absorption allowed us to use a pump wavelength widely separated from the quantum dot emission wavelength during the earlier phases of [our] experiment. We also were able to take advantage of the intrinsic resistance of quantum dots to photobleaching, [which] allowed us to interrogate our samples for extended periods of time – several hours – with repeated use over the course of months."

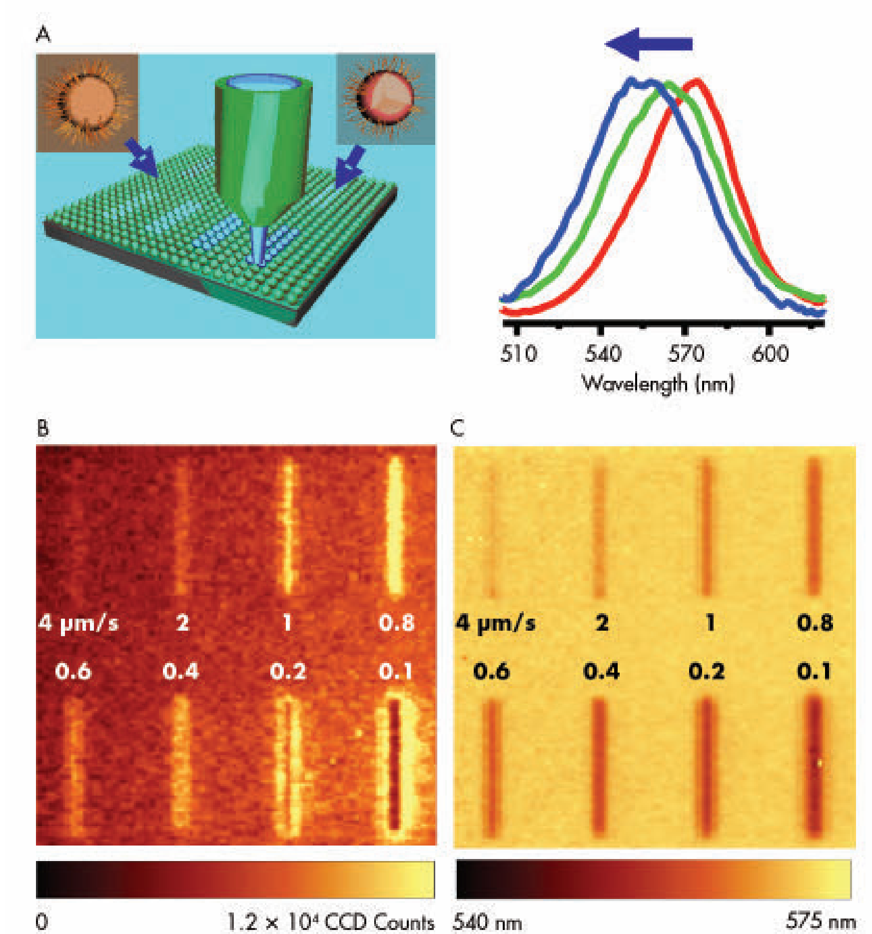
Hwang, his adviser, professor Christopher C. Davis, and Igor I. Smolyaninov, now with BAE Systems in Washington, recently reported the effects of using quantum dots instead of fluorescent dyes in these systems. They used the polymer PMMA to create gratings over a 50-nm-thick layer of gold on glass. PMMA, the



Shown, are micrographs of (A) PMMA/quantum dot composite film on gold, with an integration time of 240 s; (B) pre-spun quantum dots over PMMA on gold, 30 s; and (C) pre-spun quantum dots over PMMA on chromium, 30 s. Courtesy of Ehren Hwang, University of Maryland, College Park.



Laying out an array of quantum dots with photo-oxidizable bonds, then breaking those bonds selectively with a scanning laser, enables changes in either emission intensity (top) or wavelength (bottom). Courtesy of James D. Batteas, Texas A&M University.



Using a 488-nm laser scanning at 0.1 to 4 µm/s, researchers changed the emission intensity (B) and peak positions (C) of the arrayed quantum dots. Reprinted with permission of the American Chemical Society.

researchers noted, is inexpensive and easy to scribe with electron beam lithography. The polymer tends to absorb dye particles, making measurement of their positions and emissions less than certain, but quantum dots are much bigger, don't get absorbed into the PMMA and, thus, are more certain when it comes to measurements.

"The physical positioning of the quantum dots was of paramount importance," Hwang said. "The propensity of quantum dots to remain at the surface of the film was instrumental in enabling us to study closely the relationship between the grating and fluorescence enhancement." He cautioned, however, that the size of quantum dots may be problematic for biosensing, especially if the particles are expected to be taken up by cells. In addition, the particles also tend to be made of cadmium or other materials that can be toxic to cells.

For some tests, the investigators directly deposited CdSe/ZnS quantum dots onto PMMA; for others, they mixed the PMMA with the quantum dots prior to coating the glass/gold base. The particles had an emission peak of 640 to 660 nm and quantum efficiency of 40 to 50 percent. They also tested grated and ungrated PMMA samples and, to determine whether the surface plasmon polaritons were the sole source of fluorescence enhancement, they made still other samples using chromium or indium tin oxide instead of gold.

After irradiating each sample with a filtered mercury discharge lamp, the investigators found that the gold layer clearly enhanced fluorescence compared with the alternate materials. Interestingly, quantum dots deposited prior to carving out the grating via electron beam lithography remained on the surface afterward.

Quantum dots that were mixed in with the PMMA and that drifted close to the gold thin-film layer were quenched, which was expected.

Overall, Hwang and his colleagues reported in the Dec. 30, 2009, issue of *NanoLetters*, the thickness of the PMMA layer, the periodicity of the grating and the grating geometry all had an effect on quantum dot-based outcomes.

According to Hwang, he and Davis now are performing experiments to investigate the influence of the substrate material thickness on the quantum dot enhancement effect. They also are drilling down into the nature of fluorescence enhancement in other ways.

"If possible, we would also like to probe our substrates using a more standard Kretschmann prism-coupling setup and to study the dependence of the system on azimuthal rotation of the gratings relative to an off-axis illumination source – that is, spinning the gratings around the Z-axis," Hwang said. Additionally, "we are interested in probing our structures using a near-field scanning optical microscope in order to examine the near-field response of the interaction."

Taking a firm position

The quantum dot deposition method used by Hwang and his colleagues is typical but, ultimately, random. You can get a layer of fairly uniform thickness using spin-coating techniques, for example, but it is no way to get a finely arranged array of particles with submicron resolution between particles.

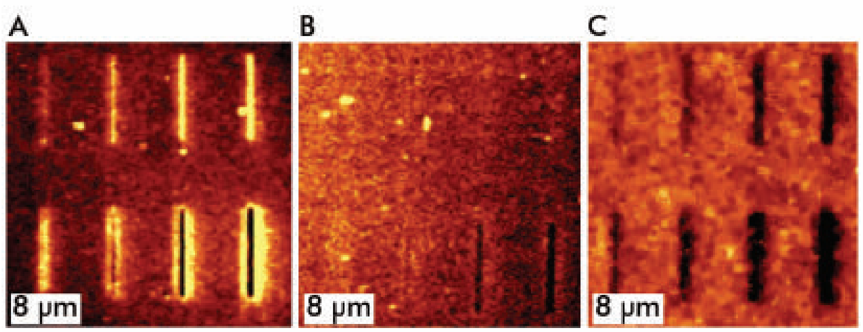
The ability to precisely lay down individual quantum dots could be the next step toward improved biosensors, but also to better LEDs, organic LEDs, solar panels and other optoelectronics.

But it's not easy, by any stretch of the imagination. First, one must create the particles, then move them around individually to the desired location. Doing this with optical tweezers would be direct, but besides other challenges, would be dreadfully slow when spacing out an array of particles on a commercial scale.

Instead, placing arrangements of quantum dots has typically been done through photochemical means. One such method is to deposit quantum dots with molecular tags, or ligands, that adhere the particles onto a substrate, then, with lasers, chemicals or both, strip the bonds of select adherents, leaving only the quantum dots required.

To researchers at Texas A&M University's chemistry department in College Station, however, this and other methods are too labor-intensive. To address the issues, they developed a method, dubbed "lithosynthesis," that takes advantage of the photo-oxidation process.

According to James D. Batteas, associate professor of chemistry and materials science and engineering, lithosynthesis is a process wherein CdSe quantum dots are capped with a photo-oxidizable molecule, then spread onto a positively charged glass, silicon or other substrate. When a laser scans the layered surface, a portion of the caps are broken, leaving behind patterned arrays of quantum dots that have various emission intensities and wavelengths.



Luminescence intensity changes also are affected by materials used. (A) shows a control sample patterned in air and soaked in CH_2Cl_2; (B) shows a sample that has been immersed in 16-MHA; and (C) shows a sample that has been soaked in porphyrin thiol solution. Reprinted with permission of the American Chemical Society.

Batteas and his colleagues report in the March 10, 2010, *Journal of the American Chemical Society* that they used 16-mercaptohexadecanoic acid (16-MHA) to cap 4-nm-diameter CdSe quantum dots and positively charged poly(diallyldimethylammonium chloride) to enable the photo-oxidation effect in their experiments.

Using a 488-nm argon-ion laser, they raster-scanned the landscape of capped particles, photo-oxidizing the tandems, breaking their bonds and leaving behind a composition of quantum dots with various intensities and wavelengths.

"This approach allows for the high spatial resolution patterning of quantum dots in which both emission intensity and wavelength can be spatially modified on a single layer of quantum dots," Batteas said. "With regards to chemical sensing, this has many advantages over carrying out these measurements in solution."

In particular, he noted, using quantum dots in solution often results in their untimely aggregation and, ultimately, their precipitation. "Since our platform is on a surface, this cannot occur."

The group also considered ligands besides 16-MHA as caps, but despite the prospect of lower quantum yields, found that quantum dots capped with 16-MHA exhibited a dramatic increase in luminescence after laser exposure. The researchers also noted that the increased luminescence following photo-oxidation is reversible by dipping the quantum dot array into a 16-MHA bath, where reconnections can occur.

An additional advantage to the technique is that the photo-oxidized quantum dots become more capable of binding to newly introduced molecules than the other, unoxidized material.

"The ability to bind new molecules to the photo-oxidized quantum dots allows us to turn their emission on and off, allowing for data storage capabilities," Batteas said. "They also show the propensity to selectively bind new molecules, allowing the modified quantum dots to be readily adapted for chemical sensing applications."

lynn.savage@photonics.com

Laser pulses put pressure on a diamond sample. The bright white light is plasma, formed as a result of ablating material with a laser to put force on the diamond. Courtesy of Eugene Kowaluk, Laboratory for Laser Energetics, University of Rochester.

Crystal-Clear Research

BY HANK HOGAN
CONTRIBUTING EDITOR

Exciting new findings about crystals – on subjects as diverse as diamonds, peptide nanofibers and colloids – could prove useful in science and industry, perhaps leading to new nanoscale constructs and better electronics.

Diamond in extremis

Diamond has long been used to put the squeeze on other materials. Now researchers have used lasers to return the favor, finding that a girl's best friend can support almost a million atmospheres. These results might lead to better high-pressure science.

Previous static experiments indicated that, when the pressure exceeds its strength, diamond deforms plastically, like a metal. The new results, reported in the Jan. 22, 2010, issue of *Physical Review B*, show that, under dynamic conditions, diamond acts like a brittle material.

There must be a transition between the two responses, and understanding that could be key, said Lawrence Livermore National Laboratory physicist Jon H. Eggert. "How this works is very important to the design of experiments using diamond as a pressure generator."

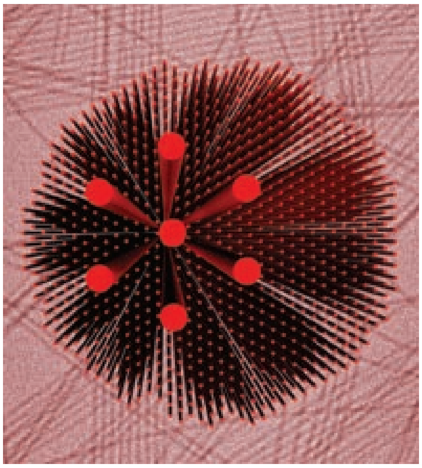
In their study, the researchers, from the University of California, Berkeley, the University of Rochester in New York and the national lab, fired laser pulses at diamond targets, using 100 GW of laser power at the Livermore Janus facility and 3 TW on the Omega system at Rochester. The two produced nanosecond pulses of 532 and 355 nm, respectively.

They focused these down, ablated material they had deposited on the surface for that purpose, and thereby created a shock wave in the diamond sample. They used a high-precision imaging interferometer to measure Doppler-shifted light reflected from the moving surface.

Future plans call for experiments to be done at the National Ignition Facility at Livermore. There, the researchers can take advantage of the system's greater power and steadier laser-driven shocks to refine their understanding of diamond.

Repulsive crystallization

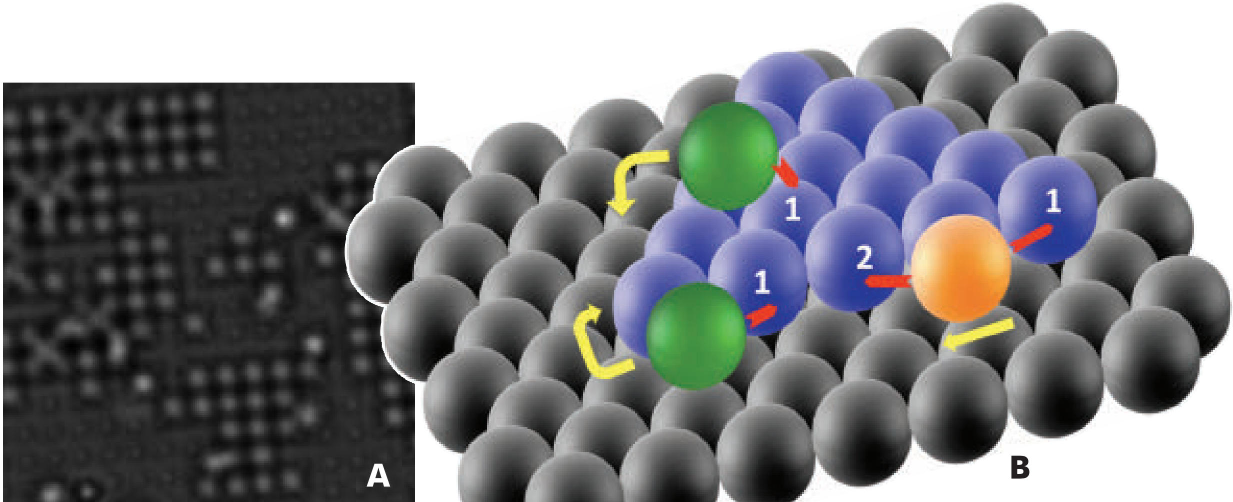
Thanks to a serendipitous discovery, there is a new way to build crystals. Investigators at Northwestern University in Evanston, Ill., showed that it could be done using repulsion, instead of attraction. The finding could have wide applicability,



Repulsion brought about by x-ray exposure can cause crystallization under the right conditions. Foreground illustration shows a highlighted hexagonal crystal lattice, formed when a peptide amphiphile (10-nm nanofibers in background) in aqueous solutions is subjected to x-rays. Courtesy of Honggang Cui and Samuel I. Stupp, Northwestern University.

said research leader Samuel I. Stupp.

"The mechanism of crystallization as a result of repulsive electrostatic forces in confined systems such as on surfaces, in networks, in micron-scale containers and so on could be used universally in



By watching a colloidal crystal form (A), researchers revealed the importance of diffusion, a result of the various barriers to particle movement around a step edge or a corner (B). Courtesy of Itai Cohen, Cornell University.

synthetic materials as a way to build structures."

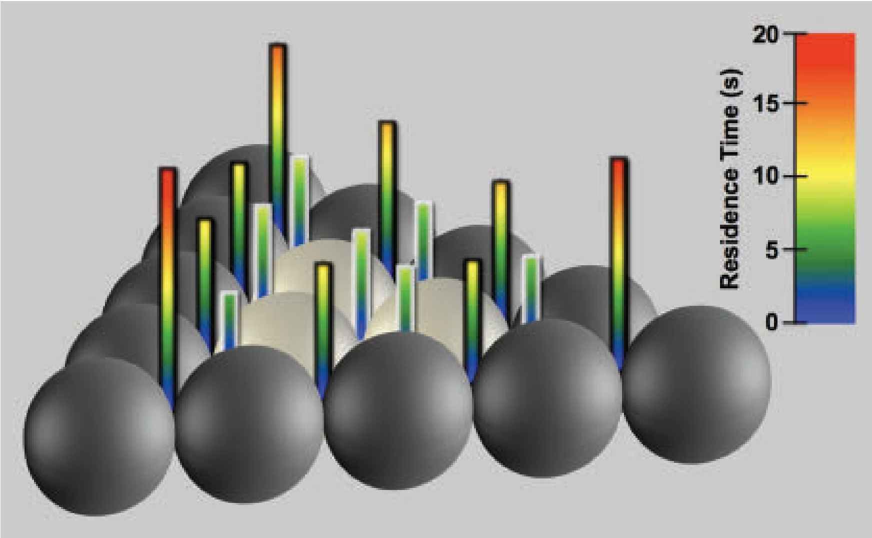
A professor of chemistry, medicine, and materials science and engineering at the university, Stupp said that the new process was revealed when the researchers applied synchrotron x-ray radiation to a solution of peptide nanofibers they were studying. The solution underwent a dramatic change from clear to opaque, and the x-ray signal showed crystallization occurring, something totally unexpected.

The same thing happened spontaneously at higher peptide concentrations, the team reported in the Jan. 29, 2010, issue of *Science*, with separations between filaments after crystallization of up to 32 nm. This self-assembly occurs because of repulsive forces between nanofibers and their mechanical confinement in a network. Something similar may be behind the construction mechanism of cytoskeleton filaments.

Applications of the new crystallization method could come in biomedical therapies or in lithography. For example, it may be possible to build organized nanostructures using x-rays, Stupp said.

Watching crystals grow – in a way

Building perfect crystals and thin films is important both for commerce and research. Unfortunately, perfection is hard to achieve, and uncovering what went wrong



A residence time image for particles that were placed on top of a triangular island shows a measure of how long the particles would stay at a particular spot. Courtesy of Itai Cohen, Cornell University.

can be difficult because revealing the source of an error may require watching atoms move on a surface.

To get around this problem, a group of researchers from Cornell University in Ithaca, N.Y., scaled things up to make what was happening more visible. In the process, they showed that random motions could play a critical role in constructing crystals and thin films, something not clear before.

The researchers used colloidal particles in solution to model atoms. Their study, which was reported in the Jan. 22, 2010, issue of *Science*, examined epitaxial growth.

In their work, they made use of holographic optical tweezers, said Itai Cohen, an assistant professor of physics. “We could take particles to specific locations and then let them go. Using that technology, we could essentially set up experiments at the single particle scale.”

Employing confocal microscopy, the researchers followed events and showed that colloidal epitaxy obeys the same two-dimensional island nucleation and growth laws that govern atomic epitaxy. They also determined the key role played by particle diffusion in colloidal epitaxy. This previously ignored effect also could extend to atomic systems because atoms get jostled by lattice vibrations.

In the future, Cohen hopes that technological improvements will allow researchers to follow the assembly of nanoscale particles. For now, he noted that being able to tune the interaction between colloidal particles can provide other important insights into physical systems.

hank.hogan@photonics.com

Judging ARPA-E

Critics question the government's role in advancing energy technology

BY GARY BOAS
CONTRIBUTING EDITOR

Created under the Bush administration, the Advanced Research Projects Agency – Energy (ARPA-E) actually set up shop only last year, when it received $400 million in funding under the American Recovery and Reinvestment Act. Its director and staff must feel a bit beleaguered already, though, with critics questioning whether it is an appropriate avenue for government funding of technology development.

The organization is modeled after the Defense Advanced Research Projects Agency – better known as DARPA, the agency that brought us the Internet and the stealth technology found in the F117A Nighthawk aircraft, for example. The mission of ARPA-E, according to its Web site, is to "enhance US economic security by identifying technologies with the potential to substantially reduce energy imports from foreign sources; cut energy-related greenhouse gas emissions; and improve efficiency across the energy spectrum," while ensuring that the US remains a technological and economic leader in the field of energy.

To use a bit of shorthand: The agency is looking for the next game-changing technology – the Google of energy.

ARPA-E selected an intriguing slate of contenders with its first round of funding. The agency recently announced that, after having received upward of 3000 applications, it has committed $151 million to 37 projects in areas such as renewable power, biomass energy and vehicle technologies. One example: 1366 Technologies Inc. of Lexington, Mass., has been awarded a $4 million grant to develop "direct wafer" technology that forms high-efficiency "monocrystalline-equivalent" silicon wafers directly from molten silicon and that could thus reduce the installed cost of solar photovoltaics dramatically.

With a second round of funding available – this time for $100 million in grants – ARPA-E has received a total of 500 submissions for three categories: advanced carbon capture technologies, high-energy storage batteries for electric and hybrid electric vehicles, and new approaches to making liquid fuels without using petroleum or biomass. Review of these applications is under way.

Federal support for radically new and potentially game-changing technologies is especially important these days, as the venture capital community is less and less

ARPA-E has come under fire from some quarters. Critics argue that the agency is essentially in the position of "picking winners" among competing technologies, contending that this is not a proper role for the federal government.

willing to invest in high-risk projects. Still, critics of the program maintain that the government should not be in the business of "picking winners" among competing technologies. Funding innovative basic science research is one thing, they say, but deciding which products should make it to market is another altogether. Here, various additional factors come into play: whether the materials are available in sufficient quantities to keep costs down, for example, or whether consumers would be willing to adopt the technology.

ARPA-E has sought to address such concerns in part by recruiting staff from the private sector, even enlisting some with hedge fund experience, as well as consulting with top researchers in particular fields.

One could also argue, however, that the potential for adoption should not be a primary consideration for ARPA-E. The agency has taken upon itself the support of some research that probably would have been deemed too risky by the investment community, because high payoff is unlikely. The ideal ARPA-E project probably looks a little crazy, but if it works … look out. In this context, judging the research based on its perceived practicality might almost seem irresponsible.

In any event, the question of picking winners and losers is often moot in the earliest stages of technology development. "The earlier you are in the development, the less you know about what the future will bring," said Milton Chang, founder of Menlo Park, Calif.-based venture capital fund Incubic and a longtime player in the field of optics. "And if you spend all your time looking for the perfect solution, you will never find it. Sometimes you just need to shoot in the right direction and see what happens."

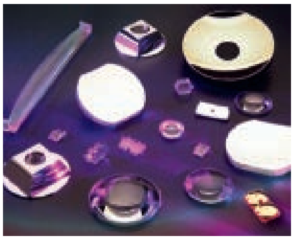
As ARPA-E director Arun Majumdar reminds us, even if only a few of the funded projects are ultimately successful, we will still see a dramatically changed energy landscape.

Others criticisms have centered on the possibility that the projects will not create a commensurate number of jobs in the short term and that many of the jobs that are created might be sent overseas once the new technologies go into production. This could be an especially contentious subject, as ARPA-E is currently paid for with stimulus package money.

Proponents of ARPA-E counter that the American Recovery and Reinvestment Act was designed to lay a foundation for long-term growth as well as provide a jolt to the economy and, that by funding the development of potentially breakthrough technologies, the agency is doing just that.

gary.boas@photonics.com

ARPA-E was created to support research into radically new technologies, including solar, that could help the US cut back on its energy imports from foreign sources. Indeed, in the first round of funding, the Lexington, Mass.-based 1366 Technologies was awarded a $4 million grant to develop a "direct wafer" technology that could result in significantly lower costs for solar photovoltaics.

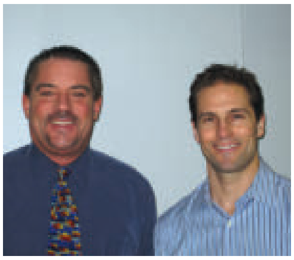


Precision Polymer Optics
G-S PLASTIC OPTICS manufactures precision polymer optics for imaging, scanning, detection and illumination applications. In addition to an extensive catalog offering of plastic optics, the company has in-house capability to provide custom-designed diamond-turned and injection-molded prototypes, production injection molding of optics, thin-film and reflective coatings, and integrated optical solutions for military, medical, commercial and consumer markets.

(585) 295-0200
info@gsoptics.com
www.gsoptics.com

Rotary Air-Bearing Stages
Aerotech's ABRT rotary air-bearing stages provide 360° continuous travel with resolution to 0.027 arcsec. Velocity stability and error motion performance are exceptional. Payload capacity is up to 69 kg due to the outstanding radial/axial stiffness. ABRT is for optical inspection and fabrication, DVD mastering, wafer inspection, high-precision metrology applications, x-ray diffraction systems, MEMS/nanotechnology device fabrication and more.

(412) 963-7470
sales@aerotech.com
www.aerotech.com/
products/stages/abrt.html



Germanium and Silicon Optics – Made in the USA
Global Optical USA, a state-of-the-art domestic manufacturing facility in Rochester, N.Y., is solely focused on the fabrication and delivery of Germanium and Silicon IR optical components. The management team, led by Scott Walker and Brett Birrittella, is dedicated to the achievement of mission-critical, cost-effective IR performance goals. We cordially invite you to tour our facility and discuss your requirements with our team.

ITAR Certified
www.globalopticalusa.com
brettb@globalopticalusa.com
(585) 223-6000

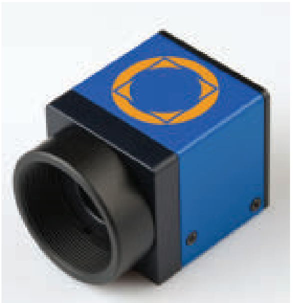
Systems Design and Fabrication
Optics Technology Inc. is a designer and manufacturer of micro-optical systems and assemblies for the medical, biomedical, industrial and defense industries. Our design and manufacturing capabilities span the deep-UV through the far-IR. Some of the markets we serve are remote sensing, biological research, semiconductor and surveillance applications. We can help you and your customers set new standards of excellence for your products. Contact us to see how we can put our expertise to work for you.

sales@opticstechnology.com
(585) 856-0950

Smallest High-Precision Hexapod Positioners
PI offers the largest selection of submicron-precision hexapod 6D micropositioners and microrobots – ideal tools for precision alignment and handling, from fibers to MEMS to heavy optics. Load range: 2 to 1000 kg. Parallel 6D motion; vacuum compatibility; very high stiffness. A virtual, vector-based pivot point and powerful software allow 6D nanoalignment faster and more precise than ever. Applications: microscopy, optics, medical technology, astronomy, tracking and alignment.

(508) 832-3456
photonics@pi-usa.us
www.pi-usa.us

spotlight
Optics & Optics Fabrication



Wavefront Sensors from Optocraft
High-quality Shack-Hartmann sensors from 193 to 1700 nm. Most models <40-nm pv accuracy and 2-nm rms repeatability. Well-developed custom software is ideal for applications including lens testing, ophthalmics and astronomy. Contact us today for more details.

Metrology Concepts
Surface and Wavefront Measurement Solutions
(585) 427-9155
info@metrologyconcepts.com
www.metrologyconcepts.com

One Custom Lens or a Million
Syntec Optics specializes in custom polymer optics and optics systems with capabilities for design, molding, diamond turning, assembly and metrology. Highly skilled in meeting tough design challenges, we have a track record of success in defense, medical, and biometrics optics and assemblies. Ask about our new cleanroom assembly capabilities. Visit us online for more information or to request a quote.

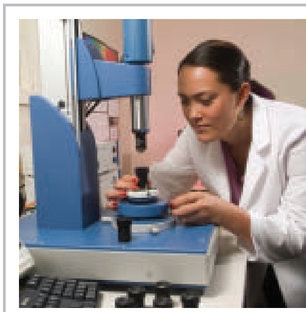
SYNTEC OPTICS
(585) 768-2513
info@syntecoptics.com
www.syntecoptics.com

BlueMode Laser
TOPTICA's new BlueMode technology unites all well-known advantages of direct blue-violet diode lasers: high power, high coherence and superior long-term mode stability. The BlueMode technology currently starts with 50 mW at 405 nm, with a spectral linewidth of less than 5 MHz. Our BlueMode is perfect for demanding applications such as interferometry, holography and high-resolution Raman spectroscopy.

TOPTICA PHOTONICS
(585) 657-6663
sales@toptica-usa.com
www.toptica.com

Mid-IR Focusing Objectives
The advent of quantum cascade lasers and other mid-IR sources has prompted the development of specialized components not often commercially available on an in-stock basis. INNOVATION PHOTONICS' mid-IR focusing objectives provide maximum efficiency in coupling the output from a mid-IR source into single-mode or multimode IR transmitting fibers. Contact us to discuss your mid-IR application needs.

innpho.com
INNOVATION PHOTONICS
(973) 857-8380
info@innpho.com
www.innpho.com

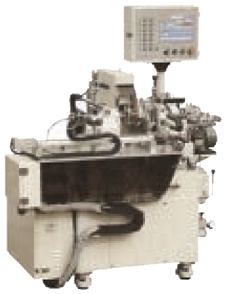


Precision Optics for Industry
Westech Optical Corporation provides precision lenses, lens assemblies and planos to OEMs worldwide. Our quality, reliability and service have kept us well ahead of global competition. Lens design and engineering services, along with fast prototype delivery, competitive high-volume production and ITAR certification, assure our customers of a reliable and cost-effective optical production center. Don't pay catalog prices for OEM optics. Call Westech today.

Westech Optical Corporation
(585) 377-2490
jcarlino@westechoptical.com
www.westechoptical.com

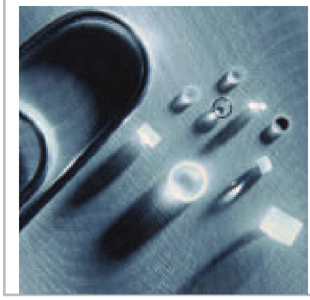
Infrared Thermal Imaging Lens Kit
ISP Optics' common thermal imaging module enables building of an infrared objective to meet specific optical requirements. We offer a selection of lens kits with focal lengths from 18 mm *f*/1 to 50 mm *f*/1.2, enabling you to make a "build yourself" imaging system for the long-wavelength infrared range. Each kit consists of two lenses and optical and mechanical layouts indicating how the two lenses should be positioned in relation to each other, along with the detector you plan to use. To maintain universal flexibility, a mechanical mount is not included. This subassembly is a low-cost, fast-turnaround solution for your custom requirements.

THE INFRARED ISP OPTICS COMPANY
(914) 591-3070
sales@ispoptics.com
www.ispoptics.com



Fully Automatic Lens Centering Machine with Loading/Unloading Robot
The Model SPCM-M1-AT50 is a machine capable of centering and beveling lenses or plano workpieces in a fully automatic cycle, including loading and unloading of the workpieces by robot. The machine is equipped with two integrated work holding pallets that can accommodate up to 600 lenses for automatic processing. Work size capacity is from 2- to ~50-mm diameter.

MILDEX INC.
(585) 473-6540
info@mildex.com
www.mildex.com



Submillimeter Optical Components
Bern Optics Inc. has exceptional expertise in manufacturing ground and polished submillimeter optical components as small as 0.20 mm from a variety of optical and filter glasses. Made to micron tolerances in prototype or production quantities, these microscopically small lenses, prisms, apertures, mirrors, windows, spheres and custom elements are unsurpassed in quality and precision. They are as pretty to look at as they are to look through.

BERN SUBMILLIMETER OPTICS
(413) 568-6800
info@bernoptics.com
www.bernoptics.com

Custom Optics
Swift Glass specializes in providing short lead times for high-volume manufacturing requiring optical tolerances and multiple diameter variances. Capabilities include: double-sided lapping and polishing; ceramic and crystal lapping and polishing; precision parallel components; scratch-dig to 20-10; machining center for close dimensions; surface coating availability; optical edge polishing; color filters; ¼-in. diameter to 36 in. square.

SWIFT GLASS
(607) 733-7166
quality@swiftglass.com
www.swiftglass.com

FireWire BeamPro
The FireWire BeamPro CCD camera-based beam profiling system with IEEE 1394 connectivity provides highly accurate measurements of ISO Standard beam profile parameters, while the interface offers enhanced ease of use and portability. The system is available in either ½- or ⅓-in. formats, with a small form factor that allows easy placement into typical optical paths. With 12-bit digitization and our renowned Beam Profiler software, you can now profile laser beams from single-shot to continuous-wave. The system has exposure and gain control, with an automatic mode for rapid, accurate settings.

PHOTON Inc. Precision Beam Profiling
(408) 226-1000
beam@photon-inc.com
www.photon-inc.com

Scientific Imaging Software ▲

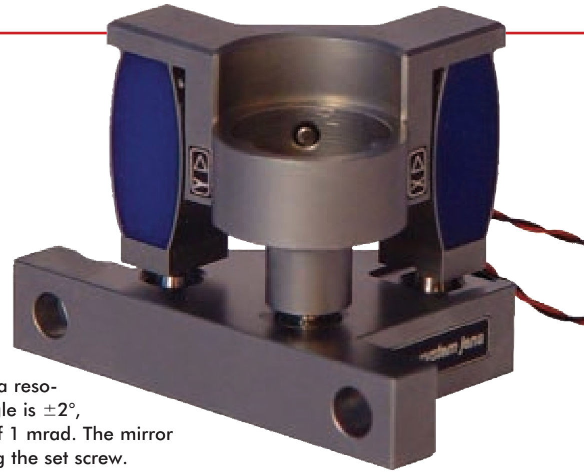
Princeton Instruments has released LightField, a 64-bit data acquisition software platform for use in spectroscopy and scientific imaging. It controls the company's cameras and spectrometers via tools that streamline experimental setup, data acquisition and postprocessing. It saves data to disk during acquisition, applies a time stamp and retains raw and corrected data and experimental details. The software is suitable for multiuser facilities and single-user labs. It remembers each user's hardware and software configurations, displaying all relevant tools via an intuitive graphical user interface. It can be extended with proprietary and patent-pending IntelliCal wavelength calibration software, suitable for use in optical imaging; in Raman, fluorescence, laser-induced breakdown and photoluminescence spectroscopy; in surface and materials analysis; in combustion studies; and in astronomy. Compatible with Microsoft Windows 7 and Vista. An event-driven application programming interface is provided.

Princeton Instruments
moreinfo@piacton.com

CEP-Stabilized Amplifier ▲

Coherent Inc. has launched the Legend Elite CEP, a carrier envelope phase-stabilized Ti:sapphire amplifier. The system amplifies the ultrafast pulses generated by the proprietary Micra CEP oscillator up to the millijoule level of energy required for high harmonics generation, attosecond physics and coherent x-ray generation. It delivers pulse durations of <435 fs with a repetition rate of 1 kHz, and it has up to 4 W of average power and 4 mJ per pulse. Typical carrier envelope offset stability is better than 200 mrad. The regenerative amplifier includes an active feedback control to lock the phase velocity of the oscillating light field to the group velocity of the phase envelope. For ultrashort pulses consisting of only a few optical cycles, the peak of the oscillating electrical field can be maximized under the phase envelope.

Coherent
tech.sales@coherent.com



Mirror Tilting System ▶

The PKS1 is a mirror tilting system developed by piezosystem jena GmbH for solid and constant positioning of an optical controlled laser. It performs precise correction of the laser adjustment by microseconds. Based on two orthogonal tilting axes, it features a compact design and high stiffness, and it delivers a resonant frequency of 450 Hz. Manual setting angle is ±2°, and the piezo drive delivers fine adjustment of 1 mrad. The mirror can be glued directly or can be mounted using the set screw.

piezosystem jena
sales@piezojena.com

◀ Miniature LEDs

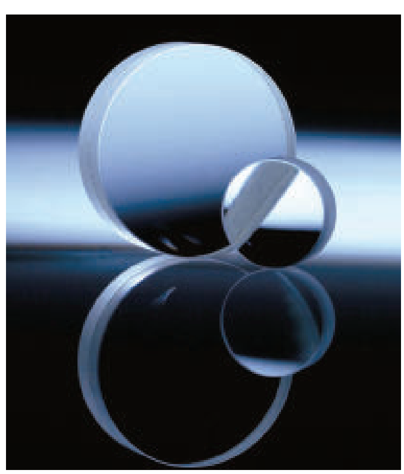
For use in interior automotive and industrial applications, Avago Technologies' PLCC-2 high-brightness miniature surface-mount-technology LEDs measure 1.0 × 2.0 × 1.3 mm. The ASMT-TxBM series devices feature viewing angles from 110° (cool white) to 120° (blue, green) and are suitable for backlighting automotive instrument cluster panels, puddle lighting, center consoles, navigation and audio systems. In industrial applications, they can be used to provide backlighting for buttons, switches and ambient light illumination. Lead-free and RoHS-compliant, they are available in an 8-mm carrier tape on a 7-in. reel.

Avago Technologies
support@avagotech.com

Light Engine ▶

Spectra, a light engine launched by Lumencor Inc., provides seven discrete solid-state outputs spanning the visible spectrum from 380 to 680 nm, making it a true arc lamp replacement. For use by microscopists, researchers and OEMs, it features more power per band for each channel than did previous models. It offers a streamlined design, full electronic control of intensity, switching speeds in the tens of microseconds and a dosimeter option. Adapters for all major microscopes are available, and custom adapters are available upon request. Custom optical design services also are offered.

Lumencor
info@lumencor.com



◀ Near-UV Achromatic Lenses

Edmund Optics Inc.'s TechSpec near-UV achromatic lenses transmit in the 345- to 700-nm range and are designed to minimize the spot size for polychromatic illumination in the 345- to 550-nm region. They are suitable for use in fluorescence applications and for focusing UV light sources such as mercury arc lamps, UV LEDs and tripled Nd:YAG lasers. An alternative to air-spaced doublets and triplets in the UV, the lenses feature a cemented design and provide >90% transmission from 360 to 700 nm and >50% at 334 nm, with no spherical aberration or coma. They are available in 12.5-mm-diameter models in 25-, 30-, 40-, 50- and 60-mm effective focal lengths, and in 25-mm-diameter models with effective focal lengths of 50, 60, 75, 100 and 125 mm. All have a UV-VIS coating.

Edmund Optics
medmund@edmundoptics.com

Pure Core Optical Fibers

Fibertronix AB has released its Bright-light pure core optical fiber line for use in harsh environmental conditions, including oil and gas, aerospace, sensors, defense, industrial and security. Resistant to hydrogen and radiation exposure, they operate from -65 to 300 °C. They are available in single- and multimode and 80-μm configurations. Coatings are polyimide, high-temperature acrylate and standard acrylate. The single-mode polyimide-coated fiber has a numerical aperture of 0.12 ±0.015 and a typical core diameter of 9 μm. The multimode version has a numerical aperture of 0.22 ±0.015 and a core diameter of 50 or 62.5 μm. Both versions have a cladding diameter of 125 ±1 μm, a core/cladding concentricity error of <1 μm, cladding noncircularity of <2% and a coating diameter of 145 ±5 μm.

Fibertronix
info@fibertronix.com

Potting, Sealing Materials

Shin-Etsu Silicones of America has introduced silicone-based potting and sealing materials. The KE-200, -200F, -210 and -210F two-component potting materials are designed to weatherproof solar panel junction boxes. They quickly cure at room temperature, making the junction box corrosion- and moisture-proof. Benefits include good adhesion to various substrates, good heat stability, no reversion under airtight conditions, high dielectric breakdown strength and easy reparability. The KE-45, -4828 and -220 one- and two-component silicone sealants seal the junction box to the back sheet and provide a waterproof seal between the photovoltaic panel and the frame. They adhere strongly to materials such as polyvinyl fluoride and polyethylene terephthalate, cure quickly at room temperature, and provide good weatherability and electrical insulation.

Shin-Etsu
ebishop@shinetsusilicones.com

Optical Tweezer System

A new version of the E3500 computer-controlled multiple-trap optical tweezer system with E4100 quadrant photodetector force measurement capability has been unveiled by Elliot Scientific Ltd. The system uses one fiber-coupled laser for trapping and another for the probe beam. It comprises an optical module containing the laser, beam-steering optics, a microscope interface, a control module with drive electronics, a computer, software, a laser blocking filter and a high-speed camera with Gigabit Ethernet. Suitable for multiple spot trapping and manipulation of micron-size particles, the system is designed to be attached to high-quality commercial instruments to upgrade them to photonic force microscopes. Applications include cell sorting, microrheology, colloid research and particle spectroscopy. The laser delivers a TEM_{00} beam with M^2 of 1.05.

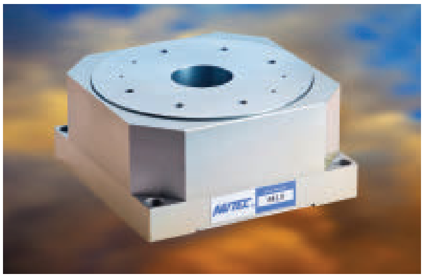
Elliot Scientific
sales@elliotscientific.com

Femtosecond Fiber Laser

Calmar Laser has released a 780-nm OEM or desktop femtosecond fiber laser for terahertz radiation imaging, optical metrology and multiphoton microscopy applications. The instrument delivers pulse energy up to 1 nJ,

peak power up to 10 kW and average power >50 mW at 50 MHz. With selectable wavelengths from 765 to 780 nm, it produces pulse widths <0.1 ps with minimal pulse pedestal and near-transform-limited output. It offers linearly polarized output, low timing jitter, radiofrequency synchronization output and turnkey operation. It requires no external cooling. The laser also is suitable for biophotonics, optical metrology, terahertz radiation imaging and materials characterization applications, and for seeding Ti:sapphire amplifiers.
Calmar Laser
peter.h@calmarlaser.com

Rotary Positioning Stage



Nutec Corp. has upgraded its TMAX 5 low-profile, direct-drive rotary servo positioning stage for higher load capacity and improved trajectory control. Applications include laboratory testing, laser machines, optical metrology, and photonic and optical testing and manufacturing. Driven by a brushless servo torque motor with a high-resolution rotary encoder system, the stage provides smooth, low-friction rotary motion with 360° continuous travel, low hysteresis, low noise and low vibration. Accuracy is within 25 arc sec, wobble is ≤8 arc sec, concentricity is ≤4 μm, and flatness of rotation is ≤6 μm. High-precision options reduce these specifications to 1 μm. The stage is constructed with a monolithic rotating hub (from 50 to 200 mm in diameter) suspended by a preloaded bearing system with duplex angular ball bearings for good angularity and stability, good dynamic characteristics and unlimited service life, even at maximum loads.
Nutec
info@nutecomp.com

Cooled MWIR Zoom Lens

Omer, manufactured by Temmek Optics, is a medium-wavelength infrared (MWIR) cooled zoom lens designed for 384 × 288-pixel focal plane arrays with a 15-μm pixel pitch. The compact f/4 lens is suitable for handheld, small unmanned vehicle and other lightweight applications. It offers three fields of view: 22.5, 55 and 135 mm. Motorized focus and field of view mechanisms are communicated via RS-422 or -232. Average transmission exceeds 91%, and operating temperature is from -30 to 55 °C. The lens measures 73 × 64 × 79 mm, weighs <250 g and has a motorized focus mechanism. Power input is 12 VDC, 0.6 A.
Temmek Optics
temmek@temmek.com

Ultrafast Laser

The FemtoFiber pro ultrafast all-fiber laser unveiled by Toptica Photonics Inc. emits at 1560 nm with a pulse width of <100 fs and average power of >350 mW. Standard repetition rate is 80 MHz, with 40 MHz and custom frequencies also available. The saturable absorber mirror ensures self-starting and stable mode-locking under all laboratory conditions. All fiber components are polarization-maintaining and robust against environmental changes. The integrated computer can be accessed via Ethernet, USB or RS-232. Three models are available: the FemtoFiber pro IR at 1560 nm, the second-harmonic-generation FemtoFiber pro NIR at 780 nm and the octave-spanning supercontinuum FemtoFiber pro SCIR at 980 to 2200 nm. Applications include life sciences, time domain terahertz, ultrafast spectroscopy, metrology and optical coherence tomography.
Toptica Photonics
info@toptica.com

Surface Metrology System

The NT9080, a surface metrology system introduced by Veeco Instruments Inc., uses white-light interferometry to measure surface topography nondestructively, from nanometer-scale roughness through millimeter-scale steps, with subnanometer vertical resolution and production-level throughput. Push-button analysis provides instant feedback, and 3-D surface data is saved for subsequent characterization, without requiring a new scan of the sample or part. The system is used in research labs and in the precision machining, medical, printing and solar cell manufacturing markets. With a small footprint, the 3-D measurement microscope accommodates a variety of samples and feature sizes as small as 0.50 μm. Running on Vision software, it provides access to more than 200 distinct analyses and more than 1000 critical parameters for measuring curvature, lay, bearing ratio, wear and corrosion. Long-lifetime green and white LEDs provide the light source.
Veeco Instruments
sales@veeco.com

Scientific Cameras

Critical Link has expanded its MityCCD back-illuminated scientific camera line with the introduction of models with front-illuminated, deep-depletion, open-electrode and InGaAs sensors. All include the MityDSP embedded, configurable and programmable CPU platform, which eliminates the need for an external host and enables complex applications to be run directly on the camera. OEM applications include Raman spectroscopy, spectrophotometry, low-light imaging, portable scientific imaging, semiconductor inspection and DNA sequencing. Features include low-noise analog front-end electronics, a maintenance-free vacuum chamber and thermoelectric cooling for low dark current, and a digital subsystem consisting of 16-bit ADC, USB and Ethernet interfaces.
Critical Link
info@criticallink.com

Wavelength-Selective Switch

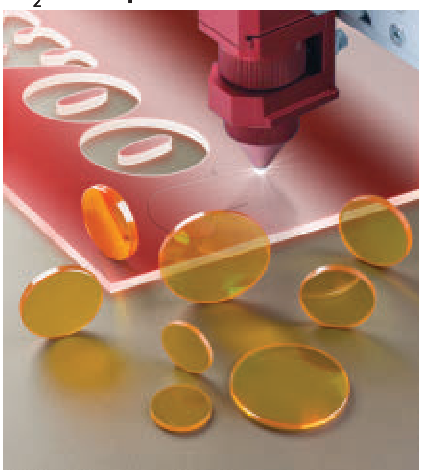
The Mini 50 WSS (wavelength selective switch) announced by JDSU is a next-generation 50-GHz module that supports network traffic through more than 16 nodes, or entry and exit points in a network, with minimal effect on the network signal. The reconfigurable optical add/drop multiplexer is an N-port module that comprises a hermetically sealed optics block with control electronics. The switch dynamically attenuates, block switches and routes wavelengths independently. Any wavelength(s) can be routed from any port(s) to any other port(s) in any order. It is Telcordia-qualified and RoHS-compliant and operates in open- and closed-loop-control modes.
JDSU
customer.service@jdsu.com

Inspection Station

The MT 200 compact inspection station offered by Laselec uses a Class 1 UV laser to mark cable samples, then produces an analysis report. Manufacturers can test, control and optimize the UV laser markability of their wires and cables during production. The system includes proprietary real-time Comet image capture software to measure the contrast of UV laser-generated marks on electrical wiring and fiber optic cables. The laser is a 355-nm frequency-tripled Nd:YAG solid-state model with a pulse duration of 7 to 9 ns. The marking zone is covered by a front panel and window to allow visualization of the laser shots and to protect against laser radiation. Marking can be performed through single shot or programmable laser shots at defined intervals. The system includes a numerical camera with zoom, autocalibration and real-time energy level control.

Laselec
infousa@laselec.com

CO_2 Laser Optics



Laser Research Optics provides field-replacement CO_2 optics for low-power cutting, engraving and marking lasers from a variety of companies. Optimized for use at 10.6 μm, they meet OEM and ISO-10110 specifications for optical elements and include a variety of lenses and mirrors. Available in 12.7- to 38.1-mm-diameter sizes with focal lengths from 25.4 to 635 mm, in 12.7-mm increments, the optics receive dual-band antireflection coatings. The CO_2 laser mirrors and reflectors are 10 to 12.7 mm thick and made from silicon, molybdenum and copper.

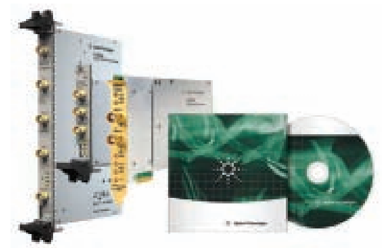
Laser Research Optics
steve@laserresearch.net

Ultraquiet Air Compressor

Newport Corp. has introduced a compact, ultraquiet air compressor that is clean, portable and more convenient than bottled air supplies. Fast-filling, the ACWS can supply air to any of the company's pneumatic isolators, optical table systems and workstations. It operates intermittently, based on air usage, and is monitored by a sensor that maintains the reserve tank's preset minimum pressure. It produces 30 dB at 1 ft and delivers vertical adjustment down to better than ±0.25 mm. Release valve sound level is 62 dB, and tank capacity is 1 liter. Standard features include an automatic turn-off switch, a safety valve, gauges, an outlet port, fittings, a drain and a 5-μm air intake filter/regulator that removes contaminants from the air and guarantees maintenance-free operation.

Newport
warren.booth@newport.com

Digitizer Software



Agilent Technologies Inc. has announced Acqiris Software Release 4.0 for its Acqiris digitizer products. It supports 32- and 64-bit versions of Windows 7, XP64, Vista 64 and 64-bit Linux and is available on CD-ROM or at www.agilent.com/find/acqiris-software-cd-rom. The high-speed digitizer products are supplied with software drivers for Windows, Linux, LabView and VxWorks operating systems, and application code examples for MatLab, C/C++, VisualBasic.NET, LabView and LabWindows/CVI, where available. The code examples provide card setup and basic acquisition functionality and are easily modified so that the card can be integrated quickly into a measurement system. With minimum software adjustments, any Acqiris digitizer can be swapped out, replaced and upgraded with the latest digitizer technology.

Agilent Technologies
janet_smith@agilent.com

Time-Delay-Integration Camera

The Piranha HS, a 12-k 90-kHz time-delay-integration camera, has been unveiled by Dalsa Corp. It delivers 12-k resolution with a 5.2-μm pixel size and operates at a line rate of 90 kHz, or 1.2 gigapixels per second. The HSLink interface builds on Camera Link and adds new features and functions. It delivers a scalable bandwith in 300-MB/s steps, from 300 to 6000 MB/s. The camera is supported by the proprietary Xcelera-HS PX8 frame grabber, which provides image acquisition bandwidth of 1.8 GB/s and host transfer bandwidth of 2 GB/s over multiple-lane PCI Express implementations. Time-delay-integration technology enables low-light imaging. The camera features bidirectionality, antiblooming and programmability and is suited for flat panel display, electronics, printed circuit board and solar cell inspection applications. It is supported by the company's Sapera Essential software.

Dalsa
sales.americas@dalsa.com

Image Dimension Measuring System

Keyence Corp. of America's IM-6000 series image dimension measurement system includes pattern registration and pattern search functions that enable "place and press" measurement. The devices eliminate the need for optical comparators, X-Y stages for part positioning, computer numerical control measuring devices, and measuring and stereomicroscopes. The user places parts on the sample tray and pushes the measurement button. Careful positioning is not necessary. The "intelligent pattern analysis search system" quickly locates, identifies and measures parts placed anywhere within the unit's 100-mm field of view. The "part evaluation library" stores the images, measurement functions and specifications of parts and provides automatic pattern search, part recognition and measurement without setup the next time inspection of the same parts is performed. The system performs up to 99 distinct measurements, including angle, radius, inner/outer diameter, and circular and linear pitch.

Keyence
keyencepr@keyence.com

Ultracompact Cameras

Point Grey Research Inc.'s next generation of Flea3 cameras offers a choice of eight Sony progressive-scan CCDs in monochrome or color, and FireWire-b (800 Mb/s) or Gigabit Ethernet (1000 Mb/s) interfaces. Housed in a 20 × 20 × 30-mm cast metal case and weighing 58 g, the cameras include an enhanced optoisolated eight-pin general-purpose input/output, an on-camera frame buffer, nonvolatile user data storage and new trigger modes. Features include a C-mount lens holder, on-camera color processing and automatic white balance. Multiple cameras networked on the same IEEE-1394 bus are automatically synchronized to within 125-μs maximum deviation and can synchronize across buses using proprietary MultiSync software. The FlyCapture software development kit is compatible with Microsoft Windows and Linux Ubuntu.

Point Grey Research
info@ptgrey.com

Vision Sensor

Sick Inc. has launched the Inspector 140 Flex, a vision sensor that produces VGA 640 × 480-pixel resolution. It offers Ethernet connectivity and increased storage capabilities that allow users to save an unlimited number of images to an off-line system or server, facilitating tracking and tracing of vision inspections. A robust pattern match algorithm locates parts independently of position, rotation or scale. Packaging applications include label position on bottles, cartons and cases; date code presence; cap inspection; blister packs; sterile soft bags; level control of fluids where nonvolumetric filling is applied; and uniformity of positioning packs in bulk. Automotive applications include small part assembly; bowl feeder inspection; verifying part assembly; verifying correct type in multitype production lines; verifying presence of holes, nuts, safety springs and simmer rings; and surface inspection of defects.

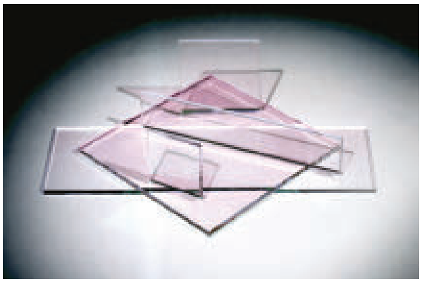
Sick
info@sick.com

Infrared Engine

Based on a 384 × 288 uncooled ASi 8- to 14-μm microbolometer detector with a 25-μm pitch, OpGal Optronics Ltd.'s Compact Eye low-power infrared engine is tuned to long-wave infrared with less than 0.08 °C sensitivity. Operating temperature is −40 to 60 °C. With night-vision capabilities, the OEM engine is suitable for security, surveillance and protection of national borders, airport perimeters and other sensitive sites. The ultracompact system can be integrated easily into predictive maintenance applications and fire detection systems. It offers user-friendly interface software, an antiblooming mechanism, high-resolution graphics overlay, an on-screen menu and a miniaturized shutter. It stores up to 50 snapshots, delivers a raw data frame rate of 60 Hz and provides a 25-μm-pixel size.

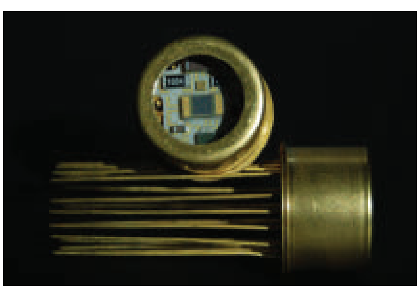
OpGal Optronics
info@opgal.com

Precision Hot Mirrors



ZC&R Coatings for Optics Inc. offers heat-control, dichroic optical coatings that filter unnecessary energy from a light source. The hot mirrors separate unwanted infrared from visible light for applications in the medical, defense, aerospace, life sciences, imaging, astronomy and entertainment industries. The HM-VS-950 models transmit the visible spectrum and reflect the infrared at normal incidence. The HM-UV-1050 UV-pass versions transmit >80% in the 245- to 460-nm spectral range and reflect >70% from 800 to 1050 nm at normal incidence. The HM-VS-1150 color-neutral types are suitable for imaging applications that require high color fidelity, transmitting the visible spectrum with minimal impact on color while reflecting IR energy. The HM-VS-1500 mirrors offer enhanced UV blocking, and the HM-VS-1600 extended-wavelength IR blockers cover a wider waveband in the infrared. Custom angles of incidence are available.
ZC&R Coatings for Optics
jwalker@zcrcoatings.com

Detectors



Lead selenide and lead sulfide detectors with electronics integrated into their industry-standard compact TO-8 hermetically sealed packages have been announced by Cal Sensors Inc. The IDA (integrated detector assembly) infrared detectors cover the 1.0- to 5.5-μm infrared region and provide sensitivity of 1.5E10 Jones. They are available in 1- and 2-mm^2 sizes. The company says that integrating the system electronics into the package expands the measurement dynamic range, provides greater resolution for low-signal detection and reduces the footprint by up to 50%. Applications include industrial and medical gas analysis, automobile and aviation emissions measurement, environmental monitoring, infrared spectroscopy, thermal imaging and flame detection.
Cal Sensors
info@calsensors.com

Diode Lasers

Jenoptik Laserdiode GmbH's Lasers & Material Processing Div. has introduced high-brightness fiber-coupled diode laser modules with up to

65-W optical output power from a 105-μm fiber core diameter and a numerical aperture of 0.15. Features include a compact footprint of 100 × 60 × 25 mm, passive cooling through to the base plate, a lifetime of >10,000 h and an integrated filter that protects against backreflection from the laser beam. Operating in both CW and pulsed modes, the devices deliver a 5-nm FWHM spectral bandwidth, typical, with 7-nm maximum. Typical slope is 6.5 W/A; maximum operating voltage is 20 V, with 16.5 typical; minimum fiber bending radius is 50 mm; and fiber length is 2 m. Applications include pumping of fiber lasers and materials processing.
Jenoptik Laserdiode
jold@jenoptik.com

Bright Lens

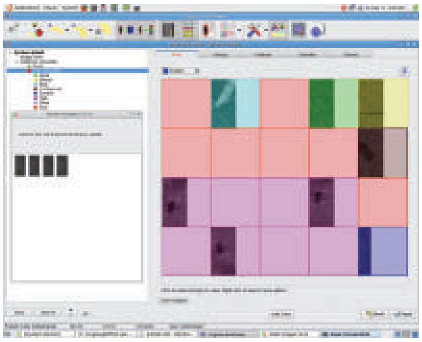
For low-light imaging applications, Universe Kogaku America is offering the EL1205B, a bright CCTV lens with an *f*/0.95 aperture and adjustable focus and iris. The 25-mm lens is suitable for use in surveillance and security applications. Aperture range is from 0.95 to 16, and image size is 16 mm. Back focal length is 13.6 ±5%, maximum distortion is 0.23%, center resolution is 100 line pairs per mm, and corner resolution is 32 line pairs per mm. All surfaces are antireflection-coated.
Universe Kogaku America
info@ukaoptics.com

Test Box

The Fiber Lab 800HE, a test box from M2 Optics Inc., is a rugged testing platform for engineers and technicians working with fiber optic products and networks. It holds up to 25 km of optical fiber in a variety of custom lengths. Fiber can be single- or multimode. The test box is housed in a rugged enclosure and is portable. Connector types are SC, FC, LC and ST, with any angle polish. Applications include manufacturing and development laboratories, harsh environment and field testing, optical network simulation, product development, quality assurance

and delay line testing. The unit includes a storage area for patch cords and other fiber optic accessories.
M2 Optics
sales@m2optics.com

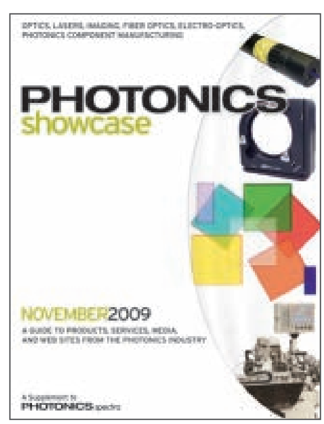
Surface Inspection Software



Cognex Corp. has released VisionPro Surface, a vision software package for inspecting the surface of materials. It combines new visual defect detection and classification technology with a simple user interface for accurate inspection during the manufacturing of solar energy, architectural glass, high-end plastics and materials coatings. The software works by monitoring the visual appearance of the material. Using statistical analysis, it identifies potential defects and classifies them into groups based on similarity in contrast, texture and/or geometry. The user adjusts the system's sensitivity and assigns values to distinguish among different defect types. During production, the system classifies the defects according to the user-defined categories. Features include point-and-click configuration and web-based reporting tools that let the user map, list and view defects with the push of a button.
Cognex
john.lewis@cognex.com

Beam Shaper

MolTech GmbH is offering improved versions of its Focal-πShaper beam shaping systems. The instruments convert a Gaussian laser beam into a beam whose shape is optimized to create a flattop, donut, reverse Gauss or other intensity profile near the focal plane of a focusing lens installed after the shaper. This increases energy efficiency, reduces the heat-affected zone and produces steep edges and accurate profiles of kerfs. The beam shapers can work with scanning heads and *f*-Theta lenses, and models are available for the near-IR, visual and infrared regions, as well as for CO_2 lasers. Applications include laser marking, scribing, dicing, micromachining, photovoltaics, drilling and controlled laser heating.
MolTech
alex@mt-berlin.com



MAY

CLEO/QELS 2010: Laser Science to Photonic Applications (May 16-21) San Jose, Calif. Includes PhotonXpo. Contact Optical Society of America, +1 (202) 416-1907; custserv@osa.org; www.cleoconference.org.

Sensor + Test 2010: The Measurement Fair (May 18-20) Nuremberg, Germany. Contact AMA Service GmbH, +49 5033 9639 0; fax: +49 5033 1056; www.sensor-test.de.

2010 IEEE International Communications Conference (May 23-27) Cape Town, South Africa. Contact Heather Ann Sweeney, +1 (212) 705-8938; h.sweeney@comsoc.org.

SID: 2010 International Symposium, Seminar and Exhibition for the Electronic Display Industry (May 23-28) Seattle. Contact Mark Goldfarb, +1 (212) 460-8090, Ext. 202; mark@sid.org; www.sid.org.

10th International Conference of the European Society for Precision Engineering & Nanotechnology (EUSPEN) (May 31-June 4) Delft, the Netherlands. Contact Debbie Nyman, +44 1234 754 154; debbie-nyman@euspen.eu.

JUNE

Photonics North 2010 (June 1-3) Niagara Falls, Ontario, Canada. Collocated with Photovoltaics Canada First National Scientific Conference. Contact Mélanie Lemay, +1 (418) 522-8182; melanie.lemay@conferium.com; www.photonicsnorth.com.

EIPBN: 54th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication (June 1-4) Anchorage, Alaska. Contact Marty Feldman, +1 (225) 578-5489; feldman@ece.lsu.edu; www.eipbn.org.

Optical Interference Coatings (June 6-11) Tucson, Ariz. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/oic.

Sensors Expo & Conference (June 7-9) Rosemont, Ill. Contact Questex Media Group Inc., +1 (617) 219-8300; www.sensorsexpo.com.

Imaging and Applied Optics (June 7-10) Tucson, Ariz. Collocated topical meetings and tabletop exhibits: Applied Industrial Optics: Spectroscopy, Imaging and Metrology; Digital Image Processing and Analysis; Imaging Systems; Optical Remote Sensing of the Environment; Optics for Solar Energy; and Photonics Metamaterials and Plasmonics. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

Automatica 2010: International Trade Fair for Automation and Mechatronics (June 7-11) Munich, Germany. Collocated with the International Symposium on Robotics 2010. Contact Messe München GmbH, +49 89 9 49 2 01 21/22; info@automatica-munich.com; www.automatica-munich.com.

PAPERS

SPIE Asia-Pacific Remote Sensing (October 10-15) Incheon, South Korea
Deadline: abstracts, May 24
The conference will focus on monitoring the impact of humans on the natural environment of the coastal zone. Papers are being accepted in areas such as lidar remote sensing; remote sensing and modeling of the atmosphere and oceans; and multispectral, hyperspectral and ultraspectral remote sensing technology, techniques and applications. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

Frontiers in Optics 2010/Laser Science XXVI (October 24-28) Rochester, New York
Deadline: paper submission, May 25, noon EDT (16:00 GMT)
Papers are encouraged for Frontiers in Optics and Laser Science, the annual meetings of the Optical Society of America and the American Physical Society Division of Laser Science, respectively. Areas to be considered include photonics, optical sciences, quantum electronics, vision and color, optical design and instrumentation, and optics in biology, medicine and information science. Contact OSA, +1 (202) 416-1907; custserv@osa.org; www.frontiersinoptics.org.

Optical SuperComputing (November 17-19, 2010) Bertinoro, Italy
Deadline: papers, June 9
Organizers of OSC 2010, the Third International Workshop on Optical SuperComputing, invite submissions. The workshop is designed to bring together people from optics and computer science who are interested in establishing principles and developing optical computers. Conference proceedings will be published by Springer in the series "Lecture Notes in Computer Science" (LNCS). Contact Bertinoro International Center for Informatics, +39 0543 4465 00; info@bici.eu; www.bici.eu.

LASYS 2010 (June 8-10) Stuttgart, Germany. Includes a short course titled "Basics on Lasers and Laser Material Processing." Contact Messe Stuttgart International, +49 711 258 9550; fax: +49 711 258 9440; www.messe-stuttgart.de.

EuroLED 2010 (June 9-10) West Midlands, UK. Contact Eve Gaut, +44 121 250 3515; eveg@astonsciencepark.co.uk; www.euroled.org.uk.

Photonics Festival in Taiwan: Opto Taiwan, LED Lighting Taiwan, Solar Taiwan, Optics Taiwan; concurrent exposition: Display Taiwan 2010 (June 9-11) Taipei, Taiwan. Contact Pamela Hsiao, +1 866 2 235 140 26, Ext. 805; exhibit@mail.pida.org.tw; www.optotaiwan.com.

Optical Fabrication and Testing (June 13-16) Jackson Hole, Wyo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/oft.

International Optical Design Conference (June 13-17) Jackson Hole, Wyo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/iodc.

Optatec 2010: The International Trade Fair for Future Optical Technologies, Components, Systems & Manufacturing (June 15-18) Frankfurt, Germany. Contact P.E. Schall GmbH & Co. KG, +49 7025 9206 0; fax: +49 7025 9206 620; www.optatec-messe.com.

Advanced Photonics: OSA Optics & Photonics Congress (June 21-24) Karlsruhe, Germany. Collocated with Access Networks and In-House Communications; Bragg Gratings, Photosensitivity and Poling in Glass Waveguides; Nonlinear Photonics; Optical Sensors; and Signal Processing in Photonic Communications. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

Renewable Energy: OSA Optics & Photonics Congress (June 21-24) Karlsruhe, Germany. Collocated with Solid-State and Organic Lighting; and Optical Nanostructures for Photovoltaics. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

Nanotech Conference & Expo 2010 (June 21-25) Anaheim, Calif. Collocated with Clean Technology Conference & Expo; Microtech Conference & Expo; BioNanotech Conference & Expo; and TechConnect Summit & Expo. Contact Sarah Wenning, +1 (925) 353-5004; fax: +1 (925) 886-8461; www.techconnectworld.com.

SPIE Astronomical Telescopes and Instrumentation 2010 (June 27-July 2) San Diego. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

Laser Optics 2010 (June 28-July 2) St. Petersburg, Russia. Contact Program and Organizing Committee, Institute for Laser Physics of Vavilov SOI Corp., +7 812 328 5734; conf2010@laseroptics.ru; www.laseroptics.ru.

JULY

17th International Conference on Ultrafast Phenomena (July 18-23) Snowmass Village, Colo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/up.

Integrated Photonics Research, Silicon, and Nanophotonics (July 25-29) Monterey/Santa Cruz, Calif. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/ipr.

Photonics in Switching (July 25-29) Monterey/Santa Cruz, Calif. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/ps.

h HAPPENINGS

AUGUST

SPIE Optics + Photonics: Optical Engineering + Applications (Aug. 1-5) San Diego. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; spie.org.

International Conference on Coherent and Nonlinear Optics (ICONO)/Lasers, Applications and Technologies (LAT) (Aug. 23-27) Kazan, Russia. Contact ICONO/LAT Organizing Committee, +7 843 272 05 03; iconolat10@kfti.knc.ru; congress.phys.msu.ru/iconolat10.

SEPTEMBER

EWOFS 2010: European Workshop on Optical Fibre Sensors (Sept. 8-10) Porto, Portugal. Contact INESC Porto, University of Porto, +351 220 402 301; ewofs@inescporto.pt; www.ewofs.org.

Metamaterials 2010: Fourth International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Sept. 13-18) Karlsruhe, Germany. Contact S. Linden, Congress Secretary, +49 7247 82 2861; congress2010.metamorphose-vi.org.

IMTS 2010: International Manufacturing Technology Show (Sept. 13-18) Chicago. Contact The Association for Manufacturing Technology, +1 (800) 524-0475; amt@amtonline.org; www.amtonline.org.

Photonics Media Advertising Contacts

Please visit our Web site Photonics.com for all your marketing needs.

Robert J. Briere, Director of Sales
Voice: +1 (413) 499-0514, Ext. 101
Fax: +1 (413) 443-0472
bob.briere@photonics.com

New England, Southeastern US, Yukon & British Columbia
Rebecca L. Pontier, Regional Manager
Voice: +1 (413) 499-0514, Ext. 112
Fax: +1 (413) 443-0472
becky.pontier@photonics.com

NY, NJ & PA
Timothy A. Dupree, Regional Manager
Voice: +1 (413) 499-0514, Ext. 111
Fax: +1 (413) 443-0472
tim.dupree@photonics.com

Northern CA, NV, Pacific Northwest, Central & Southern CA,
Karen Hardison, Regional Manager
Voice: +1 (916) 990-1473
Fax: +1 (916) 933-0752
karen.hardison@photonics.com

Rocky Mountains, AZ, NM, HI, Eastern, Central & Western Canada, FL
Jason A. Camboni, Regional Manager
Voice: +1 (312) 253-4028
Fax: +1 (312) 277-0912
jason.camboni@photonics.com

South Central US
Susanna L. Rogers, Regional Manager
Voice: +1 (413) 499-0514, Ext. 229
Fax: +1 (413) 443-0472
sue.rogers@photonics.com

Europe & Israel
Penny Pretty, European Sales Manager
Voice: +44 1494 564411
Fax: +44 1494 461198
penny.pretty@photonics.com

Austria, Germany & Liechtenstein
David Round, Advertising Associate
Voice: +44 208 773 9944
Fax: +44 208 181 6178
david.round@photonics.com

China
Hans Zhong
Voice: +86 755 2157 3066
Fax: +86 755 2872 6973
hans.zhong@yahoo.com.cn

Japan
Scott Shibasaki
Voice: +81 3 5225 6614
Fax: +81 3 5229 7253
s_shiba@optronics.co.jp

Reprint Services
Voice: +1 (413) 499-0514
Fax: +1 (413) 443-0472
editorial@laurin.com

Mailing addresses:
Send all contracts, insertion orders and advertising copy to:
Laurin Publishing
PO Box 4949
Pittsfield, MA 01202-4949

Street address:
Laurin Publishing
Berkshire Common, 2 South St.
Pittsfield, MA 01201
Voice: +1 (413) 499-0514
Fax: +1 (413) 443-0472
E-mail: advertising@photonics.com

Packaged spinach stays healthy under daylong light

Barely seven steps into most supermarkets and you are confronted with a wall of green – rows of packaged lettuce and spinach hoping to lure you toward healthy eating habits. Spinach, in particular, is full of nutrition, but how healthy can it be after being drenched in the glow of whitish-yellow fluorescent light for hours on end?

According to researchers in Texas and Nova Scotia, very healthy indeed.

Fresh spinach, especially the smaller, younger leaves called baby spinach, is one of the most nutritionally dense foods on the market. It is loaded with vitamins C, B9, E and K, as well as carotenoids such as β-carotene. Most of these provide antioxidant functions; all provide healthful benefits.

Once packaged produce reaches the store shelves, though, it typically remains refrigerated for days under artificial light 24/7. The packaging itself is transparent, not counting any labeling, which means that the spinach leaves are left to soak up the multi-wavelength radiation. Gene E. Lester and Donald J. Makus of the US Department of Agriculture in Weslaco, Texas, and their colleague, D. Mark Hodges of Agriculture and Agri-Food Canada in Kentville, Nova Scotia, wanted to know what effect the light had on the food.

The group harvested and refrigerated various sizes of two varieties of spinach leaves, then stored the samples in either dark or light conditions for zero to nine days. They then measured the samples' dry weight, plasticity and nutritional composition. They found that, for the most part, the amount of each of the nutrients remained steady – in some cases, even increased – when exposed to 24-h light. Vitamin C, curiously, increased over the first three days, then gradually reverted to baseline over the next six days.

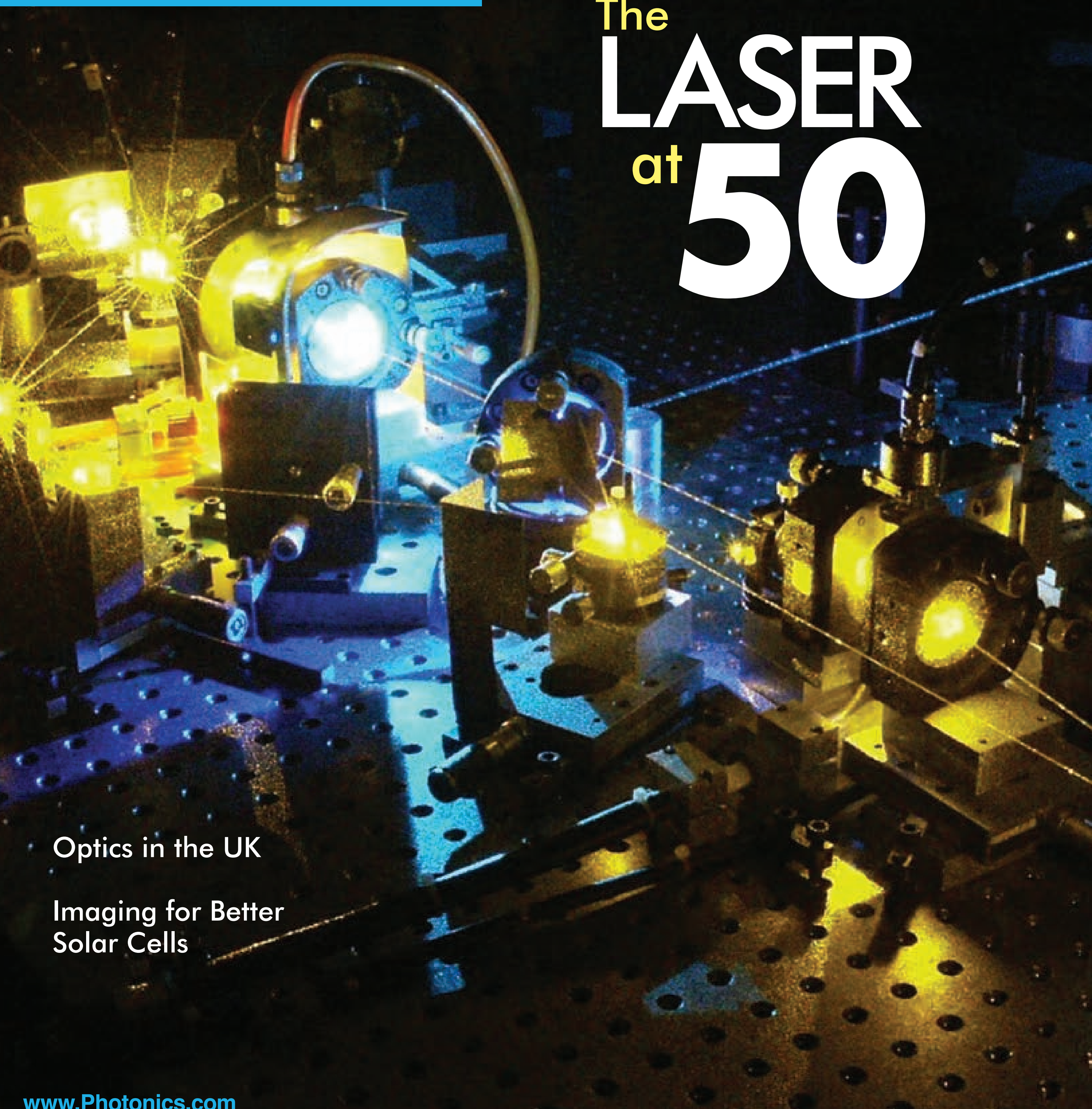
Unfortunately, as the team reports in the March 10, 2010, *Journal of Agricultural and Food Chemistry*, wilting began to increase after the third day of light exposure. The scientists also found that the light intensity is greatest for the packaged produce closest to the top of a stack compared with the light struggling to reach the depths of a display. If the spinach isn't visibly at its peak, it might entice shoppers to move on to the ready-made pizza section of the market.

The group did not address how light levels might affect spinach as it is transported – sometimes for hundreds or thousands of miles – inside dark trucks. Still, its work could result in new ways for growers and grocers to illuminate their products, thus improving, or at least maintaining, the goodness in every bite.

Lynn Savage
lynn.savage@photonics.com

euro PHOTONICS

April/May 2010



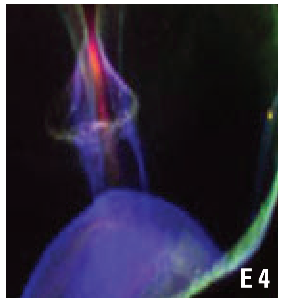
The LASER at 50

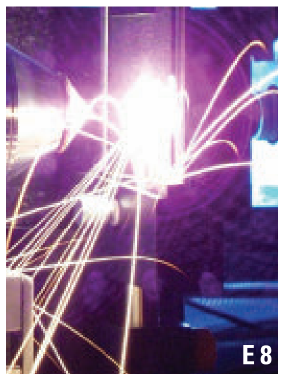
Optics in the UK

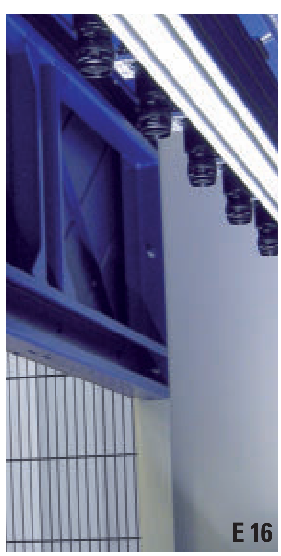
Imaging for Better Solar Cells

euro PHOTONICS

Volume 15 | Issue 3







THE COVER

A dye laser system generates short pulses with durations in the femtosecond range. The cover was designed by Senior Art Director Lisa N. Comstock.

PHOTONICS

The technology of generating and harnessing light and other forms of radiant energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to detection to communications and information processing.

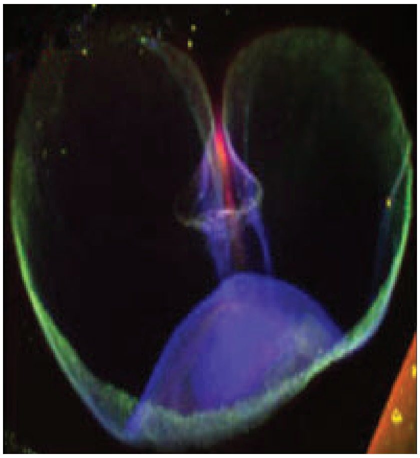
X-rays light the way to more nutritious flour

HARPENDEN, UK – Cereals, breads and pasta could be produced from wheat grain containing higher amounts of essential minerals with a little help from x-ray vision. High-intensity x-rays from the world-famous Diamond Light Source synchrotron in Oxford usually are used to observe metal distribution and chemistry in various samples. Now, however, the powerful x-rays are being redirected to carry out fluorescence analysis of wheat varieties.

Scientists at Rothamsted Research, an institute of the Biotechnology and Biological Sciences Research Council (BBSRC), hope that their studies of wheat could be used to grow potentially life-saving mineral-enriched flour.

"Iron and zinc deficiency has been estimated by the World Health Organization to affect billions of people worldwide, with deaths totaling over 1 million people every year," said Dr. Andrew Neal, who leads the BBSRC-funded project. "These deficiencies arise not because of a lack of minerals in soils, but because wheat and other cereals lay down only limited amounts of minerals in grain tissue. By increasing the amount of minerals that plants allocate to the grain, a more nutritious staple diet could be provided, and many of these deaths could be avoided."

Most of the mineral content of grain is contained in the bran and germ, but when grain is milled to produce white flour, much of the mineral content is lost and therefore missing from our diet. By studying the mineral contents and distribution in grain, the new technique will identify grain varieties that contain increased levels of minerals in the white flour. These new varieties can then be used to develop



Shown is a red-green-blue overlay of manganese, zinc and iron distribution in a cross section of wheat grain. Mineral distribution is limited to the bran and germ (observed as the large structure at the bottom of the grain). No minerals are identified in the white flour.

new commercially available wheat.

At the same time, newly developed varieties that do not contain increased flour-associated minerals can be identified rapidly so that further experimental effort is not wasted on them.

So far, the Rothamsted team has developed techniques of sectioning and visualization that use highly focused x-ray beams to image the distribution of minerals via x-ray fluorescence. This means that distribution data can be collected on a number of minerals simultaneously.

Until now, the only approach was to stain a limited number of minerals one at a time and to observe grains microscopically. "Not only can we now observe many elements in a single grain, we are also able to interrogate the complexation of each mineral," Neal said. "Mineral complexation is important because it determines the bioavailability – digestibility – in the grain."

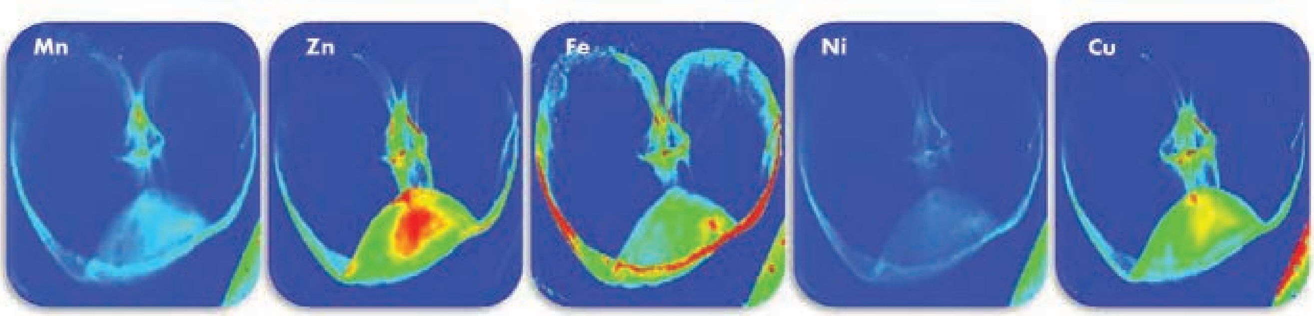
The synchrotron-based approach provides a relatively rapid method of visualizing the mineral distribution within current and new grain varieties. In the imaging process, the synchrotron accelerates and directs electrons at speeds very close to the speed of light to provide high-intensity x-ray beams.

Wheat grains are sectioned and mounted in epoxy resin at a 45° angle to the incident x-rays on an X-Y-Z stage. The sample then is moved in a stepwise manner so that its fluorescence is collected at discrete points, enabling eventual study of the whole sample.

"The fluorescence intensity due to each element in the sample is analyzed by software, and the resulting two-dimensional maps are produced," Neal said. "We have studied two new grain varieties that contain three times as much iron as current wheat varieties. However, fluorescence mapping has detected that the additional iron is stored in the bran of both varieties but is not transported across the bran into the white flour."

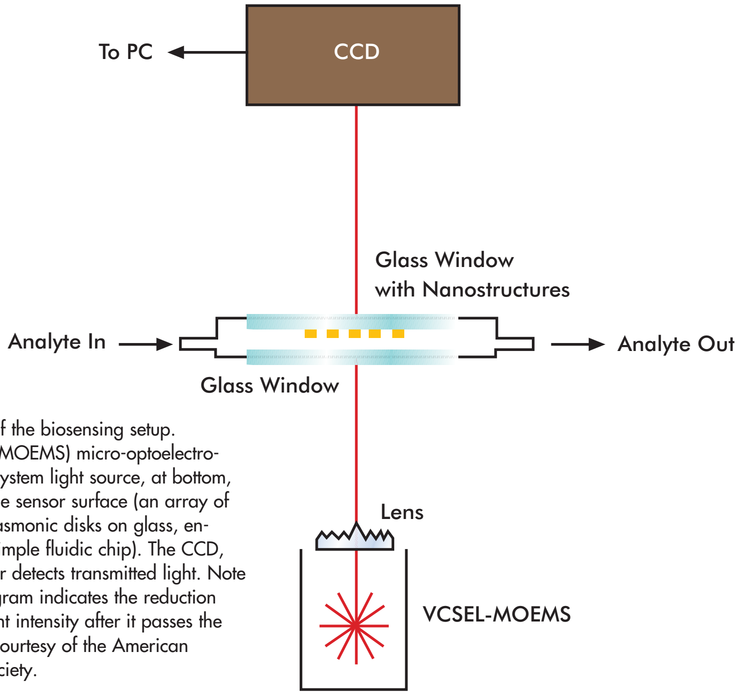
In the next stage of analysis, Neal and colleagues hope to determine not only which cells are preventing the further transport of iron but also the iron chemistry in the cells. This information will be of great use to plant breeders who can employ the Rothamsted results to develop new varieties in which iron transport into the white flour is not limited.

Marie Freebody
marie.freebody@photonics.com



This heat map representation is based upon fluorescence intensity (blue, low; red, high) of minerals in a cross section of wheat grain. Again, the distribution of minerals – manganese (Mn), zinc (Zn), iron (Fe), nickel (Ni) and copper (Cu) – is limited to the bran and germ (observed as the large structure at the bottom of the grain). Images courtesy of Dr. Andrew Neal.

Simpler, more cost-effective biosensing



Schematics of the biosensing setup. The VCSEL/(MOEMS) micro-optoelectro-mechanical system light source, at bottom, illuminates the sensor surface (an array of gold nanoplasmonic disks on glass, enclosed in a simple fluidic chip). The CCD, at top, further detects transmitted light. Note how the diagram indicates the reduction of VCSEL light intensity after it passes the fluidic cell. Courtesy of the American Chemical Society.

GÖTEBORG, Sweden – There are two challenges facing optical label-free biosensing, especially for clinical applications, according to Alexandre Dmitriev of Chalmers University of Technology.

"The system should be able to work in physiological fluids – blood, urine, saliva – which are loaded with all sorts of proteins, creating strong, unwanted background for the biosensor signal," he said. "And the instrumentation should be simple and compact enough to be placed at a point-of-care location and operated by medical – but not research – professionals."

To improve optical label-free biosensing and make it more cost-effective, Dmitriev and colleagues at Chalmers have come up with a system that employs a vertical-cavity surface-emitting laser (VCSEL)/micro-optoelectromechanical system (MOEMS), along with a specially designed nanoplasmonic sensing chip and a CCD detector.

The researchers designed a compact biochemosensing platform based on a VCSEL that generates coherent illumination at 850 nm. Rather than using a commercial one, the group developed its own. Fabricated in an in-house process, it is oxide-confined, with an oxide aperture diameter of 3 to 4 µm. During measurements, the VCSEL drive current was set to approximately 0.8 mA (Its threshold current is approximately 0.3 mA), and the beam divergence was 12° at full width half maximum, which was independent of the drive current.

A microlens, centered above the laser, was used to initially focus the outcoming light into a low divergent beam of approximately 600 µm in diameter as detected at the CCD chip of the regular monochrome Hamamatsu C3057 CCD camera, placed about 10 cm above the laser in the forward direction. A damping filter was inserted in front of the camera to prevent it from saturating.

"Among the developed biochemosensing strategies, those based on optically active nanostructured noble metals that support localized surface plasmon resonances in the visible and near-infrared spectral range are particularly attractive, as they provide the possibility of label-free detection of biological and chemical species with extremely high sensitivity," Dmitriev said. "Additionally, such systems allow the possibility of easy integration."

In explaining the reason for the research, Dmitriev said, “Our motivation was to address the second issue and to ‘strip’ optical label-free plasmonic biosensing of as many optical components as possible, leaving a still fully functional, highly sensitive analytical biosensing device. So in this work we avoided using any optical components – microscope setups, lenses, etc. – having a simple fluid handling cell, a single-wavelength light source and a CCD light detector. Note that all the mentioned components can be integrated in a compact vertical stack. From the biosensing perspective, there is no need for any extra distance between the light source (VCSEL), the fluidic cell with the plasmonic sensing chip and the surface of a CCD detector.” Dmitriev pointed out that these components are also cheap and widely available.

“Of course, the smart design of the plasmonic chip was required to maximize the performance,” he added. “Yet again, the chip itself was made with a very affordable technology: bottom-up large-scale nanofabrication (hole-mask colloidal lithography).

“Nonetheless, despite the simplicity, we straightforwardly achieved very sound sensitivity levels in the detection of protein-protein interactions.”

The group’s results were published in the Feb. 15, 2010, issue of *Analytical Chemistry*.

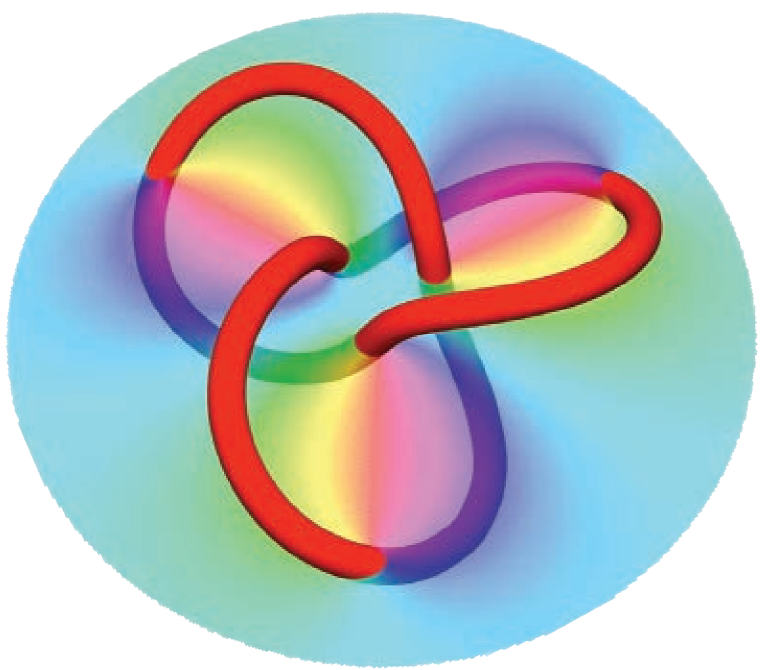
Charles T. Troy
charlie.troy@photonics.com

Twisted physics

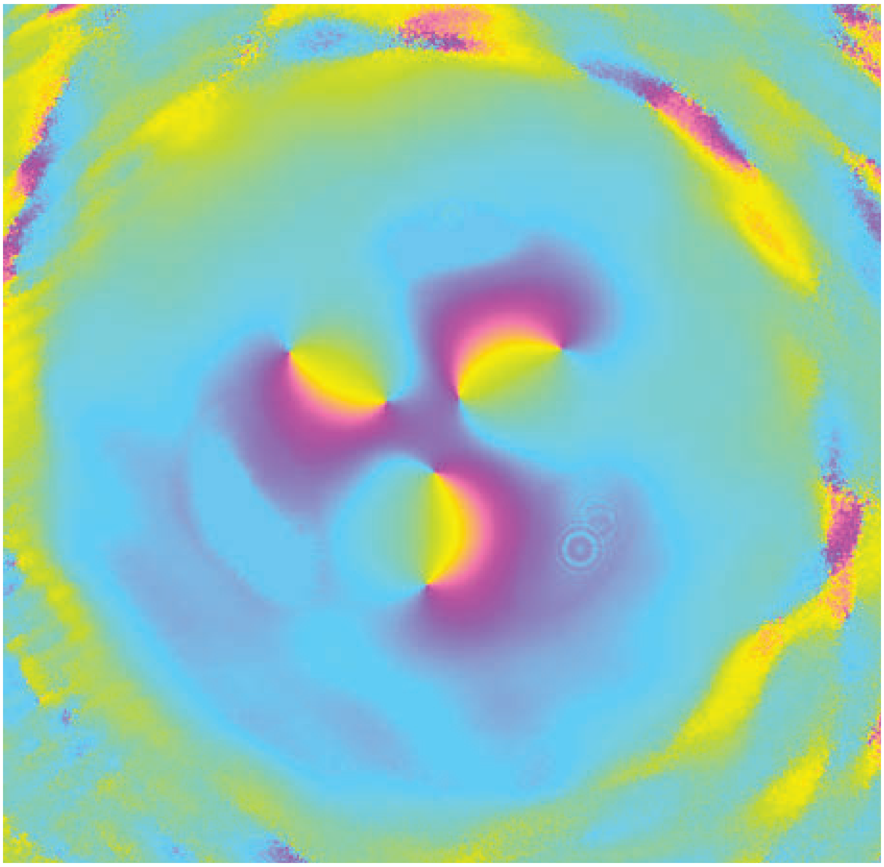
BRISTOL, UK – A group of UK scientists has light theory all tied up in a paper published in the February 2010 issue of *Nature Physics*. Using lasers under holographic control, Dr. Mark Dennis and fellow physicists at the universities of Bristol, Glasgow and Southampton have successfully twisted light into knots for the first time.

Demonstrating such advanced control of light has important implications for laser technology and could be applied to future optical trapping schemes or superresolved fluorescence imaging.

Tying light into knots draws on an abstract branch of mathematics, known as “knot theory.” Although beams of light appear to flow in straight lines, they actually contain lines of zero intensity that flow in whirls and eddies, much the same way water flows in a river. These revolving lines of zero intensity, or blackness,



This image represents the theoretical construction of a trefoil knot. Images courtesy of Mark Dennis, Robert King, Barry Jack, Kevin O’Holleran and Miles Padgett.



This image represents the theoretical construction of a trefoil knot.

are called optical vortices, and, although they can’t be seen, they fill the light all around us.

“The aim was to understand how to create optical vortex knots and create them experimentally using lasers under holographic control,” Dennis said. “Optical vortices are the most general form of destructive interference, and therefore are ubiquitous in optical fields. Without understanding them, we cannot understand the fine structure of light fields.”

Following Dennis’ theory, the Glasgow side of the collaboration optimized the knot recipe to compute the desired knotted field in the waist plane of the laser. The phase and intensity were embedded onto a computer-controlled hologram (based on a first-order diffraction scheme). Next, an incoming laser beam acquired the phase and intensity pattern of the hologram, and a CCD camera mounted on a motorized stage measured the intensity and phase of the knot field, plane by plane.

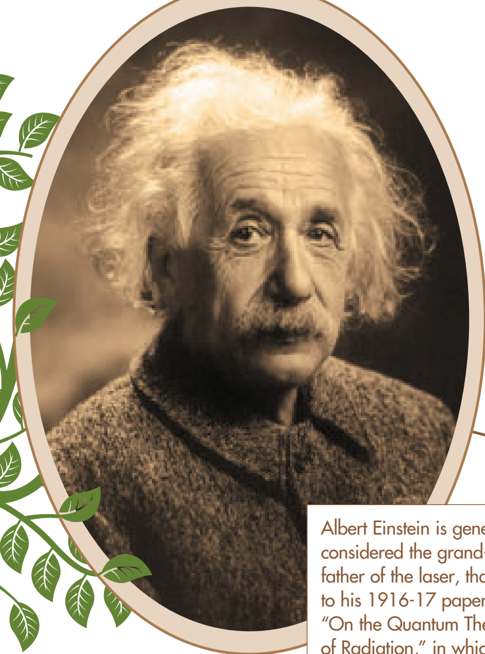
“By understanding [that] how an optical vortex (as a strand of darkness) sits in a bright light beam is related to the way looped curves occupy the 3-D space, we were able to apply abstract mathematical knot theory to find solutions of the laser paraxial equation, which have knotted vortices,” Dennis said.

These techniques frequently are used in sculpting the bright patterns in light beams for applications such as optical trapping, but now the researchers have shown that it is possible to manipulate the 3-D structure of the dark regions of a beam.

Marie Freebody
marie.freebody@photonics.com

Erratum

The CIP Technologies product pictured on page E19 of the December issue of *EuroPhotonics* under the heading “Optical Amplifier” was misidentified. The R-SOA-EAM-1550 should have been pictured. For more information, visit http://www.ciphotonics.com/cip_Monolithic_R_SOA_EAM.htm.



Albert Einstein is generally considered the grandfather of the laser, thanks to his 1916-17 paper "On the Quantum Theory of Radiation," in which he presented the concept of stimulated emission.

The Laser's European Family Tree

As we celebrate the 50th anniversary of the date when the first man-made laser saw the light of day, it is important to look back at its birth. And although that beginning took place in the hills of sunny Malibu, Calif., on May 16, 1960, this groundbreaking invention has quite a few European forebears and descendants.

BY JÖRG SCHWARTZ, EUROPEAN CORRESPONDENT

Ten years before Theodore Maiman first demonstrated a working ruby laser, Alfred Kastler of France proposed a method of optical pumping of paramagnetic atoms or nuclei in the ground state. This was an important step toward lasers and earned Kastler the 1966 Nobel Prize in physics.

In the late 1960s, Theodor Hänsch added frequency-selective elements to pulsed dye lasers, extending their use in spectroscopy and atomic physics applications. He was awarded the 2005 Nobel Prize in physics for his contributions to the development of laser-based precision spectroscopy.

Although it seems that, for this particular baby, a bit of disagreement exists as to who the parents were, there is good certainty about the grandfather: Albert Einstein. He came up with the concept of stimulated emission in 1916-17 in his paper "Zur Quantentheorie der Strahlung" ("On the Quantum Theory of Radiation"). Much later – but still 10 years before Maiman's first demonstration of a working ruby laser – another European, Frenchman Alfred Kastler, proposed a method of optical pumping of paramagnetic atoms or nuclei in the ground state. This was considered an important step toward lasers and earned Kastler the 1966 Nobel Prize in physics.

Stanford professor Anthony Siegman, author of well-known laser textbooks and reviews, sees the development of the laser as having been facilitated by the postwar situation, in which many very capable scientists "returned to their home laboratories, carrying with them … new skills and … pieces of their wartime apparatus – waveguides, cavities, signal generators and receivers, sensitive detection methods – which they were eager to apply to more basic scientific pursuits. At the same time, the wartime experience … led to unprecedented funding." Because of the Cold War situation, financial backing was significant in the US and the Soviet Union, leading to major, speedy steps on both sides.

Europe was in the middle of this competition and, interestingly, the first lasers built in Berlin were constructed around the time the Wall was built in 1961 – "and on both sides of the Iron Curtain," remembers Hans Joachim Eichler, professor at the Technical University of Berlin, one of the first places in Germany where lasers were (and still are) developed. The two researchers who did the first experiments there, Horst Weber and Gerd Herziger, became landmark figures on Germany's laser scene. During their careers, they left a trail of laser research centers that they established in Germany and Switzerland, including the Fraunhofer Institute for Laser Technology in Aachen and Laser Medicine Technology Berlin.

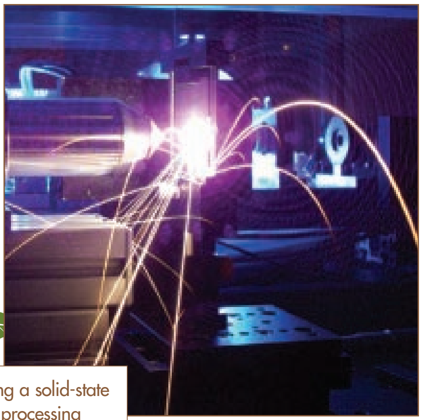
Mastering applications

"Many other of [the] top research centers for laser technology were set up by Europeans returning from the US, such as Wolfgang Kaiser from TU Munich, or Herbert Welling, who made Hanover a center of laser research," says Eichler, who made himself a name in nonlinear optics, one of the first offshoot fields of research, which was practically not possible without the laser. Promoting this investigation were many European research centers, such as the Polytechnic School of Milan, where Orazio Svelto worked on ultrashort laser pulses and solid-state lasers, including the recent invention of the hollow-fiber compressor used in extreme nonlinear optics and attosecond science.

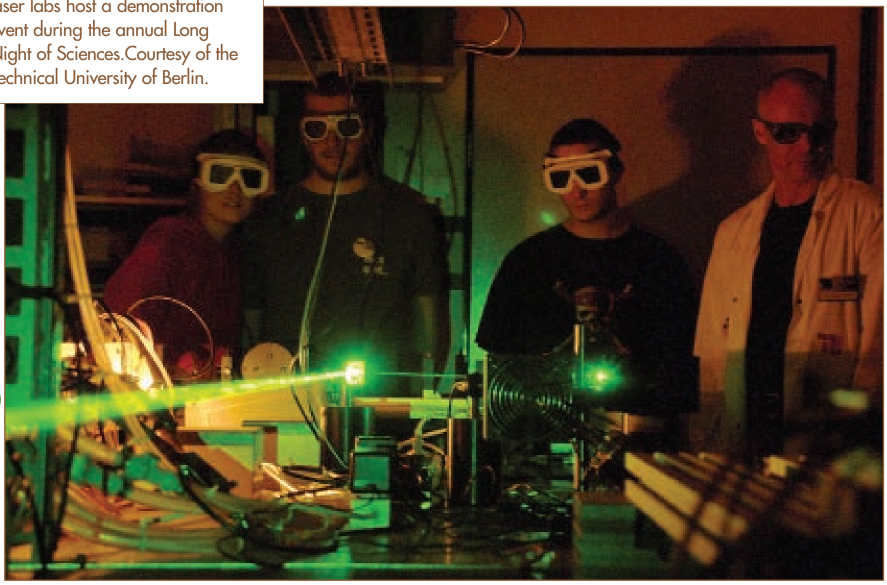
After the birth of the ruby laser, many Europeans were involved in bringing its brothers and sisters to life. For example, groups in the UK – such as Royal Signals and Radar Establishment under Cyril Hilsum – and in France – Maurice Bernard and Guillaume Duraffourg, working at CNET, for example – were strongly involved in developing the first semiconductor laser, launched on Sept. 16, 1962, at General Electric Research Development Center in Schenectady, N.Y. In fact, there are reports that Pierre Aigrain from École Normale Supérieure in Paris was planning to visit the US with a working semiconductor laser in his pocket ... in 1961.

Another sibling that was conceived almost in parallel, but independently, in Europe and the US is the dye laser introduced in 1966 by both Fritz Peter Schäfer at Marburg University and P.P. Sorokin at IBM. A little later, Theodor Hänsch added frequency-selective elements to pulsed dye lasers, extending their use in spectroscopy and atomic physics applications. Incidentally, Hänsch received the Nobel Prize in physics for his contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique he developed.

Schäfer, however, moved to Göttingen to become director of the Max Planck Institute for Biophysical Chemistry, from which the commercial laser manufacturer Lambda Physik was spun off in 1971. Lambda Physik became a very successful player in the fieof excimer and dye lasers and is now part of Coherent Inc. Another example of an early – and yet still successful – commercial player is French Quantel, started in 1970. Quantel remains a big player in the field of solid-state lasers.



A drilling application using a solid-state laser is shown. Materials processing was one of the first applications identified for the laser, and today lasers have replaced classical tools in many fields. One of them is mechanical engineering, in which European companies are historically strong and have maintained their position, thanks to early investments in laser development. Courtesy of the Technical University of Berlin.



Technical University of Berlin's laser labs host a demonstration event during the annual Long Night of Sciences.Courtesy of the Technical University of Berlin.

In general, Europeans have been doing very well in commercializing lasers and developing their applications. "In the early days, industrial giants such as Siemens or Telefunken took a strong interest in developing lasers," Eichler said.

Take Rofin-Sinar, for example, which is a former Siemens subsidiary and today a leading industrial laser supplier. Trumpf, an international heavyweight in the field of metal cutting and welding, has its roots as a "classical" machinery supplier. Berthold Leibinger saw the trend and acquired a lot of the engineering talent in the field, recently by purchasing Southampton Photonics of the UK, a leader in fiber lasers. The company sees great potential in fiber lasers and also in direct applications of semiconductor lasers for materials processing.

Europe has also contributed to general laser applications in telecommunications and consumer electronics. The extremely popular compact disc was developed by Dutch Philips Electronics NV and subsequently commercialized in cooperation with Sony of Japan.

Charles Kao, 2009 Nobel Prize winner, suggested glass fibers for communications in the early 1960s while working at Standard Telecommunications Labs in the UK. Eichler predicts further growth and progress in everyday laser use in medicine and optical sensing. He foresees a bright future for the integration of optics and electronics through the use of silicon photonics and polymer materials. So there is a lot to come for the laser and its offspring, and let's wish them many happy returns – and many more happy children and grandchildren – that is, technologies that would not exist without the laser.

joerg.schwartz@photonics.com

Optics in the UK needs government backing for success

BY MARIE FREEBODY
CONTRIBUTING EDITOR

From Newton's early research on the composition of light and James Clerk Maxwell's study of electromagnetism, to John Logie Baird's patenting of the concept of holey fibers, the history of optics and photonics in the UK is littered with famous names.

Today, the strength of UK photonics lives on in five main areas: defense photonics; plastic electronics; optical communications; medical technology and life sciences; and optical components and systems.

With 96 distinct research groups currently involved in photonics and more than 1500 photonics companies in operation, the field is thriving in the UK. The majority of photonics companies are small- and medium-size enterprises (SMEs), with 70 percent employing between one and nine employees, 22 percent employing between 10 and 49, and 7 percent employing from 50 to 249. Only 1 percent of the UK's photonics companies employ 205 or more workers. A recent study, carried out by the UK's Photonics & Plastic Electronics Knowledge Transfer Network (PPE KTN), found that the UK photonics industry has a turnover of at least £5.9 billion ($8.8 billion) and employs more than 51,000 people.

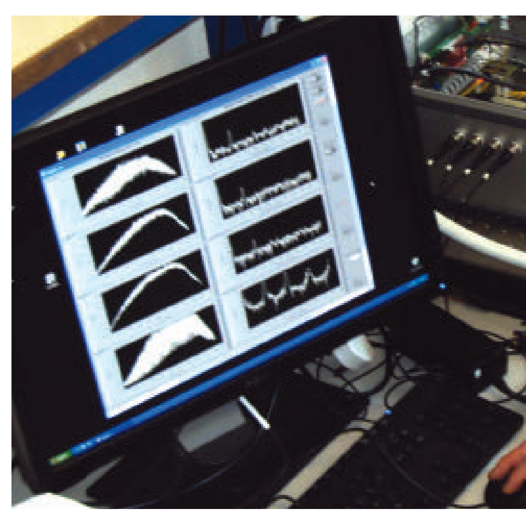
This image illustrates TeraView's highly flexible pulsed terahertz engine. Additional modules and fibers allow its use for a wide range of imaging and spectroscopy applications. Courtesy of TeraView.

Underpinning industrial activities is a solid academic base as well as governmental support. So far, the UK government has played an important role in strengthening certain areas of photonics, but most believe that this could always be improved. In 2007, the UK government launched the Technology Strategy Board (TSB) to promote, support and invest in technological areas that offer the greatest scope for boosting UK growth and productivity.

A key area identified by the board is the global market for consumer electronics and photonic products, which was valued at $291 billion in 2007. Market growth is attributed to the increasing popularity of items such as flat panel displays, digital imaging equipment, CD and DVD players, portable entertainment (of which a large percentage is MP3 players) and portable navigation devices.

According to the TSB's 2008-2011 strategy for electronics, photonics and electrical systems, the UK has the world's fifth largest market for electronic goods and the seventh largest production base; in Europe, it ranks as a close second to Germany. Electronics, photonics, and information and communication technologies directly account for around 10 percent


TeraView offers people screening capabilities using terahertz light. Courtesy of TeraView.



TeraView's tablet imaging instrument for development and quality assurance of drugs. Courtesy of TeraView.

of the UK's economy but also bolster a broader base of activity.

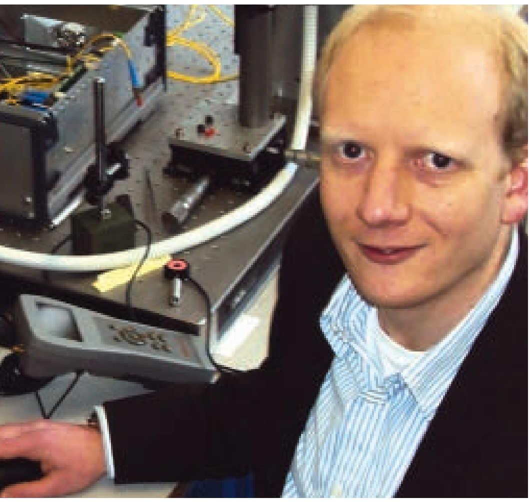
To support growth in this sector, the TSB sponsors the PPE KTN, an initiative that sets out to promote the photonics and plastic electronics sectors of UK industry and academic research and to facilitate the transfer of technology from academic research to industry.

UK sensing hits the headlines

Another area highlighted in the TSB strategy is the global sensors market, estimated at $61.4 billion in 2010. The global instrumentation and control market is estimated at £100 billion with the UK having annual sales of around £12 billion ($17.9 billion); these instruments are an essential part of the £165 billion ($246 billion) of manufactured goods in the economy.

The UK has always had a strong record in developing new sensing techniques. A good example of this is TeraView of Cambridge, which develops terahertz sources and sensors with the support of its collaboration partners. One of TeraView's sensors recently hit the headlines when terahertz light was demonstrated for the first time to detect different types of plastic explosives through clothing; included was PETN, the explosive that the Detroit bomber successfully carried undetected onto an aircraft.

As with many UK photonics companies, TeraView started life as a spin-off from an academic center – in TeraView's case, the Toshiba Cambridge Research Laboratory in Cambridge. TeraView's chief executive officer believes that, although setting up in the UK is simple enough, maintaining momentum can be tricky.



Application scientist Daniel Woods of Michelson Diagnostics is at work on the company's groundbreaking multibeam optical coherence tomography technology. Courtesy of Michelson Diagnostics.

Professor Andrew Harvey, left, of Heriot Watt University in Edinburgh is a director of the Industrial Doctorate Centre in Optics and Photonics Technologies. Courtesy of Heriot Watt University. At right, CEO of Michelson Diagnostics, Jon Holmes, gives his views on the photonics industry in the UK. Courtesy of Michelson Diagnostics.

"Setting up companies in the UK is relatively straightforward in terms of administrative and legal issues," said Dr. Don Arnone. "Raising funds for new ventures, however, is getting steadily more difficult."

The CEO of Michelson Diagnostics in Kent agrees. There are a lot of photonics SMEs in the UK, which suggests that it is easy to start up, says Jon Holmes. However, it is harder for these companies to reach profitability in the UK than in the US, due to a smaller domestic market. This results in most UK startups focusing on export markets, especially to the US, but this is expensive.

Arnone believes that it is up to the UK government to step in and plug the funding shortfall. At the level of fundamental science, there are good programs in place coupled with EU funding. There are opportunities for universities, companies and other organizations, such as the TSB, the Engineering and Physical Sciences Research Council and so on. But as for the transition of technology from early-stage laboratory-based research to field-deployable systems, Arnone believes that there is a gap in the UK government's funding in addressing large markets.

"In the past, this gap was filled by venture capitalist funding, but this is becoming progressively more difficult," he said. "The US government funds such activities through its Small Business Innovation Research and related programs, but the UK lags behind. This has affected critical areas such as homeland security and defense, where new technologies could play an important public role."

According to Holmes, however, photonics is well-recognized by the UK government as a sector with strong potential to address key societal and market needs, such as telecommunications, energy efficiency and health care in the aging population. To date, Michelson Diagnostics has received several matched funding grants to support R&D worth a total of £466,000, as well as advice and support on accessing export markets. In addition, Michelson's investors include seed funds that are backed partly by the government.

Investment from industry

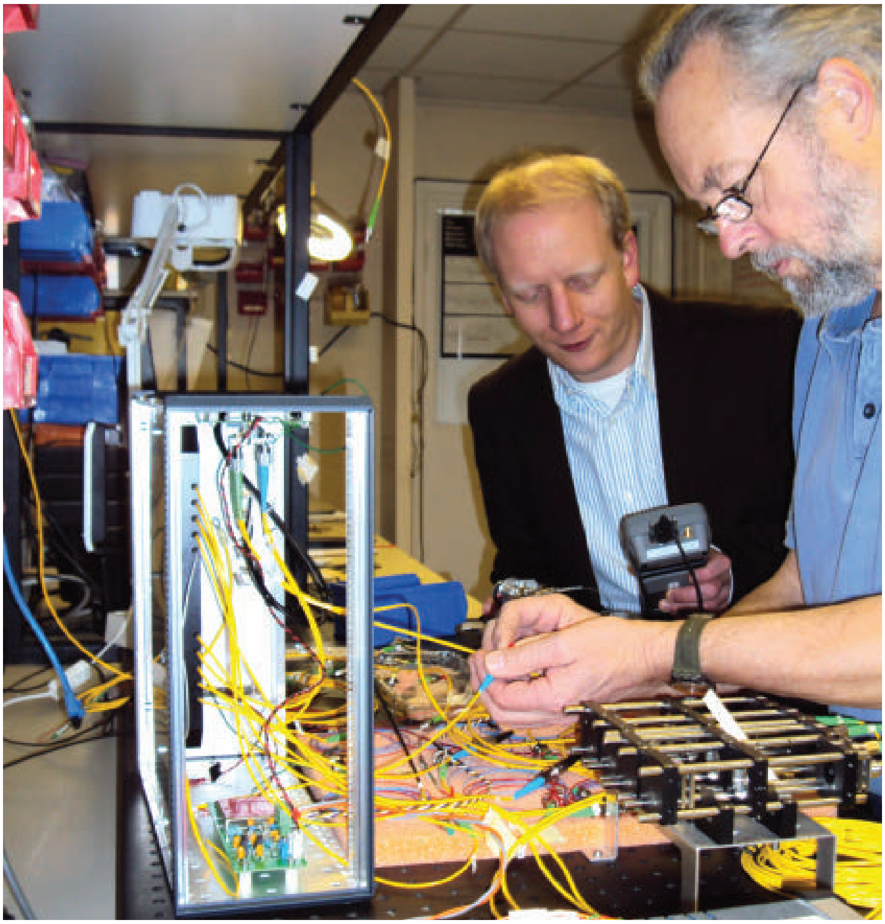
Recognizing the importance of investment is not simply the job of the UK government, however; those within the industry must also play their part. The UK boasts a strong R&D base in laser materials processing (LMP). Although Germany remains the world leader in the use of lasers in manufacturing, there is strong technological know-how in the UK that could be pushed. What is missing, according to Mike Green, executive secretary of the UK's Association of Laser Users (AILU), is a strong market pull from the manufacturing industry.

"German organizations seem to try harder to keep laser processes within Germany (i.e., they use lasers to increase productivity and add value to the product), whereas UK organizations are more willing to export the process to Asia," he explained. "In a recent assessment of LMP machines in the UK undertaken by AILU, we concluded that the use of lasers in Germany per unit of manufactured output is around five to 10 times that of the UK."

Green cites the relatively low level of capital investment by the UK manufacturing industry as another problem. "It is claimed that expected payback times on investments are broadly one year in the UK, three years in Germany and 10 years in Japan," he said. "If true, this would certainly discriminate against high capital cost purchases in the UK. To improve the situation requires a change in attitude in the UK manufacturing industry, including a willingness to increase its level of long-term investment."

Academics versus industrialists

Marrying the pursuits of academia with those of industry is not always easy in any country, but when the right balance is struck, a fruitful partnership can emerge. Holmes believes that, although UK photonics companies work very actively with the academic sector as well as with other firms, cooperation could be further improved by making more funds available



Members of the Michelson Diagnostics team are shown in the lab testing the optics for the VivoSight high-resolution scanner. Courtesy of Michelson Diagnostics.

for small collaborative projects, which could seed larger-scale collaborations.

Andrew Harvey, a professor of optics at Heriot Watt University in Edinburgh and a director of the Industrial Doctorate Centre in Optics and Photonics Technologies, believes that the UK photonics industry would benefit from a narrowing in the gap between the agenda of academics and industrialists.

"Generally, there is significant scope for improving mutual understanding between academics and industry. There remain elements of academic snobbery where practical application is not sufficiently valued and, equally, there are elements within industry that are unaware of the rich potential for wealth creation by partnering with universities," Harvey said. "In reality, there is a large area of overlap where universities and companies can work together for mutual benefit – the key is to find the appropriate funding schemes."

Recruiting photonics professionals in the UK

Although a number of universities offer optics and photonics courses in the UK, it is not always easy to attract students into the industry. Harvey believes that a misconception among students draws them into alternative industries.

"There is a perception that the manufacturing industry, engineering and the sciences are in some way of lower status than the service industries," he said. "I believe that correcting this misunderstanding is the single biggest obstacle to the UK's prospects as a high-wage, high-technology society, but that would be to reverse the deep-seated trend set in place since the end of the industrial revolution."

Perhaps one answer would be to adopt a more industrial approach to learning, suggests Holmes. "We have been fortunate in finding some graduates with the right skills, but it has not been as easy as I would like," he said. "I admire the French system, which places greater emphasis on placing students in industry (fully funded) as part of their degree. This results in graduates who require less training when they start in a company, as they already have exposure to a variety of commercial environments."

marie.freebody@photonics.com

Improving solar module manufacturing with imaging

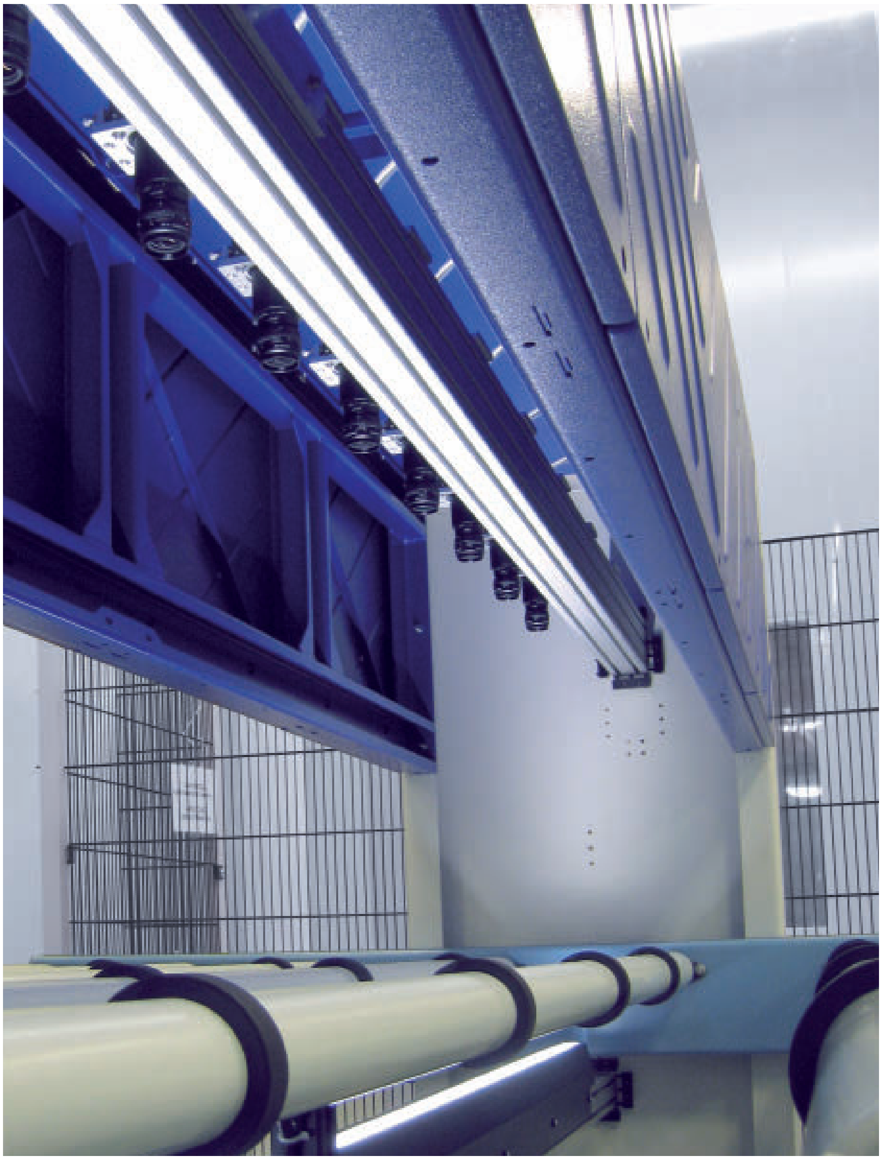
GROßRÖHRSDORF, Germany – In-line metrology systems developed by industrial vision specialist Basler Vision Technologies have been integrated into the production line of solar module manufacturer Sunfilm AG at its Großröhrsdorf plant near Dresden. The company is the first manufacturer to introduce large-scale production of silicon-based tandem junction thin-film modules, at a plant that went into production in April 2009 and uses Applied Materials equipment.

Thin-film solar modules use about 2 percent of the amount of silicon per watt of electricity produced compared with traditional solar cells fabricated using crystalline silicon wafers. Even more importantly, tandem junction cells' photovoltaic devices offer higher efficiency by better utilizing the solar spectrum. They use more than one semiconductor material, each with a different bandgap – i.e., absorption peak – which means that larger parts of the solar spectrum are "harvested" or absorbed and converted into electrical energy. Sunfilm makes cells with two materials, a combination of amorphous and microcrystalline silicon. This combination offers more than 8 percent efficiency with a prospect of 10 to 12 percent in the longer term; solar cells using a single layer of amorphous silicon convert only about 6 percent of sunlight.

Making these cells requires several process steps because the production involves deposition of several thin layers on a transparent conductive oxide (TCO)-coated float glass substrate. Key elements are the absorber layers – i.e., amorphous and microcrystalline silicon – but equally important is the back contact, consisting of another conductive oxide and several metal layers, as well as protective and encapsulation/lamination layers. Accurate process handling is therefore absolutely essential, particularly for large sizes involved. Up to 5.7-m^2 substrates are processed in the factory, so metrology systems are important to support the "latest state-of-the-art process control," as Dr. Wilhelm Stein, Sunfilm's chief engineer noted.

Basler's solution is based on the company's experience in LCD inspection, built over the past 10 years and now adapted and optimized for thin-film applications. It is used to perform three different jobs in the solar cell production line. First, the glass is inspected (TCO-coated or -uncoated), and the cleaning process is checked. At this stage, edge defects are of particular importance because they can

Sunfilm's production facility manufactures tandem junction thin-film solar modules in Großröhrsdorf, Germany. The plasma-enhanced chemical vapor deposition system is important for depositing critical light-absorbing silicon layers on 5.7-m^2 glass substrates, with the quality of the coating being checked by optical metrology systems. Courtesy of Business Wire.



Pictured is Basler's imaging system, first developed for liquid crystal display manufacturing and now integrated into a solar cell production line that can process 5.7-m^2 glass substrates. The system helps improve efficiency and reduces the cost of solar module manufacturing.

lead to glass breakage and significant production downtime.

Once the glass passes inspection, a second system checks the semiconductor coatings applied via plasma-enhanced chemical vapor deposition (PECVD). Here, pinholes are the biggest issue, as they will cause short circuits that reduce the efficiency of the photoactive layers. The detection system not only counts the number but also provides the distribution of the pinholes.

Finally, after the lamination process, the end product is checked for bubbles, scratches and delamination on the peripheral and photoactive areas. Lamination bubbles on the edge of solar modules can lead to penetration of moisture, degrading the lifetime of the product.

The metrology system has been fully integrated with the factory automation system via the SECS/GEM protocol. The semiconductor industry uses this interface for equipment-to-host communications. In an automated fab, it can start and stop equipment processing, collect measurements, change variables or select recipes for products – and now it has the vision to support greener energy more efficiently.

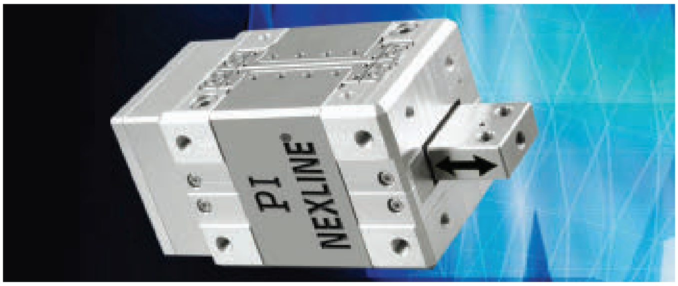
Jörg Schwartz
joerg.schwartz@photonics.com

PRODUCT PREVIEW

Piezo Motor

The N-216 Nexline high-load piezo linear motor from PI (Physik Instrumente) LP is an ultraprecision nanopositioning actuator that provides travel ranges to 20 mm and push/pull forces to 600 N. Based on coordinated motion of a number of highly preloaded linear and shear piezo elements acting on a ceramic runner, the motor is available in two versions for open- or closed-loop operation, as well as in two different load configurations. Used with the company's PiezoWalk drive, it is suitable for high-end applications, including ultraprecision manufacturing, semiconductor test equipment, astronomy and high-energy physics. It can be used also for instrument internals that are difficult to access, where nanometer-realm adjustment and/or vibration cancellation is required.

PI
photonics@pi-usa.us



Light Modulator

The Pluto phase-only spatial light modulators from Holoeye Photonics AG are based on LCOS microdisplays with high-definition TV 1920 × 1080-pixel resolution, and they provide a phase shift of 2π up to 1550 nm. For easy integration into optical setups, they are packaged in a compact 121 × 73 × 22-mm housing. Four models are available, covering the 405- to 700-nm, 700- to 900-nm, 900- to 1100-nm and 1550-nm wavelengths. The programmable devices are supplied with driver software to control settings and image parameters. Tailored application software enables generation of dynamic optical functions such as gratings, lenses, axicons and apertures, as well as calculation of diffractive optical elements based on user-defined images.

Holoeye
contact@holoeye.com

Microscopy Camera

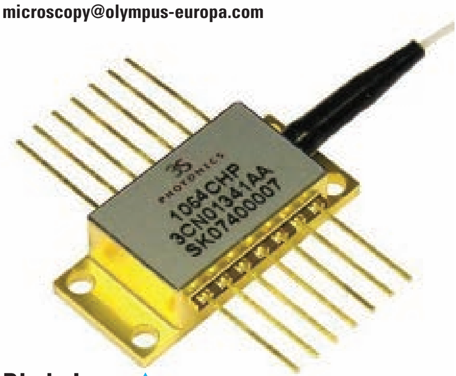
Olympus Life Science Europa GmbH has released the DP21 digital microscopy camera for high-definition, real-time image capture. Suitable for materials and life sciences, the 2.11-megapixel stand-alone camera displays 1600 × 1200-pixel-resolution images at 15 fps, maintaining high definition throughout the focus changes and rapid movement. Featuring an intuitive handset, it enables all functions to be completed without a PC.

Olympus
microscopy@olympus-europa.com

Fluorescence Microscopy

The VivaTome module for fluorescence microscopes from Carl Zeiss MicroImaging GmbH enables developmental and cell biologists to examine the dynamics of biological specimens. For the visualization of fast processes, the system provides quantifiable measurements for cell structures and tissue sections, for example. It uses white-light illumination and operates at rates of up to 30 fps. It can be attached to the proprietary Axio Observer, Axio Imager and Axio Examiner microscope systems using a C-mount. It can also be used to retrofit existing wide-field systems.

Carl Zeiss
g.vogel@zeiss.de



Diode Laser

3S Photonics now offers a 1064-nm wavelength-stabilized diode laser at high power. The 1064 CHP series single-mode module is a pump source designed for both pulsed and CW fiber laser applications requiring operating wavelengths in the 1050- to 1070-nm range. The module contains a fully qualified, internally developed laser chip and is available with a polarization-maintaining fiber single-mode pigtail. The device incorporates a thermoelectric cooler, an NTC thermistor and a back-facet monitoring photodiode. Applications include fiber lasers, frequency-doubling, and pumping and printing.

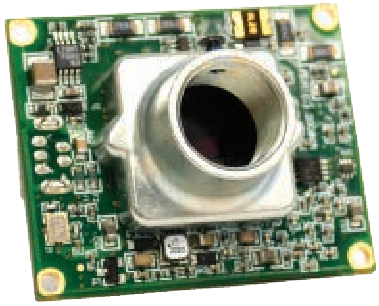
3S Photonics
jphirtz@3sphotonics.com

Terahertz Platform

TeraView Ltd. has unveiled the Spectra 400, a continuous-wave terahertz system with fiber-fed external devices. The compact and fully tunable spectrometer and detector operate in the 50- to 1500-GHz range with high spectral resolution. The turnkey system employs proprietary GaAs-based photomixers and optical fibers for flexibility. The system is suitable for solid-state physics research, terahertz propagation in metamaterials, high-frequency dielectric measurements, gas and solid-phase spectroscopy, medical tissue characterization and nondestructive testing. Imaging and spectral analysis software is supplied, and a gantry can be added for imaging of large objects.

TeraView
phil.taday@teraview.com

Microlens Accessories



Point Grey Research Inc. has introduced new accessories for its Firefly MV, Dragonfly 2 and Chameleon cameras. The cast-metal M12 lens holder is suitable for applications requiring a small, durable optical solution. The holder is made of zinc alloy and is designed to fit larger-format sensors, including the Sony ICX445 CCD and IMX035 CMOS. Other features include a set screw for adjusting back focal distance, dowel pins for precise alignment of the lens holder with the camera circuit board and an infrared cut filter preinstalled to reduce sensitivity in the visible light spectrum to help prevent smear.

Point Grey Research
info@ptgrey.com

Servo Inclinometers

Sherborne Sensors' LSW angular sensors series is designed for use in demanding all-weather applications. Offered in resolutions down to 0.2 arc sec and in angular ranges from ±3° to ±90°, the sensors' full range outputs are ±5 VDC. The rugged, high-precision instruments are designed to withstand mechanical shock to 1500 *g*. They are housed in a durable, stainless steel case and sealed to IP67, with a field-replaceable waterproof connector and cable system. They also are fully self contained and can connect to a DC power source and a readout or control device to form a complete operating system. They are suitable for high-precision measurement within physically challenging environments, adverse weather conditions or where high levels of shock and vibration are present.

Sherborne Sensors
sales@sherbornesensors.com

HT Diode and YAG Filter

Sperian Protection Deutschland GmbH & Co. KG is offering a high-transmission (HT) diode and YAG filter for its laser safety eyewear. Filter 162 has an outer diameter of >6 at 800 to 820 nm, 920 to 1064 nm, and 10,600 nm, with

visible light transmittance of 56%. It is available in the company's Milan and GPT XC laser eyewear, both of which have antifog and anti-

scratch coatings. The GPT XC features custom adjustments and patented multimaterial technology for added comfort. The filter also is available in the Encore over-the-glass spectacle for people who wear prescription eyewear.
Sperian Protection Deutschland
glendale-mainz@sperianprotection.com

SPV Power Supply

The Sunpower SPV (solar photovoltaic), a power supply range from Sunpower UK, is available for applications demanding highly controllable DC power. Providing power possibilities from 150 to 4500 W, the power supply's outputs can be remotely trimmed over a range from 20% to 110% of its nominal value of 12, 24 or 48 VDC. Its automation is enhanced by remote sense inputs and by remote on/off switch control. Alarm signal outputs also are provided. Its compact design features protection against short circuits, overload, overvoltage and overtemperature. Applications include LED lighting, mechanical, electrical and integrated circuit testing equipment.
Sunpower
sales@sunpower-uk.com

Video Processor

Calibre UK Ltd. has unveiled a range of HQView video processors, including eight compact or IU rack-mountable models that perform sophisticated warp mapping and seamless soft-edge blending of multiple projected images. The scaler-switchers combine Integrated Device Technology Inc.'s Reon video processing with Calibre's state-of-the-art HQV (Hollywood quality video) algorithms, hardware and firmware to deliver image quality that is suitable for professional, broadcast and corporate audiovisual applications. Users can select between low-latency and highest-quality image modes, with picture-in-picture, picture-and-picture, or picture-on-picture output.
Calibre
markl@calibreuk.com

Mobile Table

Trumpf Medical Systems has relaunched its Saturn Select mobile operating table for use in any surgical discipline. Featuring an electrically adjustable column and manually adjustable tabletop, it has pneumatic springs that allow the surgical staff to adjust the back and leg plates without undue exertion.

Patients may rest on either the Comfort Plus upholstery or the optional viscoelastic FoamLine pads, which alleviate pressure. Large double-swivel castors permit the table to be rolled into the desired surgical theater or treatment room, transporting patients weighing up to 225 kg. Carbon fiber elements permit 360° fluoroscopy for neuro- and cardiovascular surgery.

Trumpf
info@de.trumpf-laser.com

CCD Camera

Andor Technology plc has announced that its Clara series now offers sensitivity that is optimal for a high-resolution interline CCD camera. Based on Sony's 1.3-megapixel ICX285 sensor, it produces typical read noise of 2.4 e^- and has a standard dynamic range of >6000:1 at 1 MHz. It operates at a rate of 11.6 fps and offers 1-, 10- and 20-MHz readout speeds. The active area is 1392 × 1040 pixels, the pixel size is 6.45 × 6.45 µm, and the image area is 8.98 × 6.71 mm. It features cooling to −55 °C with an internal fan only, and to −20 °C when the fan is off. It is suitable for high-resolution cell microscopy and OEM applications.

Andor
marketing@andor.com

Beam Shaping

Fisba Optik AG has introduced a fast-axis collimator lens with total internal reflection that can deflect beams at a 90° angle and that offers customizable focal lengths up to 1.5 mm. Its beam-shaping optic features near diffraction-limited collimation; its high-performance coating allows for optimized transmission to the laser diode wavelength and features a surface quality that minimizes scattering losses, ensuring a high-brightness beam quality. Its standard line features a numerical aperture of 0.8, transmission of ≥98% and a working distance from 50 to 100 µm over a wavelength range from 800 to 1000 nm.

Fisba Optik
aol@fisba.ch

Tube Auditor

Performing high-speed sample volume measurement that is accurate to better than ±10 µl, the tube auditor from RTS Life Science is a benchtop instrument that is suitable for use in compound management, high-throughput

screening and biobanking applications. It features precipitate and cap detection, image storage and recall, and manual or remote operation, and it can audit a 96-way stimulated Brillouin scattering tube rack in <2 min. Because there is no need to de-cap tubes during the auditing process, samples are kept safe from degradation. Employing vision technology, the system works with Split-septa, Sepraseal, Duraseal and screw caps.

RTS Life Science
lifescience.info@rts-group.com

Miniature Camera

Measuring 22 × 24 × 24 mm, the IDS uEye XS camera from Stemmer Imaging offers an 8-megapixel sensor with an autofocus lens and a USB 2.0 interface. The compact camera provides electronic image stabilization, automatic image control, backlight compensation and a complete software development kit. The built-in face detection and tracking feature can monitor up to four different faces in real time, while providing the viewing angle of every face it detects. Image blur caused by camera motion and vibration can be minimized with the electronic image stabilizer. Autoexposure and white balance functions are also available. With the autofocus feature, the camera can track live images at 15 fps with a resolution of 1280 × 720 pixels.

Stemmer Imaging
info@imaging.de

Data Transmission

VI Systems GmbH has released the A40-300C integrated circuit for optical data transmission applications. Its vertical-cavity surface-emitting laser (VCSEL) driver chip, with serial data rates of 25 and 40 Gb/s over a 50/125-µm multimode fiber, is designed for high-speed optical transceivers. The integrated circuit is suitable for use in conventional VCSEL products and in the proprietary EOM DBR (Electro-Optical Modulated Distributed Bragg Reflector) VCSEL design. Measuring 800 × 600 µm, it can be used universally for voltage or current modulation.

VI Systems
sales@v-i-systems.com

Advertising Contacts

Please visit our Web site, Photonics.com, for all your marketing needs.

Robert J. Briere, Director of Sales
Voice: +1 (413) 499-0514, Ext. 101
Fax: +1 (413) 443-0472
bob.briere@photonics.com

Penny Pretty, European Sales Manager
European Main Office
Laurin Publishing Company
Whitehouse
134 Templewood
Walters Ash
High Wycombe
Bucks, HP14 4UF, UK
Phone: +44 1494 461071
Fax: +44 1494 461198
penny.pretty@photonics.com

David Round, Advertising Associate
Photonics Media
19 Pine Ridge, Carshalton
Surrey, SM5 4QQ, UK
Phone: +44 208 773 9944
Fax: +44 208 181 6178
david.round@photonics.com

USA
Timothy A. Dupree, Regional Manager
Phone: +1 413 4990514, Ext. 111
Fax: +1 413 4423180
tim.dupree@photonics.com

Rebecca L. Pontier, Regional Manager
Phone: +1 413 4990514, Ext. 112
Fax: +1 413 4423180
becky.pontier@photonics.com

Joanne C. Gagnon, Advertising Associate
Phone: +1 413 4990514, Ext. 226
Fax: +1 413 4423180
joanne.gagnon@photonics.com

China
Hans Zhong
Phone: +86 755 2157 3066
Fax: +86 755 2872 6973
hans.zhong@yahoo.com.cn

Japan
Scott Shibasaki
Phone: +81 3 5225 6614
Fax: +81 3 5229 7253
s_shiba@optronics.co.jp

Reprint services
Voice: +1 (413) 499-0514
Fax: +1 (413) 443-0472
editorial@laurin.com

Mailing addresses:
Send all contracts, insertion orders
and advertising copy to:
Laurin Publishing, PO Box 4949
Pittsfield, MA 01202-4949

Street address:
Laurin Publishing, Berkshire Common, 2 South St.
Pittsfield, MA 01201
Voice: +1 (413) 499-0514
Fax: +1 (413) 443-0472
E-mail: advertising@photonics.com