PHOTONICS spectra

December / 2009

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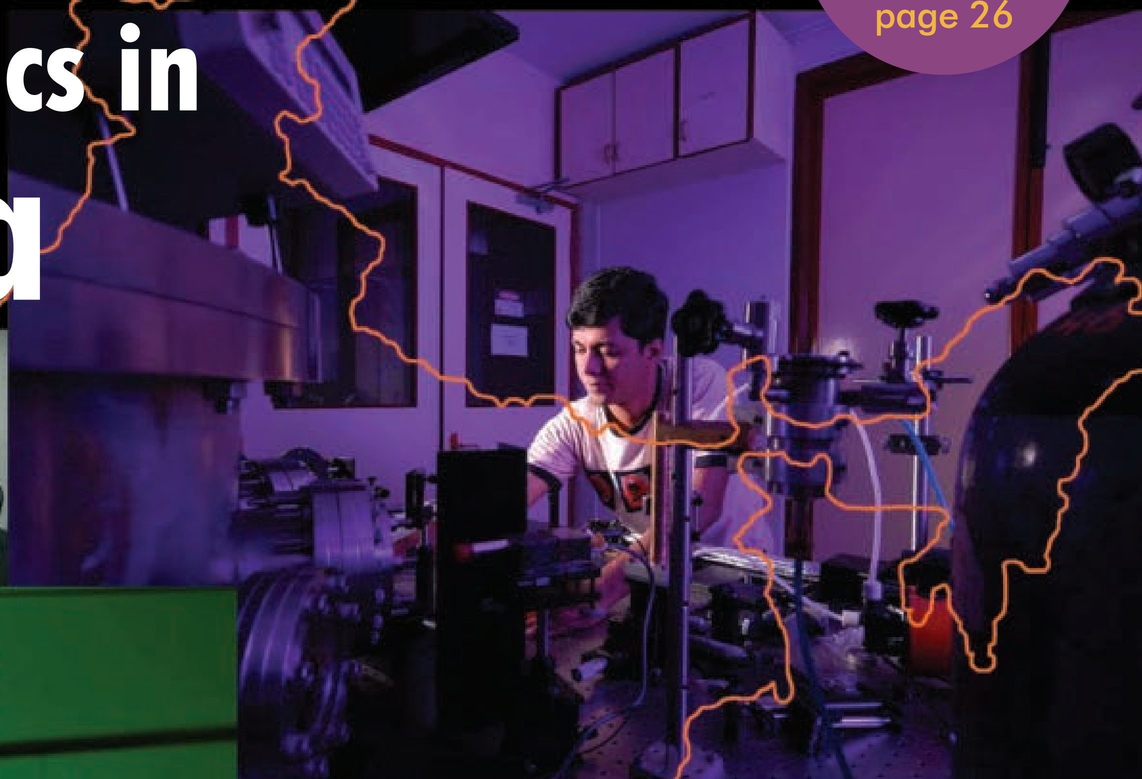
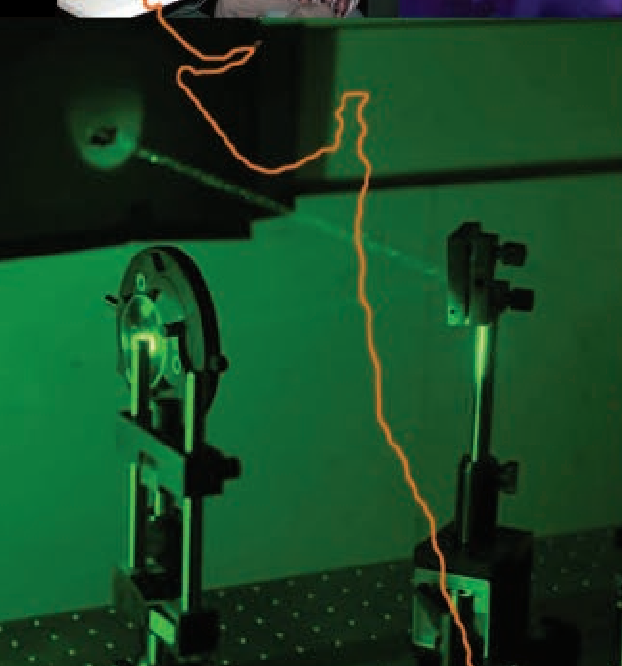
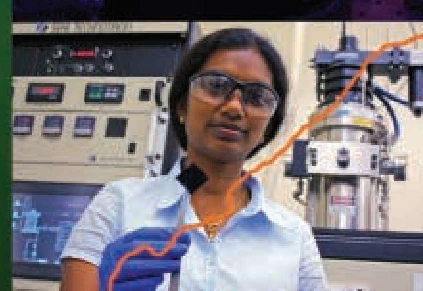
Photonics in India







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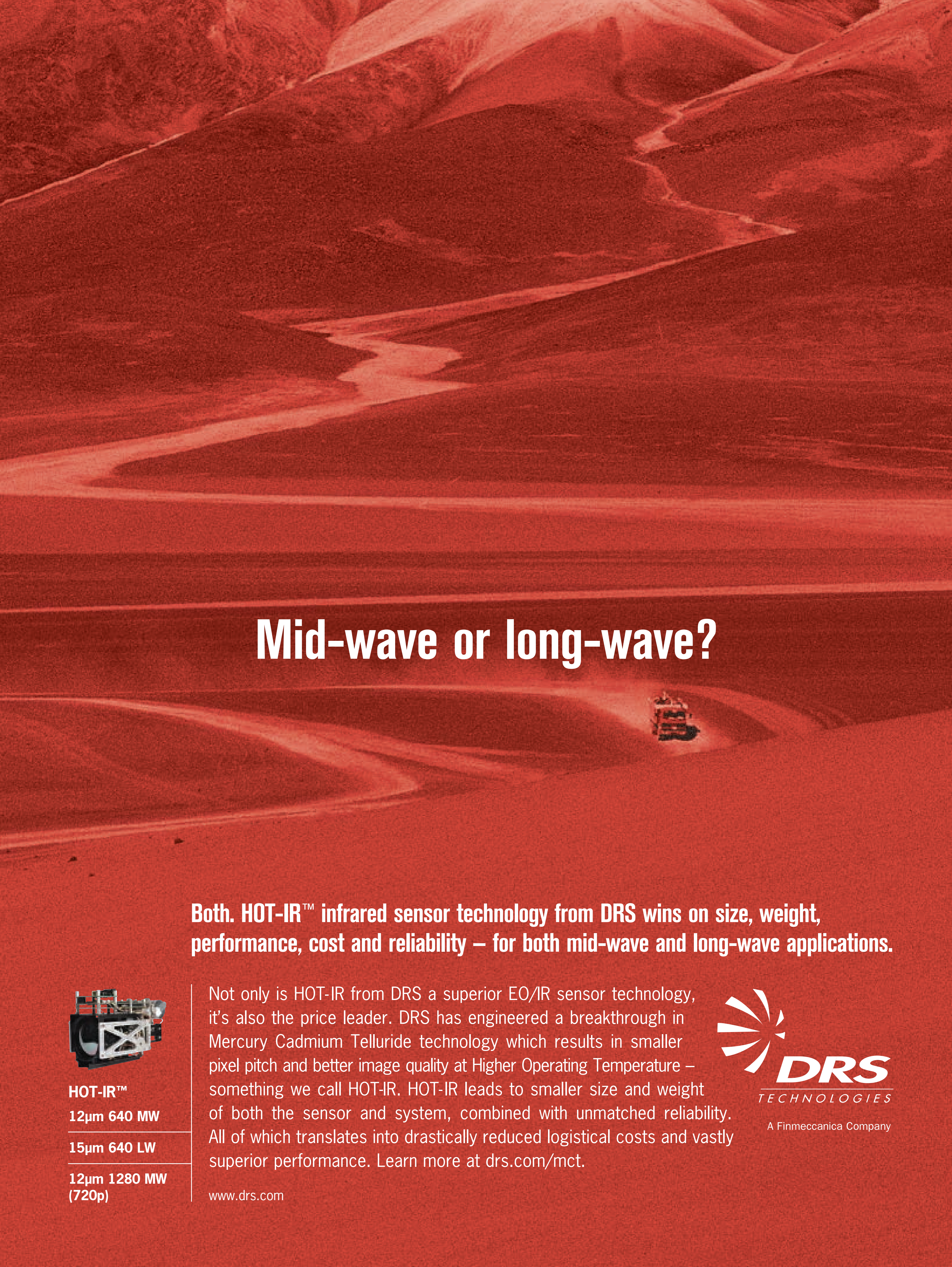
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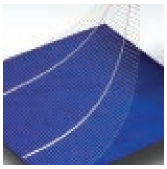
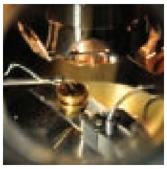
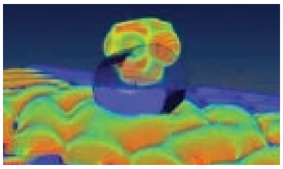

NEWS & ANALYSIS

DEPARTMENTS

THE COVER
This month's cover was inspired by the Indian photonics industry feature on page 35; designed by 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.

Volume 43 | Issue 12
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FEATURES

Special EuroPhotonics Supplement

THE EUROPHOTONICS COVER

This month's cover photo shows student Henning Zimmer setting the last solar panel on Team Germany's house at the US Department of Energy's Solar Decathlon 2009. See related article on page E14. Photo courtesy of Stefano Paltera, US DoE Solar Decathlon.

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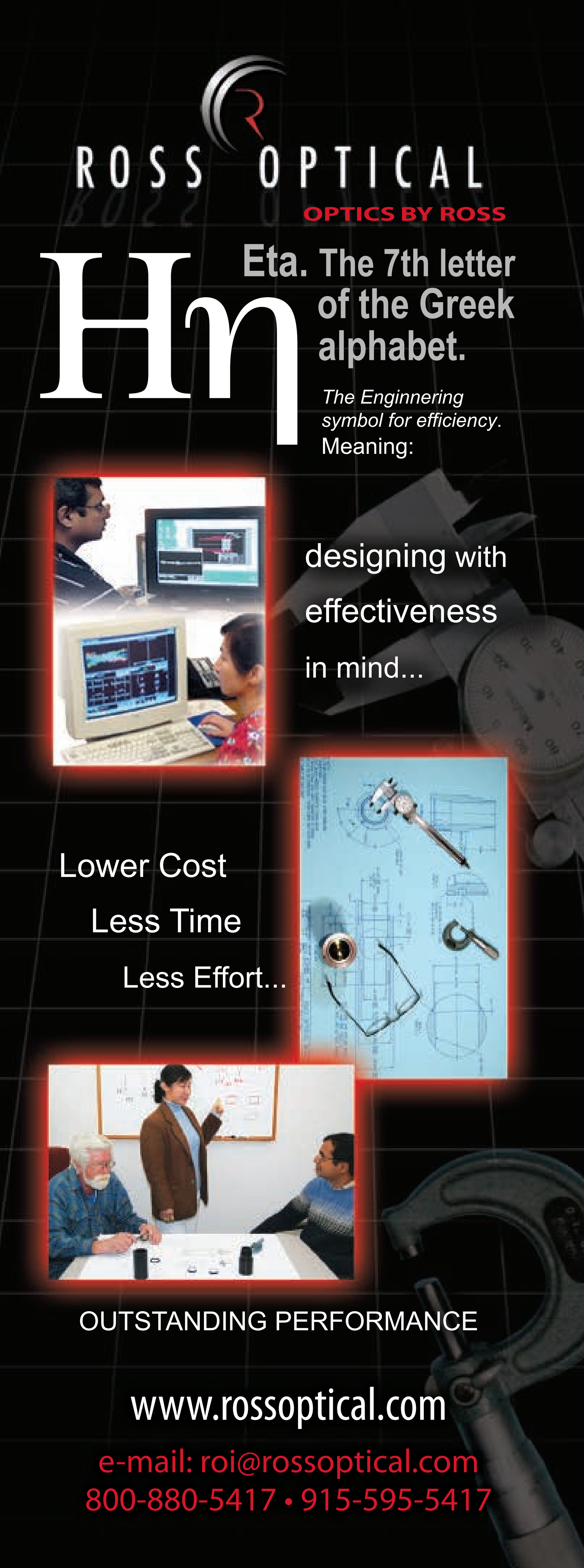

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Ultrasmall, ultrafast, ultraexciting

As we send this issue to press, the very first experiments are lighting up at the Linac Coherent Light Source (LCLS), located at the SLAC National Accelerator Laboratory in Menlo Park, Calif., and operated by Stanford University for the US Department of Energy.

For more than four decades, SLAC's two-mile-long linear accelerator (linac) has produced high-energy electrons for use in physics experiments. And now it has begun a new phase of its career, driving a new kind of laser and creating x-ray pulses that illuminate objects and processes at an unprecedented scale and speed.

The LCLS – the world's most powerful x-ray laser – enables groundbreaking research in all kinds of fields. Its x-ray pulses are reported to be more than a billion times brighter than the most powerful existing synchrotron sources.

Six instruments are planned for the LCLS. The first, already operational, is the Atomic, Molecular and Optical science instrument. The rest are expected to be brought online by 2013 for use by researchers in fields including materials, energy and environmental sciences; medicine; chemistry; physics; and biology.

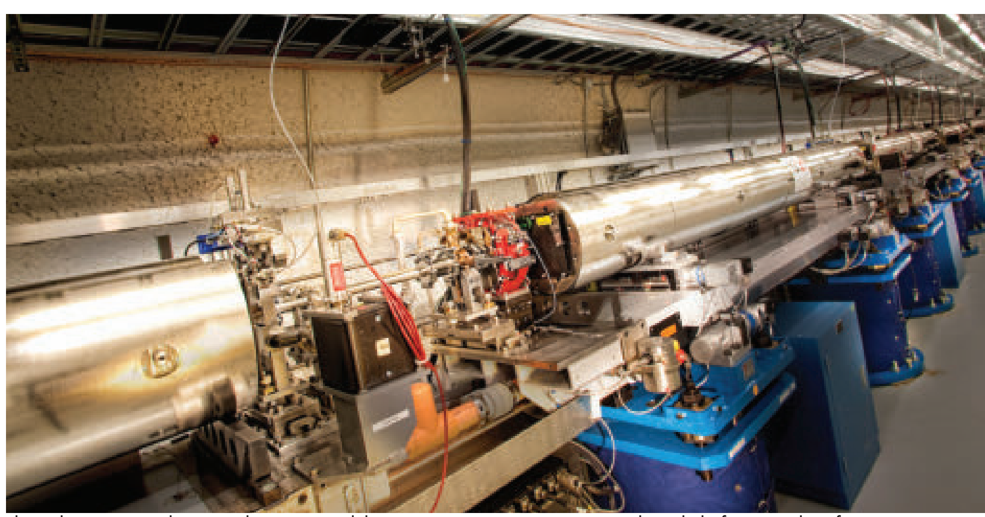
"No one has ever had access to this kind of light before," said Jo Stöhr, LCLS director. "The realization of the LCLS isn't only a huge achievement for SLAC but an achievement for the global science community. It will allow us to study the atomic world in ways never before possible."

Those last three words, "never before possible," are exciting. The photonics industry has a history of staying on the cutting edge, of pushing boundaries and exceeding limits, and whenever a new technology or process is developed that can take us even further – in this case, smaller and faster than ever – it's an inspiration.

The researchers and engineers who developed the LCLS project and those like it are the driving force behind innovation not only in photonics but in basic science, as are those who use these light sources to advance human knowledge and understanding.

We commend them.

Tom Laurin



Thirty-three Linac Coherent Light Source undulator magnets create intense x-ray laser light from a pulse of electrons traveling 99.9999999 percent the speed of light. Courtesy of Brad Plummer, SLAC.

On another planet?

Kevin Bolam's letter in the October issue of *Photonics Spectra* has left me (almost) speechless.

Women are not making breakthroughs in science? Women have passion toward family but not their careers?

In what era is Mr. Bolam living?

Although many women (and men) do prioritize family over career, that does not mean they are not successful, dedicated or passionate!

Perhaps more women are not applying to these positions because they are tired of fighting the ridiculous perceptions and attitudes to which outdated men such as Mr. Bolam continue to adhere.

Emily Kubacki
Director of Sales and Marketing
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Boulder, Colo.

Outdated thinking

Gary Boas' article "Understanding the 'sex gap' in science and math" (September 2009 *Photonics Spectra*, page 45) about Brian Nosek's research on gender stereotypes caught my attention because Nosek's work seems so dated, so "'60s." The obsession with stereotypes seems entirely to have missed a whole generation of research that renders it quite obsolete.

Dr. Leonard Sax has written a fascinating survey of the recent research on innate gender differences, most particularly in the ways boys and girls learn, titled *Why Gender Matters* (Doubleday, 2005). The best way for me to describe modern findings in a few words is to quote from the book: "Are boys and girls really that different? Twenty years ago, doctors and researchers didn't think so. Back then, most experts believed that differences in how girls and boys behave were due mainly to differences in how they were treated by their parents, teachers and friends. It's hard to cling to that belief today. An avalanche of research over the past 20 years has shown that sex differences are more significant and profound than anybody guessed. Sex differences are real, biologically programmed and important to how children are raised, disciplined and educated." Having read Sax's book, I would have to add that the sex differences are *very* important.

I think the belief motivating Nosek – that boys and girls pursue subjects like math and physics because of gender stereotypes – is not just mistaking the symptom for the disease but directing attention and resources to misguided and counterproductive work. One need only observe that females already outnumber males in many sciences, most notably chemistry and biology, to deduce that their upbringing in no way discouraged them from pursuing science in general.

As Sax shows, girls can be highly motivated in any field, given pedagogy that is appropriate to their ways of learning and behaving. Women's schools and colleges are excellent exhibits, where females pursue and excel in traditionally "male" fields like math and physics in large numbers. Where low female enrollments may be perceived as a problem, it is due mainly to natural behavior in the co-educational and gender-neutral educational environment that Nosek is so anxious to promote, not to stereotypes. Gender stereotypes are a false and misleading issue; proper pedagogy that recognizes and takes advantage of the differences between the sexes is where attention is needed.

By the way, somebody needs to speak up for proper English usage, Dr. Sax. "Gender" describes the categories of words in languages like French, German and Latin: feminine, masculine and neuter. The difference between boys and girls is *sex*, not gender.

Laurence N. Wesson
Broad Axe, Pa.

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WEB EXCLUSIVES:

"Watching the Detectors…"
Demand for infrared detectors is growing in a variety of application areas, especially in military, medical and environmental monitoring applications. Gary Boas, news editor for Photonics Media, looks at how two recent developments in infrared detection technology are helping to meet this demand.

Science in the City of Angels
As an extension of his article titled "The value of discovery" in the October *Photonics Spectra*, Gary Boas blogs about his experience at the California Science Center in Los Angeles. He takes us into the museum and shares some of his hands-on experiences, emphasizing the value of informal learning institutions that encourage guests to experiment, to ask questions, to discover – and that inspire them to learn.

Check out a sample of the new digital version of *Photonics Spectra* magazine at www.photonics.com/DigitalSample. It's a whole new world of information for people in the global photonics industry.

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In the January issue of Photonics Spectra …

The January issue of *Photonics Spectra* is our annual trends issue, offering an in-depth examination of the latest and greatest developments in photonics as well as a look at what to expect in the year ahead … and beyond.

- **Trends in Lasers**
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You'll also find all the news that affects your industry, from tech trends and market reports to the latest products and media.

You can't afford to miss this issue.

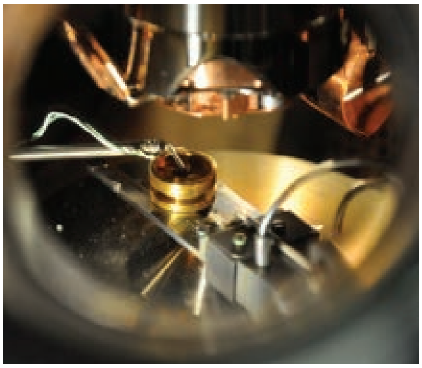
Getting to the electrochemical core makes for better materials science

NOTTINGHAM, UK – Scientists have, for the first time, probed the inner core of electrochemical interactions as they happen. The application of this new spectroelectrochemistry technique could lead to a more efficient and more intelligent design of new materials to be used as catalysts or sensors, said Peter Licence, associate chemistry professor at the University of Nottingham. “Applications could be as broadly ranging as microelectronics, medical, catalysis and performance materials.”

To accomplish this, researchers have devised a way to do spectroelectrochemistry in a high vacuum. Traditionally, such studies are done using infrared, visible or ultraviolet techniques, but these methods yield information only about the outermost electron structure of the electroanalytes.

Getting to the core requires the use of x-rays, which, in turn, means that the reactions must be studied under a high vacuum. Typically, the pressure needs to approach a billionth of a torr, or about a trillionth of normal atmospheric pressure. Unfortunately, most solvents evaporate in a high vacuum. Thus, researchers have used x-rays to analyze electrochemical products after the fact.

To get around this problem, Licence and his group turned to a new class of solvents called room temperature ionic liquids. These are salts that form a liquid at room temperature with very low vapor pressure.



Use of an ionic liquid enabled researchers to perform spectroscopy of electrochemically generated species during a reaction in an ultrahigh vacuum. X-rays produce photoelectrons from the electronic core of analytes placed in the ionic liquid. Courtesy of Peter Licence, University of Nottingham.

Consequently, the materials do not evaporate in a vacuum, and they are electrolytic by nature, allowing them to act as both solvent and electrolyte.

In a proof of concept, Licence and his colleagues monitored the electrochemical reduction of iron, capturing Fe (III) being transformed into Fe (II). They used a cell coated with a millimeter layer of gold and a millimeter-diameter platinum electrode, bombarding the area near the electrode with x-rays. The result was the production of photoelectrons, which the investigators captured using a spectrometer from Kratos Analytical of Manchester, UK.

X-ray photoelectron spectroscopy is a surface-sensitive technique with a penetration depth of only a few nanometers. Even a thin layer on top of the electrode would be enough to keep the x-rays from reaching its surface, which is where the chemistry of interest would take place. The researchers couldn’t stir the electrode around in the ionic liquid as it sat in a vacuum. Thus, it was difficult to see new electrochemically generated species without waiting too long. The group was able to solve this problem and probe the near-electrode area through careful cell and electrode design, Licence said.

Their measurements showed expected results, with photoelectron peaks at the beginning indicating only Fe (III). They then captured the growth of other photoelectron peaks of a lower binding energy, indicating Fe (II). They reported these results in the October 2009 issue of *Chemical Communications*.

Applications of the technique could include construction of molecularly clean surfaces for sensors and other uses. The group already plans to put the tool to use, Licence said. “Our work will now move toward metal deposition and stripping in a controlled environment, hopefully leading to higher-quality film-metal layers for high-tech applications.”

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Fiber laser reaches record length

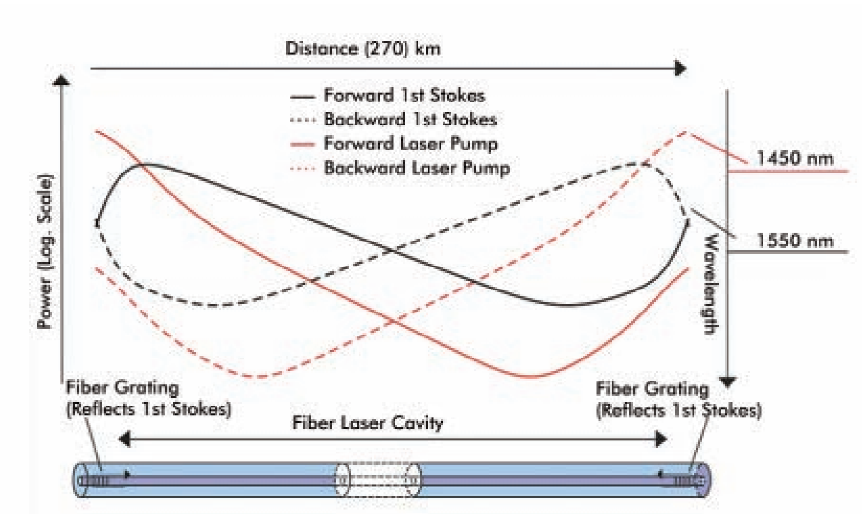
BIRMINGHAM, UK – In a bid to push the boundaries of laser science, a team of scientists from the UK, Spain and Russia has built the longest-ever fiber laser cavity. The group’s aim was to find out just how long it could make a fiber laser cavity in which lasing with a resolvable longitudinal mode structure could still be observed. And the answer is pretty long: 270 km, to be exact.

Such ultralong fiber lasers could be used in future high-speed optical communications systems. Rather than being a source of coherent light, ultralong fiber lasers are an ideal transmission medium for carrying information and providing secure communication.

The fiber laser’s width is approximately 120 Hz and its peak separation, approximately 380 Hz in the radio-frequency spectrum, said Sergei K. Turitsyn, a researcher from Aston University.

“Lasers with such a long cavity and so large a number of modes have never before been studied,” Turitsyn said. “We hope that our results will open up a new research field closely linked with a range of other areas of physics, such as nonlinear science, theory of disordered systems and wave turbulence.”

Despite extraordinary advances in laser physics, only recently have the fundamental limits of laser cavity length become an area of exploration. Turitsyn and colleagues achieved their record-approaching theoretical limits set by relevant physical



This schematic depicts an ultralong Raman fiber laser design and optical power distribution. Pumping at 1450 nm generates laser radiation at 1550 nm. Reprinted with permission from Turitsyn et al, *Physical Review Letters*, 103, 133901 (2009). ©American Physical Society 2009.

effects; first, backreflection of light resulting from fiber medium inhomogeneities.

As reported in the Sept. 25, 2009, issue of *Physical Review Letters*, the technique combines several optical technologies, including the fundamental nonlinear effect of stimulated Raman scattering.

First, distributed Raman fiber amplification provides a gain medium for signal transmission in standard telecommunication optical fiber over distances of 100 km or more. Second, the laser cavity is formed by fiber Bragg gratings, which act as reflectors for 1.5-µm wavelength light. And, finally, both the pumping and signal waves propagate close to the window of transparency of silica, minimizing fiber losses.

The team believes that new applications and technologies will continue to emerge from studying the physics of ultralong fiber lasers.

"Our results indicate that the physical mechanisms underlying the operation of such lasers involve nontrivial, nonlinear interactions of the resonator modes and are quite different from those in other types of lasers," Turitsyn concluded. "We have revealed interesting connections between the new field of ultralong fiber lasers and many areas of fundamental science, and we plan to study the physics involved in more detail."

Marie Freebody
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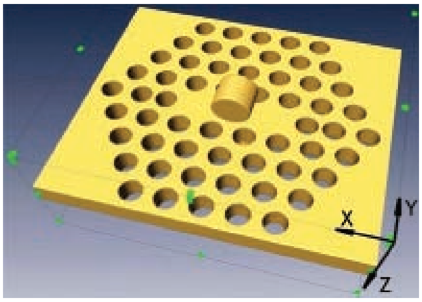
Nanocavity brings optical tweezing down to size

SHANGHAI, China – An international team of researchers is taking steps to bridge the gap between nanophotonics and nanomechanics by harnessing the induced near-field force within a nanocavity.

Yuchuan Jian at Fudan University and at Duke University in Durham, N.C., together with colleagues Junjun Xiao at Hong Kong University of Science and Technology and at Harbin Institute of Technology in Shenzhen and Jiping Huang at Fudan University, has designed the first powerful optical tweezer system that operates on the nanoscale.

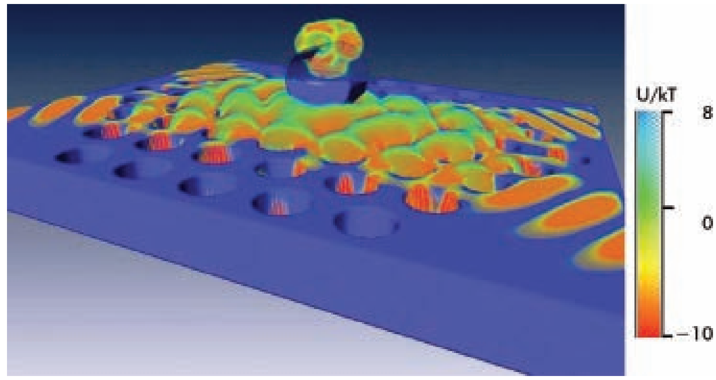
In the device, a strong local field is generated by a nanocavity within a photonic crystal slab. This intense localized force can be used to manipulate, sort and select nearby complex dielectric nanorods.

"For the first time, we have proposed the use of a remarkably localized nanocavity as a general light source," Jian said.



This schematic graph shows the system of a nanorod coupled with the cavity of a photonic crystal slab. Notice that the system axis Z is perpendicular to the slab (X-Y plane) in the figure. Images courtesy of Duke University.

Shown is distribution of the normalized electromagnetic energy (U) in the coupled system. Here, k is the Boltzmann constant and T, the room temperature. An attractive optically induced potential ball is formed at the top part of the nanorod.



"The photonic crystal cavity can exert an optical force on dielectric nanorods that have a high refractive index – much in the same way as a near-field optical tweezer."

Today's optical tweezers use the concentrated gradient potential nature of a tightly focused laser beam to trap cells. However, manipulating objects on the nanoscale requires much stronger confinement of light, beyond the normal diffraction limit.

Jian and colleagues turned to photonic crystal nanocavities, which are ideal candidates for next-generation near-field optical tweezers because of their compact size and straightforward fabrication process. Jian said the devices can locally address individual nanorods, promising benefits to biosensing, cell/DNA isolation and molecule sieving applications.

"Our device could be used in future on-chip integrated photonic circuits on the nanoscale," he noted. "Our specific goal is to show that a potential all-optical coupling operation using light can be achieved by the synthesized optomechanical potentials in this integrated system. We also want to demonstrate that the device can be applied in current semiconductor nanodevice fabrication processes."

In the computational experiment, described in the *Journal of Physical Chemistry C* on Sept. 3, 2009, a dielectric nanorod is placed above a high-Q photonic crystal cavity. An optical-dipole force field surrounds the cavity and interacts with the nearby nanorod. In turn, the nanorod creates small perturbations within the high-Q cavity, which affects the system's behavior and stability.

"An optical force is exerted on the nanorod, which pushes or pulls it to an equilibrium position, thanks to the evolving attractive/repulsive interaction between the nanorod and cavity," Jian said. "What's more, this optical force or light source is tunable through spontaneous emission within the nanocavity."

The Fudan-Duke group recognizes that much work still must be done to bridge the gap between current fundamental research and future industrial applications. The next step is to extend the calculations to investigate an array of nanocavities to see whether both parallel and large-scale manipulation is possible. Another avenue of research planned by the team is to shift the working frequency to determine whether broadband operation is possible.

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Synchronized flying in space makes for good detection

TEDDINGTON, UK – Researchers from the National Physical Laboratory (NPL) are using femtosecond laser combs and optical imaging features on multiple spacecraft with the idea of creating one large detector that will enhance Earth observation and exploration of the universe.

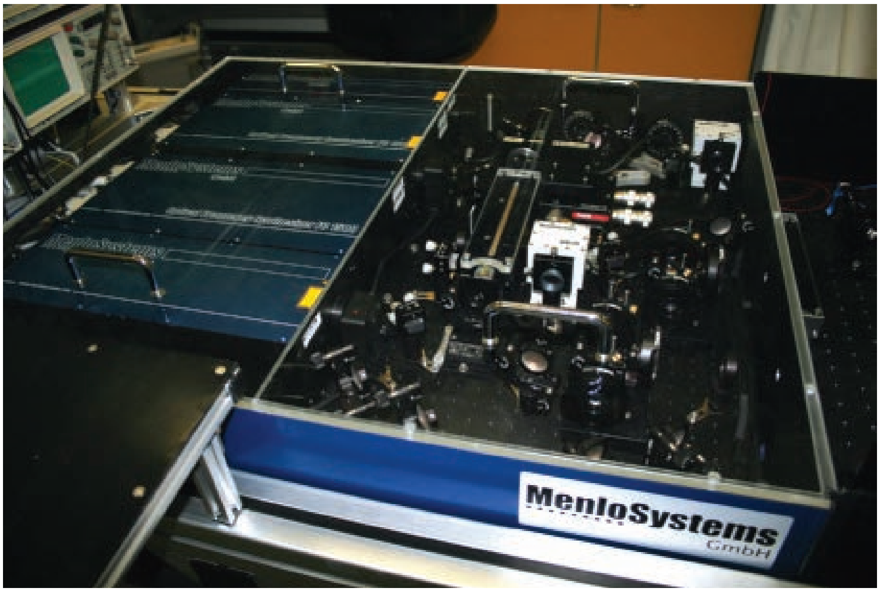
Their theory, that formation-flying spacecrafts could gather data in a way different from a standard spacecraft, might help determine the place from which all magnetic fields originate, answer the age-old question of how the universe developed after the big bang and ascertain whether Albert Einstein's general theory of relativity is true.

Absolutely accurate

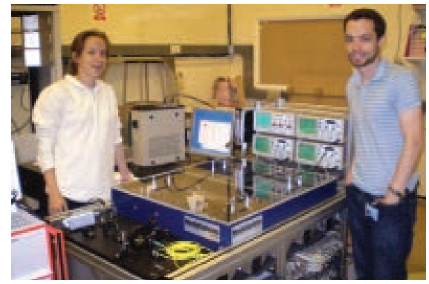
"Rather than trying to launch a craft hundreds of meters in size, comparable performance might be obtained by having two or more small crafts hundreds of meters apart," said Geoffrey P. Barwood, a member of the time quantum and electromagnetics team at NPL. The method is comparable to an individual spacecraft operation because x-rays taken from a "formation flight can have the [same] resolution of a single craft that is of the size of the [overall] formation," he said.

During formation space missions, two spacecrafts are engaged in flight with a regulation of a minimum of tens to hundreds of meters between them. The crafts operate autonomously, positioning themselves in relation to each other via femtosecond laser combs, a detector and optical imaging systems.

To establish formation, the lasers precisely measure absolute distance between crafts by emitting very short pulses of light, each lasting about 5 fs, with a repetition rate of 250 MHz and average power of 70 mW. The pulses are centered at a



Shown is a transportable femtosecond comb laser that is used to measure the frequency of a stable laser source. The mechanism directly converts optical frequencies to low-frequency signals that can be electronically counted. Components include an erbium-doped fiber laser that produces a frequency comb operating at a range of 500 nm to 2.1 µm, a high-stability oscillator and a GPS-disciplined Rapco 2804AR rubidium oscillator. Courtesy of National Physical Laboratory.



National Physical Laboratory scientists Helen Margolis and Barney Walton stand next to their transportable femtosecond comb laser.

wavelength of 1560 nm, designed to determine distance within a few microns by enabling time-of-flight measurements.

The lasers are positioned on one craft, while a second spacecraft carries a mirror to reflect the emitted pulses back to the first craft. The time delay between the emitted and received pulses determines the distance from the known value of the speed of light, Barwood said. "This is required for the correct operation of the detectors on the spacecraft. The imaging optics and detector are on different parts of a flexible craft."

A proposed version of the technology is called the International X-ray Observatory mission, planned to launch after 2010. Barwood said that the system is not a true formation-flying mission, but that the concept is similar because the spacecraft is flexible and requires absolute distance of 300 µm in length and an angle of 10 arcsec between the front and back of the craft to obtain clear, focused x-ray images.

Two obstacles NPL has faced with the technology are the extreme accuracy required by the femtosecond lasers, which must be strong enough to endure takeoff, and the negative effects of space, such as gravitational fields or radiation.

For formation-flying missions to begin, the femtosecond comb prototypes must be verified by a national standards laboratory, such as NPL. Certain specifications also must be implemented, including size, weight and power consumption, to become space-certified.

The project was funded by the European Space Agency with collaboration from Germany-based corporations Menlo Systems GmbH of Martinsried and Kayser-Threde of Munich, and from Laser Centre Vrije Universiteit Amsterdam in the Netherlands.

Amanda D. Francoeur
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"Photonic machine gun" fires up supercomputer research

LONDON – The entanglement of photons is key to developing quantum computers and cryptography devices. However, understanding exactly what entanglement means is tricky, as is generating entangled photons at defined points in time. Researchers at Imperial College London have now come up with an idea for a system that can shoot out large numbers of entangled photons when needed – and they call it a "photonic machine gun."

Quantum computing is a concept that uses the laws of quantum mechanics, such as superposition and entanglement, to perform operations on data. Quantum computers use qubits rather than the bits used by today's computers; although somewhat similar to a classical bit, qubits are quite different. Like a bit, a qubit can have two possible values – normally 0 or 1 – but while a bit *must* be either 0 or 1, a qubit can be 0, 1 or a superposition of both. This means that qubits are described by probabilities – which are not 100 percent as with bits – and measuring them destroys their quantum mechanical nature.

The other difference, also a result of superposition, is that two qubits can be in any quantum superposition of four states, and three qubits in any superposition of eight states, etc. This means that far fewer qubits than bits are needed to compute a large number of states. A quantum computer operates by manipulating those qubits via quantum logic gates – that is, the quantum algorithm – until it is terminated. At that point, the quantum state is collapsed down to classical (probability) values and the result being read.

The need for relatively few qubits for complicated operations is the good news, but the bad news is that all of them must be entangled – i.e., they need to know about each other in a quantum-mechanical sense. "When looking for possible realization of qubits, photons don't look very promising at the first glance," said Dr. Terry Rudolph, a researcher at Imperial College. Although photons can be used for quantum communication (See "Alice and Bob talk quantum encryptedly across Vienna," October/November 2009 *EuroPhotonics*), entangling them for quantum computing is not straightforward because photons do not interact with each other.

One way around this involves using the fact that photons do interact with other particles, such as atoms, and achieving the entanglement indirectly through interaction with such a mediator – for example, in a microresonator (See "Catching photons in a bottle," October/November 2009 *EuroPhotonics*). But another, more direct, approach is making the photons entangled at the time when they are generated, which is central to Rudolph's new proposal with colleague Netanel H. Lindner from Technion-Israel Institute of Technology in Haifa.

Rudolph and Lindner suggest using a quantum dot, a special energy-level structure that is included in many semiconductor devices these days, at low temperature. In a process referred to as "creation and subsequent decay of a charged exciton (trion)," electrons in the quantum dot are excited by a light pulse. Upon relaxation, the energy is released as a photon that is entangled with the electron. Under the right circumstances, the electron "remembers" this, and the next electron being released is also entangled with the electron – creating two photons that are entangled via their joint relationship to the electron. And repeating the process yields a third photon, also entangled with the previous two photons, and so on.

The other good news is that the generation of these entangled "clusters" can be triggered, unlike other methods of generating entangled photons – via interferometers, for instance, in which case generation is based on statistics, so a lot of luck is needed to make more than two entangled photons. The only bad news about the "machine gun" proposal presented in the Sept. 11, 2009, edition of *Physical Review Letters* is that it is purely theoretical so far. However, "all the pieces are there, and I know that quite a few people are out there trying to make this happen – as there is almost certainly a *Nature* paper in it," Rudolph said.

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Machine vision market: Registering recovery?

WELLINGBOROUGH, UK — In the fourth quarter of 2008, machine vision companies saw sales fall an average of 15 percent from fourth quarter 2007 figures, according to John Morse, senior market analyst for the Automation Control Group at IMS Research. The firm's research showed that some machine vision companies saw up to a 50 percent decline in sales revenues during the first two months of 2009.

As a result, in May, the company reduced its worldwide forecast for machine vision hardware, from 2008 to 2009, from a predicted growth of 7 percent to a revenue reduction of 13.4 percent. It indicated at that time that sales to the automotive, semiconductor and related industries were the worst affected, while sales to medical and infrastructure-related industries fared better.

In September, IMS Research reported that the machine vision market appeared to be on the road to steady recovery, based on data submitted by companies that supply machine vision-related products. Data for the second quarter of 2009 signaled that the machine vision market revenues in America, Europe, the Middle East and Africa experienced some leveling, Morse said. The apparent stabilization could be the result of more encouraging economic forecasts – and restocking within the industry – after many users had been living off their inventory since the downturn hit, he added.

"Asian revenues were estimated to have grown 10 percent in second-quarter 2009, following a sharp decline in the first quarter," he said. "Around 40 percent of the machine vision business in the Asia-Pacific region is centered in Japan, which suffered particularly badly when the downturn hit." Japan relies on exports to Europe, North America and other regions, and demand from these areas had dried up during the recession, he explained.

Morse said that some leveling off of the affected markets, possibly even mild growth, was expected in the third quarter of 2009, driven mainly by auto-related industries such as machine tooling, which is seeing a slight increase in orders.

He considers the main challenges for the machine vision market to be survival and riding out the economic storm, without sacrificing the staff and resources that can be used to advantage when the upturn comes. He said the main drivers in the upcoming years will be the overall economic need for automated inspection to reduce manufacturing costs and ensure the quality of products. An important application is in-line inspection, especially where records must be kept, such as for pharmaceutical products and aircraft parts, he said.

Smart growth

Paul Kellett, director of market analysis at the Automated Imaging Association in Ann Arbor, Mich., expects that smart cameras will continue to have a high rate of growth. He said that, once capital budgets begin to increase, cameras offering high bandwidth interfaces and frame rates also are likely to sell well, along with other machine vision products used with them.

He said that the value proposition of machine vision likely will prove increasingly compelling. He noted that recovery in the broader economy is not immediately translating into recovery for the machine vision industry.

First, Kellett said, the manufacturing sectors must begin to expand, and then production capacity must be sufficient to entail increases in capital budgets. Until capital budgets start to increase, there will not be much growth in machine vision orders, he said. Those orders then must be converted to shipments before sales revenue is realized. To the extent that sufficient inventory does not exist, new machine vision products must be manufactured, resulting in additional delay in revenue realization from the product order cycle.

In nontraditional industries, machine vision technology will enable new applications, such as the inspection of solar cells, microelectromechanical devices, weld seams on wind turbine tower sections and turbine blade surfaces, and advanced lithium battery electrodes and enclosures, Kellett said. As recycling grows in scope, the need for automated sorting based on machine vision technology will grow with it, he added.

Machine vision companies may be able to capitalize on the current efforts of automobile companies to develop electric cars and the advanced new batteries that will be used to power them, he said, noting that the US government's Advanced Battery Manufacturing Initiative is an available source of funding in this area.

Countries with modernizing economies such as China and India may be considered rising areas of demand for machine vision products, as well as established countries where new technology markets are emerging, Kellett said.

"Like other industries, machine vision has suffered through the 'great recession.' While that has been long and painful, and will not end this year, the longer-term prospects for machine vision look bright. Time is on our side," he said.

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Chinese photonics expo scheduled for March

SHANGHAI, China – Laser World of Photonics China 2010, the country's leading photonics exhibition, will be held March 16 to 18 at Shanghai New International Expo Center and will present the latest laser and photonics technology and applications. Held yearly since 2006, the show will feature more than 200 exhibitors on a floor space measuring 11,500 sq m. International companies, representing about half the exhibitors, will include Rofin, Trumpf, Coherent, Newport, Dilas, GSI Group, Physik Instrumente and IPG Laser. The event will be held in conjunction with a conference organized by Messe München International, with representatives from research institutes and industry associations, and with media partners from China and elsewhere.

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2009 Prism Awards finalists named

Prism Awards sponsors Laurin Publishing and SPIE have announced the finalists in the 2009 competition. The Prism Awards for Photonics Innovation recognize the best in new photonics technology and products worldwide. Finalists in each of the nine categories – Optics; Lasers; Other Light Sources; Detectors, Sensing & Imaging Systems; Analytical, Test & Measurement; Photonics Systems; Photonics Processes; Sustainable/Green Technology; and Life Sciences – are listed below.

The distinguished panel of acknowledged technology experts chose three finalists in each category, with the exceptions of Analytical, Test & Measurement and Other Light Sources, where there were ties. The winners will be announced during SPIE Photonics West on Wednesday, Jan. 27, 2010, at the Prism Awards ceremony and banquet in the Grand Ballroom of the Hilton San Francisco Union Square.

The finalists by category:

Optics

OneChip Photonics
OneChip PIC-based PON transceivers
Fully integrated passive optical network transceivers for access networks and other mass-market broadband applications.

Semrock Inc.
Polarizing beamsplitter filters
Polarizing bandpass filters that combine an *s*-to-*p*-polarization extinction ratio of $<10^{-6}$ with high transmission, steep edges and deep blocking of a high-performance bandpass filter for *p*-polarization. The filters provide larger apertures than thin-film coatings.

Swamp Optics
BOA pulse compressor
A pulse compressor for shortening ultrashort pulses.

Lasers

High Q Laser Innovation GmbH
picoEMERALD
This remote-controlled, hands-free one-box CARS light source provides pump and Stokes pulses that overlap in space and time.

Laser Operations LLC – QPC Lasers
Brightlock Ultra-G
A compact, athermal, multiwatt green laser (532 nm) with near-diffraction-limited beam quality based on on-chip wavelength stabilization of high-brightness laser diodes.

VI Systems GmbH
Ultrahigh-speed components for data networks
An electro-optical modulated EOM distributed Bragg reflector VCSEL.

Other Light Sources

Hamamatsu Corp.
160 kV open-type microfocus x-ray source
A microfocus x-ray source (MFX) with 0.25-µm resolution for x-ray nondestructive inspection and computed tomography.

Innovations in Optics Inc.
LumiBright LS line source
The LumiBright LED high-intensity white-light line source is characterized by uniformity and long life. It is available in 4- to 24-in. lengths and in wavelengths from the UV to the near-IR, including broadband white.

Innovations in Optics Inc.
LumiBright LE light engine
The LumiBright LE ultrahigh-brightness light engine offers a high-intensity LED light engine, with several integrated nonimaging optics choices. It includes an integrated photosensor and thermistor option for closed-loop monitoring and control. The LEDs are mounted on a metal core PCB for optimal thermal performance, intensity and lifetime.

National Tsing Hua University
Sunlight-style color-temperature tunable OLED
The sunlight-style color-temperature tunable organic LED can change its color temperature throughout the day, matching the natural daylight chromaticities produced by the sun.

Detectors, Sensing and Imaging Systems

GE Healthcare
Gemstone HD CT detector
The Gemstone high-definition detector enables higher special resolution and material decomposition through fast kilovolt switching, lower patient radiation dose and better image quality.

InfraTec Infrared LLC
MEMS tunable Fabry-Perot interferometer microspectrometer for infrared absorption spectroscopy
This device targets mid-wave-infrared gas analyzer and spectroscopic applications to identify substances by detecting their unique absorption signatures. It is based on a bulk micromachined spectrally tunable Fabry-Perot interferometer with an electrostatically tuned air cavity integrated into an infrared detector.

Novelx
mySEM
The patented Novelx stacked silicon technology was designed wafer-scale using semiconductor processing technologies. In a small form factor that installs easily, the system's low-voltage imaging capabilities offer sub-10-nm resolution.

Analytical, Test and Measurement

Agilent Technologies
Scanning microwave microscopy
Scanning microwave microscopy mode from Agilent Technologies is an atomic force microscopy method designed to enable quantitative electromagnetic materials characterization at high resolution.

Lehighton Electronics Inc.
1605 mobility mapping unit
This instrument measures electron mobility, sheet resistance, carrier concentration and density in a noncontact, nondestructive manner, eliminating destruction of expensive wafers for measurement. The 1605 can map the mobility of 2- to 6-in. wafers in minutes and can measure samples smaller than wafer size.

Olympus America
LEXT OLS-4000 laser scanning microscope
Olympus' LEXT OLS-4000 measurement tool for surface analysis combines dual confocal technology and dedicated 405-nm optics. The laser confocal microscope has a traceable accuracy and repeatability guarantee and offers the ability to image near-vertical slopes (85°).

QED Technologies
Aspheric stitching interferometer (ASI)
The ASI is a turnkey metrology tool that can measure everything from large, strongly curved (convex, concave) spherical surfaces to steeply aspheric surfaces using Variable Optical Null (VON) technology – a revolutionary advance in optics manufacturing.

Photonics Systems

Aerotech
ANT130-L
Aerotech ANT130-L series direct-drive linear stages offer nanometer accuracy, repeatability, resolution and in-position stability in a linear stage featuring from 35- to 160-mm travel.

IRphotonics
iCure thermal spot curing system
This thermal spot curing system provides localized heat via high-intensity infrared radiation in a portable unit that can be integrated into a production line.

OEwaves Inc.
Ultrahigh-performance automated phase noise measurement system
OEwaves' ultralow phase noise/jitter measurement system, based on microwave photonics cross-correlation homodyne detection, can measure ultralow absolute phase noise and jitter of microwave and pulsed optical signal sources. The system offers simple, automated operation and achieves high performance without requiring separate, expensive low-noise reference sources or equipment.

Photonics Processes

General Resonance LLC
Resonance science
A photochemical catalysis of chemical and materials processes using frequency-specific photonics in the infrared, microwave and radiowave regions.

Linden Photonics
Strong tether fiber optic cable
Linden's patented strong tether fiber optic cable (STFOC) uses extruded liquid crystal polymer on commercial-grade optical fibers such as SMF28 and Allwave. STFOC has moisture barrier properties and eliminates the need for metalized fiber in hermetic packaging of optoelectronic components.

Shasta Crystals
Modified laser-heated pedestal growth technique
Shasta Crystals' laser-heated pedestal process reduces the steps and increases the speed necessary to grow NLO crystals, reducing their cost in commercial quantities.

Sustainable/Green Technology

BaySpec Inc.
Portability-3 Raman instrument
An ultracompact laboratory-grade measurement tool with a flexible sample collection point-and-shoot probe, this instrument is for low-light spectroscopic measurements of biofuels, such as algae, and for the nondestructive analysis of chemical reactions. It is available in longer 785- and 1064-nm wavelengths for fluorescence-free results.

Electronic Housekeeper
Electronic housekeeper (EHK)
EHK is a smart home/smart building system that wirelessly monitors resource use and controls building systems (HVAC, lighting, security/alarm) and devices (appliances, lights) to reduce carbon footprint and energy/water consumption by up to 40 percent.

National Semiconductor
SolarMagic power optimizer
The optimizer provides an electronic solution to long-standing challenges with solar arrays, enabling systems to realize their full power-producing potential. Using advanced algorithms and mixed-signal technology, SolarMagic minimizes the negative effects of panel mismatch caused by real-world conditions such as system aging, varied tilts and orientations, and debris or shade.

Life Sciences

LightLab Imaging Inc.
C7-XR optical coherence tomography system (FD-OCT)
The C7-XR frequency-domain system employs

advanced photonics technologies to provide cardiologists with an interior view of coronary arteries. Its ultrafast imaging speed, micron-scale resolution and 3-D visualization capabilities streamline the clinician's work flow and redefine the possibilities of interventional cardiology imaging.

Nanonics Imaging Ltd.
Hydra multiprobe bioimaging NSOM SPM
This nano-optical bioscanned probe microscope captures near-field nano-optics for live bioimaging, integrating upright and dual 4 Pi nonlinear optical microscopes, even with water-immersion objectives. It incorporates multiple independently controlled scanning probes for optical pump probe on a nanoscale with nanomanipulation capabilities.

Photometrics
Photometrics Evolve camera
This electron multiplying CCD camera makes experimental imaging data quantifiable and reproducible by measuring images in photoelectrons as opposed to arbitrary analog-to-digital units.

Accurate Timekeeping Eblana Photonics of Dublin, Ireland, has received a contract from the European Space Agency. The company will develop lasers for use in more precise atomic clocks. Atomic clocks are employed in the Galileo satellite system design that is used for global positioning.

Sales Partnership Analyze IQ Ltd. of Galway, Ireland, has signed an agreement with Ocean Optics Inc. of Dunedin, Fla., whereby the latter will sell and support its partner's software suite for chemometric analysis. The contract includes products such as Analyze IQ Lab, Spectra Manager and Raman Library.

Hyperspectral Imaging A $70,000 Small Business Innovation Research Phase 1 contract has been awarded by the US Navy to Bodkin Design & Engineering LLC of Newton, Mass. The company will develop a hyperspectral imaging system to be integrated into periscopes and photonic masts to perform contact recognition and identification in marine environments. The device will capture both spectral and spatial information in one video frame, eliminating motion artifacts.

RNT Acquisition Indium Corp. of Clinton, N.Y., has acquired the processes, equipment and know-how of Reactive NanoTechnologies Inc. (RNT) of Hunt Valley, Md. The latter, the developer and manufacturer of NanoFoil, will be moved to the former's Utica, N.Y., facility. Orders and inquiries will be placed directly through Indium.

$5 Million Award A team led by Rice University of Houston has won a three-year grant from the Army Research Office, with funding from DARPA. The group, representing seven universities, will build a simulator to investigate high-temperature superconductivity using ultracold atoms in an optical lattice created with lasers. The $5 million grant is the second phase of funding for this project.

Military Camera Collaboration Flir Systems Inc. of Washington, a manufacturer of thermal imaging, infrared cameras and night vision systems, has announced that it will collaborate with infrared detectors manufacturer Sofradir of Paris to create thermal cameras with enhanced capabilities for military and commercial applications. Flir will design cameras and insert them into both US and international developed systems, while the French company will contribute its mass-production capabilities.

$15 Million Acquisition Coherent Inc. of Santa Clara, Calif., a photonics-based solutions provider, has acquired the North American operations of StockerYale Inc. for $15 million in cash. Coherent has acquired all of the latter's assets and certain operating liabilities of the laser module product line in Montreal and of the specialty fiber product line in Salem, N.H.

Instrumentation for Lab California Nano-Systems Institute at the University of California, Los Angeles, has collaborated with high-speed imaging systems and image analysis software manufacturer Photron USA Inc. of San Diego to develop specialized instrumentation for its core laboratory facilities. Photron has donated three cameras for use in the institute's Advanced Light Microscopy/Spectroscopy core lab, which focuses on optical and advanced image analysis techniques.

Application Center Infrared-based materials and systems manufacturer IRphotonics of Hamden, Conn., has established the Application Engineering Center. The expansion is a result of increased interest in the company's thermal spot curing system as an in-line portable heat source for localized heating of bonded assemblies and curing of adhesives.

LED University Program Cree Inc. of Durham, N.C., has announced that Alfred University of New York has joined the Cree LED University program, an international community of universities working to accelerate the adoption of energy-efficient LED lighting across its campuses. The university has installed more than 175 Cree LED lights and 18 LEDDynamics EverLED TR fluorescent tube replacements throughout "Ann's House," its newest residence hall.

LED Alliance In Germany, Lumenova GmbH of Esslingen and Jenoptik Polymer Systems GmbH of Triptis have agreed to collaborate on LED lighting. The companies will work together to develop technology based on Lumenova's Light-engine and to create new reflector optics for a range of applications.

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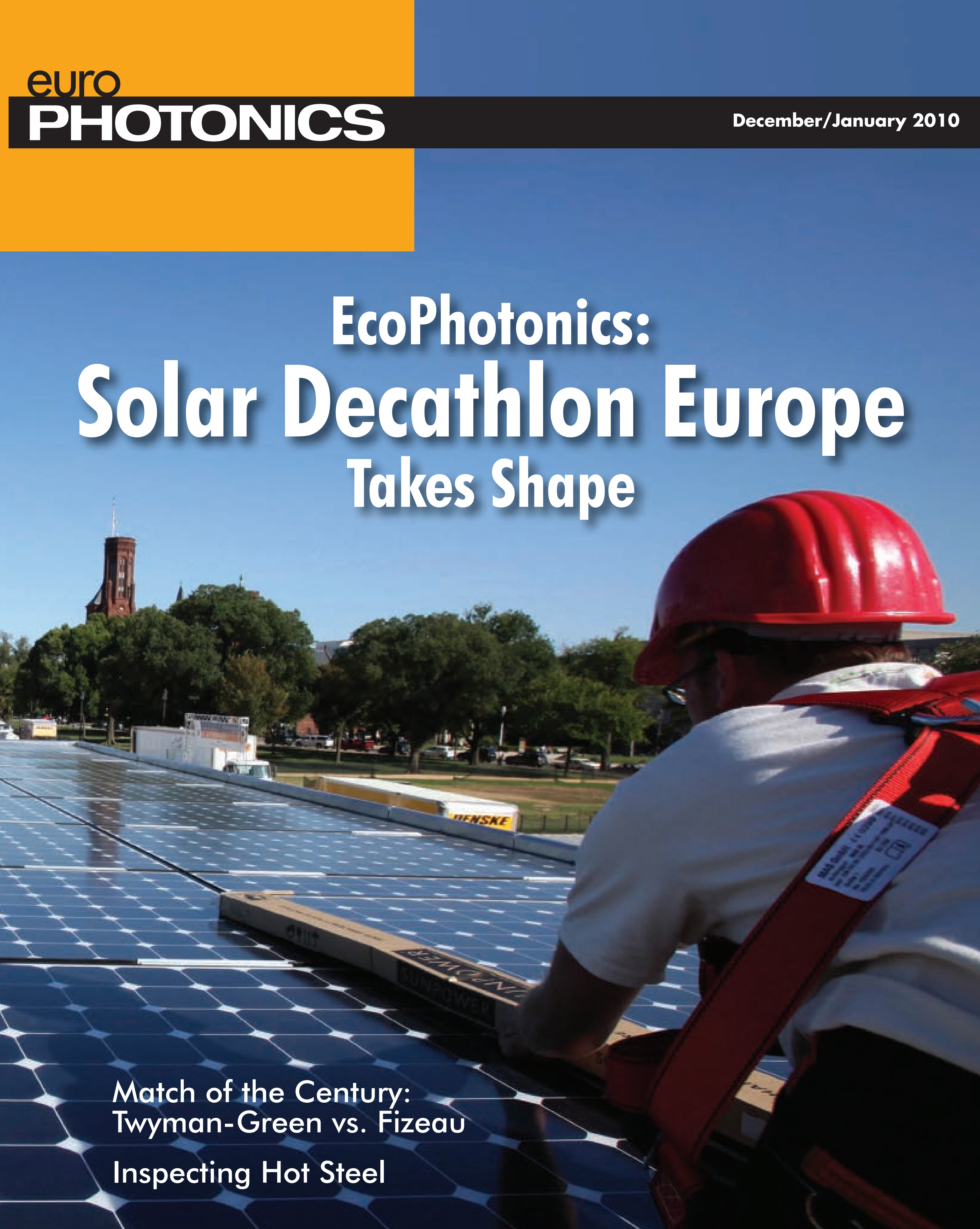
PHOTONICS

December/January 2010



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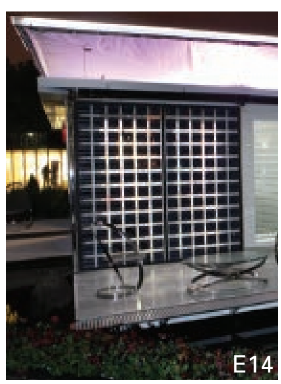

E14

THE COVER
This month's cover photo shows student Henning Zimmer setting the last solar panel on Team Germany's house at the US Department of Energy's Solar Decathlon 2009. See related article on page E14. Photo courtesy of Stefano Paltera, US DoE Solar Decathlon.

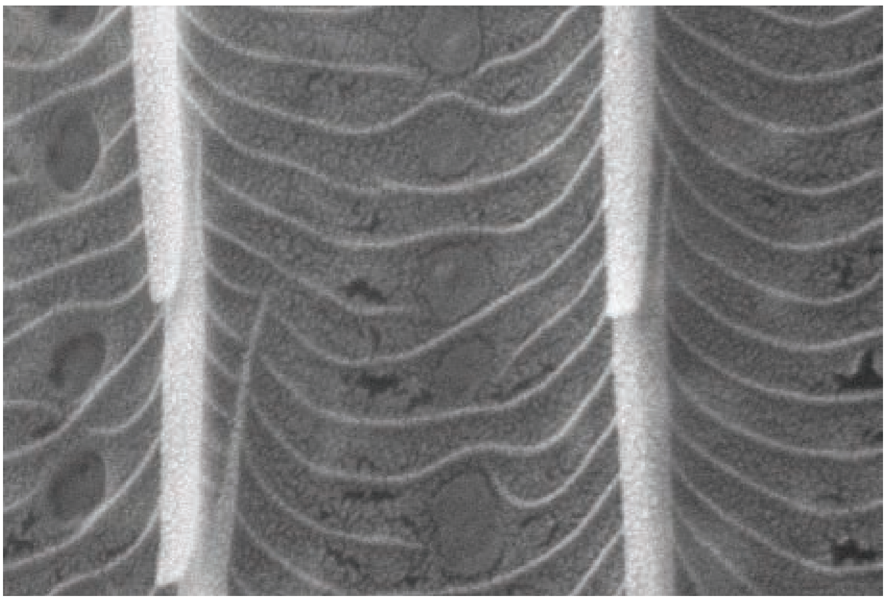
PHOTONICS
The technology of generating and harnessing light and other forms of radiant energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to detection to communications and information processing.

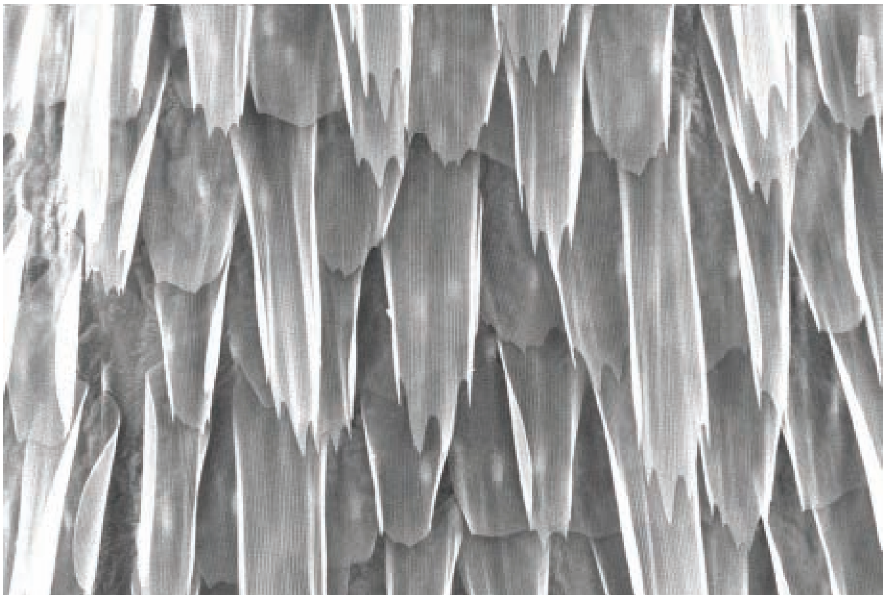
Butterfly wings could lead to new optics

MADRID, Spain, and UNIVERSITY PARK, Pa. – New optical technologies are taking flight, thanks to a technique that can replicate butterfly wings. The manner in which these wings are formed, and their properties of luminosity, could help researchers develop light-emitting devices with enhanced properties or antireflection coverings that increase light absorption in solar cells.

Through a microscope, a butterfly's wing shows intricate surface features: thousands of colorful scales, both large and small, arranged elaborately in rows. Nanosize photonic structures on the cuticles determine the wing's physical color and iridescence and provide it with the ability to appear metallic and to change tones at different angles.

"The technique that we have developed can be used to replicate biotemplates with micro- and nanoscale features distributed over planar and curved surfaces that could further the development of highly efficient photonic devices," said Raúl J. Martín-Palma, professor of physics at Universidad Autónoma de Madrid and an adjunct professor of materials science and engineering at Pennsylvania State University. "It is a simple, highly reproducible and inexpensive process for fabricating complex nanostructures with biologically inspired functionalities."





Two scanning electron microscope images reveal the external structure of a butterfly wing coated with chalcogenide glass. The removal of the wing by submersion in orthophosphoric acid allows the conformal coating and chitinous coating to separate from the wing, resulting in a free-standing replica.

Rotate, rinse and replicate

Martín-Palma and fellow researchers Akhlesh Lakhtakia, the Charles Godfrey Binder professor of engineering science and mechanics, and Carlo G. Pantano, director of the Materials Research Institute, both at Penn State, applied their method of conformal evaporated film by rotation (CEFR) – a technique based on the combination of thermal evaporation with simultaneous substrate tilting and rotation – while a biological template (butterfly wing) rotated in a low-pressure chamber.

The researchers first coated the wing with a germanium, antimony and selenium (GeSbSe) compound, then thermally evaporated the material at a current of 80 A with a vapor flux aimed at the biotemplate at an angle of 82°. Meanwhile, they continuously rotated the substrate at 60 rpm. As a result, a GeSbSe chalcogenide glass coating formed on the wing at a thickness of about 500 nm.

They then immersed the wing in an 85 percent orthophosphoric acid solution for 72 hours to dissolve its chitinous exterior coating without damaging the outer surface, or the conformal coating. This resulted in a free-standing replica of the wing. Other conventional methods of removing the chitinous coating destroyed nanoscale surface features, while thermal treatment charred the wing.

A Philips XL30 scanning electron microscope revealed the coated wing and free-standing replica's scales as measuring approximately 200 × 50 µm. The lamellae, or ridges of the wing, were raised and approximately 2.5 µm apart and, between the lamellae, were fine tubes composed of netlike reticulum, or latticework. The scales "are intricately shaped with stratification, voids and grooves of complex shapes that result in several optical effects, such as interference, scattering and diffraction," Martín-Palma said.

Both the lamellae and reticulum supply the wing with its physical coloring, but because the sample is only several microns in size, color and iridescence could not be seen. So the researchers measured reflectance spectra >200 to 850 nm with a PerkinElmer Lambda 950 UV/VIS/NIR spectrophotometer to observe the optical behaviors in the visible regime of the coated wing and replica. They determined that the colors of each were similar to the other because of a reasonable correspondence between the two spectra in the visible regime. A report on their study was published June 25, 2009, in the journal *Bioinspiration & Biomimetics*.

Flying into the future

The investigators are trying to improve their process so as to eliminate all chitin from a sample and increase dissolution speed. They also hope to enlarge the replicas within a few months, which could amplify color and iridescence. By replicating the vibrant colors found in a natural wing, they could develop "swatches of fabrics that would sense magnetic fields, temperature changes [and more]," Lakhtakia said. "[The swatches of fabric] could absorb a gas and provide a color signal to indicate that a gas had been sensed."

The researchers believe that the development of replicating eyes of flies or hornets using CEFR could improve angular vision for cameras, optical sensors, mobile telephones, displays, security surveillance systems and medical devices such as endoscopes.

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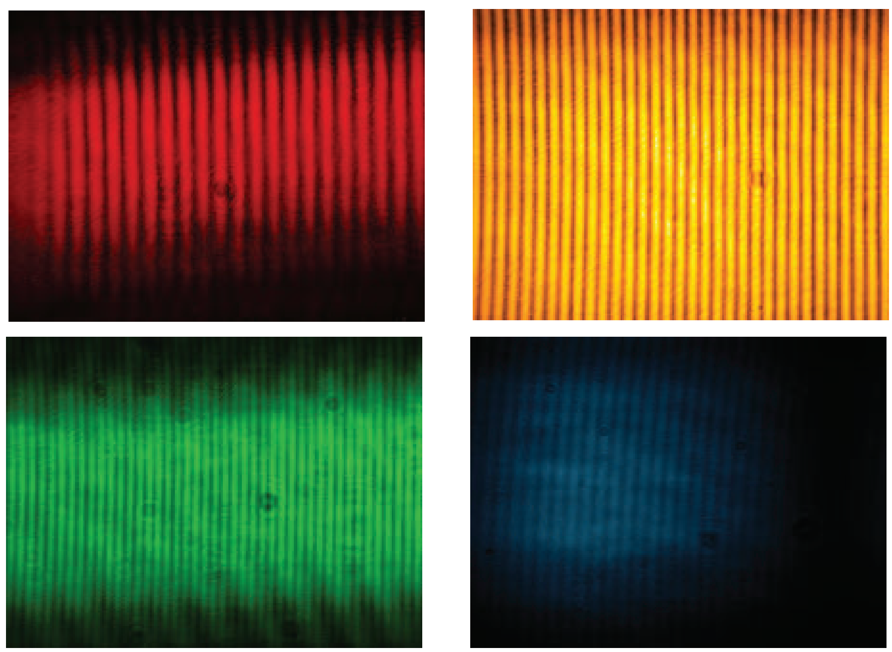
Faster repetition gives comb teeth you can see

KONSTANZ, Germany – Frequency combs have been the basis for a Nobel Prize, but their "teeth" have never been visible – until now. Thanks to recent advances in laser technology, researchers at the University of Konstanz and the US National Institute of Standards & Technology (NIST) in Boulder, Colo., have created a frequency comb with teeth – individual comb frequencies – that can be seen by eye with a grating and a microscope.

NIST physicist Scott Diddams said the output from the comb is essentially the same as that of 50,000 frequency-stabilized lasers spanning the spectrum from 470 to 1130 nm. The researchers hope to use this array of stable frequencies in spectroscopy experiments aimed at identifying and controlling the quantum state of specific gases, he added.

"This could have applications for everything from basic research to chemical analysis to the detection of trace gases important for environmental or security monitoring," Diddams said. "Another interesting application is using the comb to calibrate high-resolution astronomical spectrographs. Such a tool could be helpful to astronomers searching for planets around other stars."

A third use involves the generation of optical and microwave waveforms with very low timing jitter. This last application exploits the frequency control of the comb as well as the ability to address and control many of its individual modes.



A frequency comb with teeth that can be seen is now possible, thanks to new laser technology. Showing the entire comb would comprise 1500 such photos. Courtesy of Scott Diddams, NIST, and Albrecht Bartels, Gigaoptics GmbH.

As for why such a comb can now be built, Albrecht Bartels, research group leader at the university and CEO of Gigaoptics GmbH, pointed to two advances. The first is the creation of a femtosecond laser with a 10-GHz repetition rate, a critical threshold for visibility.

"The 10-GHz repetition rate is important because it spreads the emitted frequency comb teeth wide enough in frequency space to be resolved with a grating spectrometer," he said.

Besides being visible, he said, the wider spacing makes it possible to manipulate the comb on a mode-by-mode basis. It is even possible to isolate single modes and make them individually available to a spectrometer, enabling previously impossible applications.

The second enabling development was microstructured fiber technology, which allows the creation of a white light quasi-continuous spectrum when laser pulses are sent through the fiber. A key advance here was that the group achieved very efficient coupling of the laser to the continuum generation fiber, an improvement that was needed because the peak power intensity fell by the same ratio as the pulse rate went up.

The technology for such a laser has been around for years but had been applied to 1-GHz systems. It was a challenge to shrink it in size – and thereby increase the repetition rate – by a factor of 10 while still maintaining femtosecond pulse operation, Bartels said.

As for the future, the researchers do not envision the new technology making it into the field anytime soon. “We are at the early stages of these applications. There is still plenty of development at a basic level to be carried out in the lab over the coming years,” Diddams said.

The group described its work in the Oct. 30, 2009, issue of *Science*, with Bartels the lead author.

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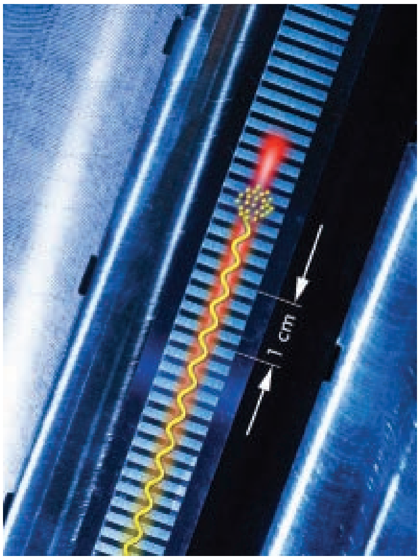
Affordable x-ray source shrinks to fit



Ultrarelativistic electrons (yellow) are forced on a sinusoidal trajectory by the periodic magnetic fields of an undulator, emitting short-wavelength radiation (red). Driving these synchrotron sources with laser-accelerated electron beams holds promise to reduce their dimensions from kilometers to a university-laboratory size. Courtesy of Thorsten Naeser. Artwork: Christian Hackenberger.

GARCHING, Germany – A tunable x-ray source hundreds of times smaller than a conventional synchrotron has been successfully demonstrated by an international team of researchers at Max Planck Institute of Quantum Optics. The feat marks an important step toward building x-ray sources that are more widely available to hospitals for advanced medical diagnostics and therapy.

The source is not only small in size but also affordable. Its designers hope that their novel approach to creating coherent, ultrafast, pulsed x-rays will open up the tool to fundamental research including drug discovery, materials science, biology and nanotechnology.

“Since current synchrotron sources are big in size [typically hundreds of meters in diameter] and very costly [up to $1 billion], only a few of these facilities exist worldwide, and therefore limit the number of users that can benefit from them,” researcher Matthias Fuchs explained. “Our experiment paves the way for a new generation of brilliant, compact x-ray sources with the potential for widespread application in university-scale laboratories.”

What is more, the source delivers photon pulses with an intrinsically ultrashort duration, estimated to be only a few femtoseconds. The duration of comparable synchrotron facilities is typically more than three orders of magnitude longer.

In the experiment, which was described in a *Nature Physics* paper on Sept. 27, 2009, a high-intensity laser is focused into a gas target, where it separates electrons from their atom core to produce a plasma. As the laser propagates through the plasma, it pushes electrons away just like a snowplow and, in combination with the electric fields of the plasma, generates a so-called “plasma wave,” or wave of electrons. The wave trails the laser pulse at nearly the speed of light, exactly the way a water wave trails a boat.

The electrons then are focused into a narrow beam by magnetic lenses and fed into an undulator, a periodic magnetic structure that forces electrons to transversely oscillate. This quivering motion causes them to emit an intense burst of radiation in the soft x-ray range.

By increasing the energy of the electrons, Fuchs and colleagues can decrease the wavelength of the x-rays into the hard x-ray range.

Although the experiment is currently at the proof-of-concept stage, the team is hopeful that its x-ray source eventually will become a more accessible alternative to current synchrotron facilities.

“This experiment is also a milestone on the path toward tabletop, free-electron lasers, which are based on a similar principle,” project leader Florian Grüner said. “In the short term, with minor improvements to our setup, we expect to have a source that is capable of performing state-of-the art experiments.”

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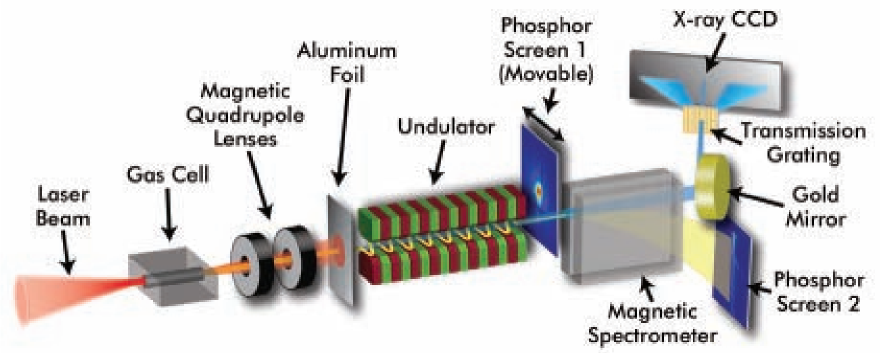
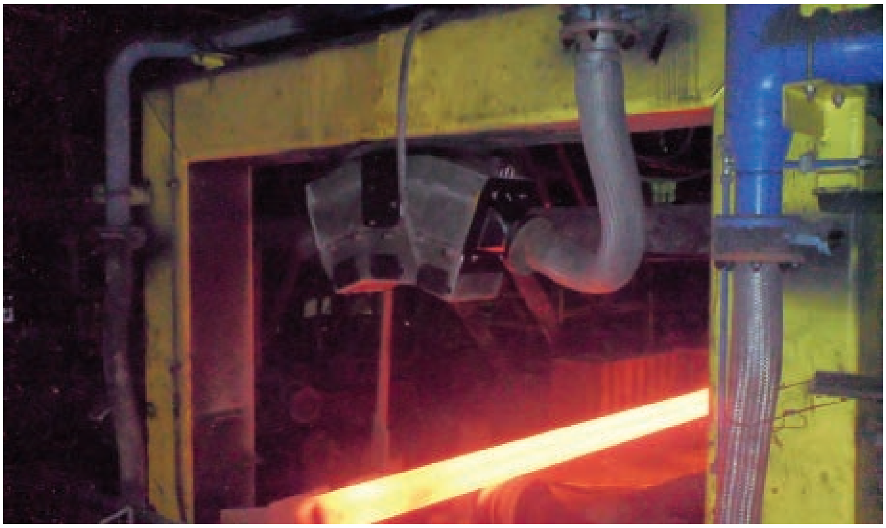


In this experiment, a laser pulse (red) is focused into a gas cell in which plasma waves accelerate electrons (yellow) to energies of several hundred megaelectronvolts. The electron beam is collimated by a pair of quadrupole lenses. Plasma radiation and the laser beam are blocked by a 15-μm aluminum foil. The electrons propagate through an undulator and emit soft x-ray radiation into a narrow cone along the forward direction (blue). The radiation is collected by a spherical gold mirror and characterized by a transmission grating in combination with an x-ray CCD camera. Stray light is blocked by a slit in front of the grating. The pointing, divergence and spectrum of the electron beam are diagnosed by phosphor screens. Courtesy of Matthias Fuchs, Max Planck Institute of Quantum Optics.

Inspecting hot steel in a new light



Hot steel glows visibly as it emerges from a push bench, making automated machine inspection of the surface difficult. Images courtesy of José Angel Gutierrez, Robotiker-Tecnalia.

BILBAO, Spain – Inspecting hot steel as it rolls off a manufacturing line can present a difficult problem for machine vision systems. For one thing, the steel glows, making surface imperfections hard to see. For another, steel is manufactured in environments with dirt, high temperatures and humidity.

Now, the private nonprofit Robotiker-Tecnalia foundation has come up with a solution that enables defects to be spotted while the metal is hot. All that was needed was to look at things in the right way and with the right light, said project manager José Angel Gutierrez. “The idea is to irradiate the object with [a] wavelength far enough from the emitted spectrum of hot steel. In this case, blue, but it could be green in some cases, or violet.”

A few years ago, steelmaker Tubos Reunidos SA of Amurrio approached Robotiker-Tecnalia with a problem. The company makes hot rolled seamless pipes ranging in diameter from 140 to 220 mm and in length from 7 to 20.5 m. The very last step in the manufacturing process involves press rolling at a push bench, with tube temperatures of about 1200 °C. Defects introduced as a result of the rolling stands repeat down a tube and from tube to tube, until the stands are changed. Consequently, catching and correcting defects as early as possible is important.

Enclosures protect cameras and light sources (top) that illuminate the processed steel using blue light and scan it for defects (below).

However, the heat of the steel made it glow an orange-red, bright enough to be visible in sunlight. That glow made the steel itself a light source for any machine vision camera trying to inspect its surface.

For a solution, the team at Robotiker-Tecnalia used a laser, a high-speed linear camera, and thermal and passband filters. It packaged these up in three protective enclosures equally spaced around the steel, cooling everything with an air-based refrigeration system, and pressurized the enclosures to keep out dust.

The optical filters, Gutierrez explained, eliminated everything from the camera's view but the reflected light from the laser. He noted that the monochromatic source helped with this, but that it was just as important that the laser was a bright source that could be focused as needed.

The three cameras captured 1024 pixels per line and 14,000 lines per second. All of this data was fed over a fiber link to a processing unit, which looked for defects on the tubes as they traveled past the inspection point at 5.5 m/s.

The system has been operational for some time. Some defects are picked up well, but capturing others must be improved. Better algorithms for defect classification or other enhancements could help with that. There also have been problems with laser nonuniformities and with aligning the laser and camera.

Nonetheless, the system has attracted the attention of other metal-processing companies. It isn't just steel or metal that could make use of the technology, Gutierrez said. "It can be used in any application where hot elements must be inspected."

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Light offers read-and-write access to brain cells

OXFORD, UK – A new set of methods allows experimental interaction with biological systems composed of many interacting cell types, such as neural circuits in the brain. Researchers at the University of Oxford have used light to manipulate the memories of fruit flies, allowing them to learn from mistakes they never made and to pinpoint the nerve cells that make them do so.

"Remote-controlling these cells and turning them on using light creates an illusion in the brain of the fly that it is experiencing something bad. The fly learns from the 'mistake' it never really made and improves its actions the next time," explains Professor Gero Miesenböck of the department of physiology, anatomy and genetics, who led the work.

Miesenböck is one of the key players in the field of optogenetics, which develops genetic strategies for observing and controlling brain circuits using light. He uses optical approaches for genetic engineering to remote control the action of specific cells within tissues, or whole organisms like worms, fruit flies, fish and mice; he focuses on the structure and dynamics of circuits involved in processing and memorizing sensory information and on how actions are selected or patterns are generated in the brain.

In his paper "The Optogenetic Catechism," published in the Oct. 16, 2009, issue of *Science* (Vol. 326, p. 395), he outlines how two kinds of devices perform complementary functions: While light-driven actuators control electrochemical signals, light-emitting sensors report them. The actuators pose questions by delivering targeted perturbations, and the sensors (in combination with other measurements) signal the answers. He says that these catechisms are beginning to yield previously unattainable insight into the organization of neural circuits, the regulation of their collective dynamics, and the causal relationships between cellular activity patterns and organism behavior.

This is accomplished by encoding proteins in DNA. DNA molecules act as pieces of code that are packaged into different kinds of delivery vehicles before being integrated into the genome of organisms. Once a piece of DNA has been introduced into a cell, the cell's machinery is directed to produce the required protein.

This solves the problem of delivering experimental agents deep into the tissues of intact organisms. That is, after genetic modification, the organism itself generates the mechanisms necessary for the light interaction: Light-driven actuator proteins, used to control genetically targeted cells in a circuit, convert optical commands into de- or hyperpolarizing currents, whereas light-emitting sensor proteins report changes in membrane potential, intracellular calcium concentration or synaptic transmission.

In a recent experiment funded by the UK's Medical Research Council and reported in the journal *Cell* (Oct. 16, p. 405), Miesenböck's team genetically engineered fruit flies so that a small set of nerve cells in the flies' brains would "fire" in response to a flash of laser light. This showed the investigators which cells are involved in how a fruit fly learns and remembers what to avoid – research offering an opportunity to investigate how memories are formed.

Fruit flies are attracted by some odors and repelled by others. "We tracked the flies using a video camera as they moved around a small chamber while two different odors were fed into the chamber from either end. We found that we could implant a lasting preference for one odor over the other by remotely activating a specific set of brain cells each time a fly strayed into a particular odor," says researcher Dr. Adam Claridge-Chang, who is now at the Wellcome Trust Centre for Human Genetics at Oxford University.

Using this method, the researchers were able to pinpoint the precise nerve cells that are responsible for telling the flies that they've done wrong, narrowing down the search from the 100,000 cells in the brain of a fruit fly to a set of just 12 neurons, implying that aversive memories are dependent on just a small cluster of neurons.

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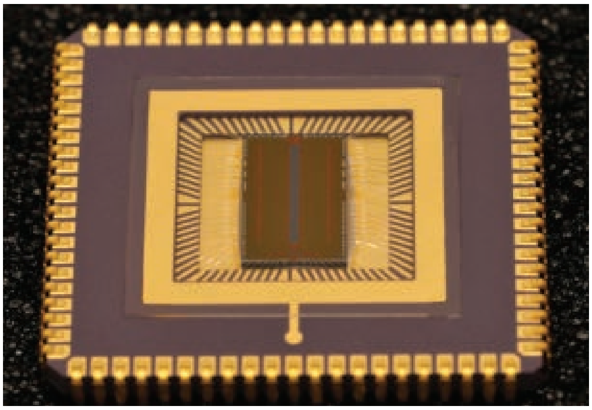
Researchers at Oxford University in the UK used lasers to manipulate fruit fly memories, allowing them to learn from mistakes they never made and permitting scientists to pinpoint the nerve cells that regulate such actions.

Clever cars get color cameras

MUNICH, Germany – In a move that is reminiscent of the 1980s hit series *Knight Rider*, researchers at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have developed a process that will give a futuristic boost to in-car driver assistance systems.

Thanks to high-tech cameras, the car of the future will help park itself, warn the driver of blind spots or obstructions, and even recognize traffic signs.

Driver assistance systems typically come equipped with special cameras housing CMOS image sensors that convert light signals into electrical pulses. These sensors have limited sensitivity to light, however, and are essentially color-blind, providing only monochrome images. Regardless, the sensors are expected to meet a wide range of requirements. They must be small, light and yet tough enough to endure high ambient temperatures. Additionally, they must reliably capture all the required images and should cost as little as possible.



The innovative CMOS image sensor can distinguish color and is much more light-sensitive than conventional sensors. Image Fraunhofer IMS.

Now, however, Fraunhofer researchers are boasting a new production process that makes these sensors much more sensitive to light and allows them to recognize and distinguish color.

"We have integrated a color filter system in the process," explains Dr. Holger Vogt, deputy director of IMS. "In the same way as the human eye needs color-specific cone types, color filters have to be inserted in front of the sensors so that they can distinguish color."

This is done by coating each pixel on the sensor with a micrometer-thick layer of polymer dyed in the primary color of red, blue or green. A mask that is transparent only on the desired pixels and UV light are used to fix the dye at the requisite points, and the rest is washed off.

In addition, special microlenses have been developed to help the sensor capture and measure light more efficiently. With the aid of a transparent polyimide, the investigators created a separate lens for each individual pixel, almost doubling the light sensitivity of the image sensor.

According to the researchers, the optimized CMOS process not only makes cost-efficient driver assistance systems possible, but it could also improve endoscopic probes.

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Molecules in motion

MUNICH, Germany – Moving and then trapping freely dispersed molecules can be a challenging process, especially if they are suspended in liquid. To lessen the difficulty, a novel method has been developed using infrared light to thermally drive and control particles.

The technique functions like an optical conveyor belt, helping bring together biological elements on a micrometer scale. The method may improve diffusion-limited surface reactions, cell signaling control and observation of biomolecules over time.

Optical divide

Dieter Braun and Franz Weinert from the physics department at Ludwig Maximilians University used a technique employing thermophoresis, the repositioning of particles as a result of temperature gradients. The molecules, 1-µm fluorescent single-stranded DNA, were placed in 2-µm-thick bulk water between a glass surface and a metal-coated base. An infrared laser operating at 1455 nm and 5 W was directed at the base, heating the liquid locally to a diameter of 70 µm. A thermal gradient developed with cooler liquid at the top of the container, pushing the DNA to the top.

The laser was then moved in a radial pattern, causing the solution to change in viscosity and the fluid on either side of the laser beam's moving spot to contract and expand and thus flow away from the center. The liquid at the top moved in the opposite direction of the "belt," conserving mass and creating a steep gradient in the Z-direction. With this motion, the molecules within the container were pulled toward the center, where they accumulated. Overall, it took approximately three seconds for the entire process to take place.

The researchers established that the conveyor belt method can assemble molecules from a few nanometers to hundreds of micrometers in length. For smaller molecules that would be less affected by thermophoresis, researchers could increase the radius of the trap to increase the concentration level in the center.

Unlike conventional methods such as using gravity to drive fluid, the conveyor belt technique implements flow by thermoviscous expansion. However, temperature gradients are not a factor in the conveyor's efficiency; instead, its effectiveness is determined by the speed of the flow.

Advantages to the system include not having to use microfluidics, electrodes or surface modifications. Because of its optical operation, the trap can be repositioned, reducing the time needed to collect all of the particles in comparison to diffusion into an immobile trap. The study was published online Oct. 6, 2009, in *Nano Letters*.

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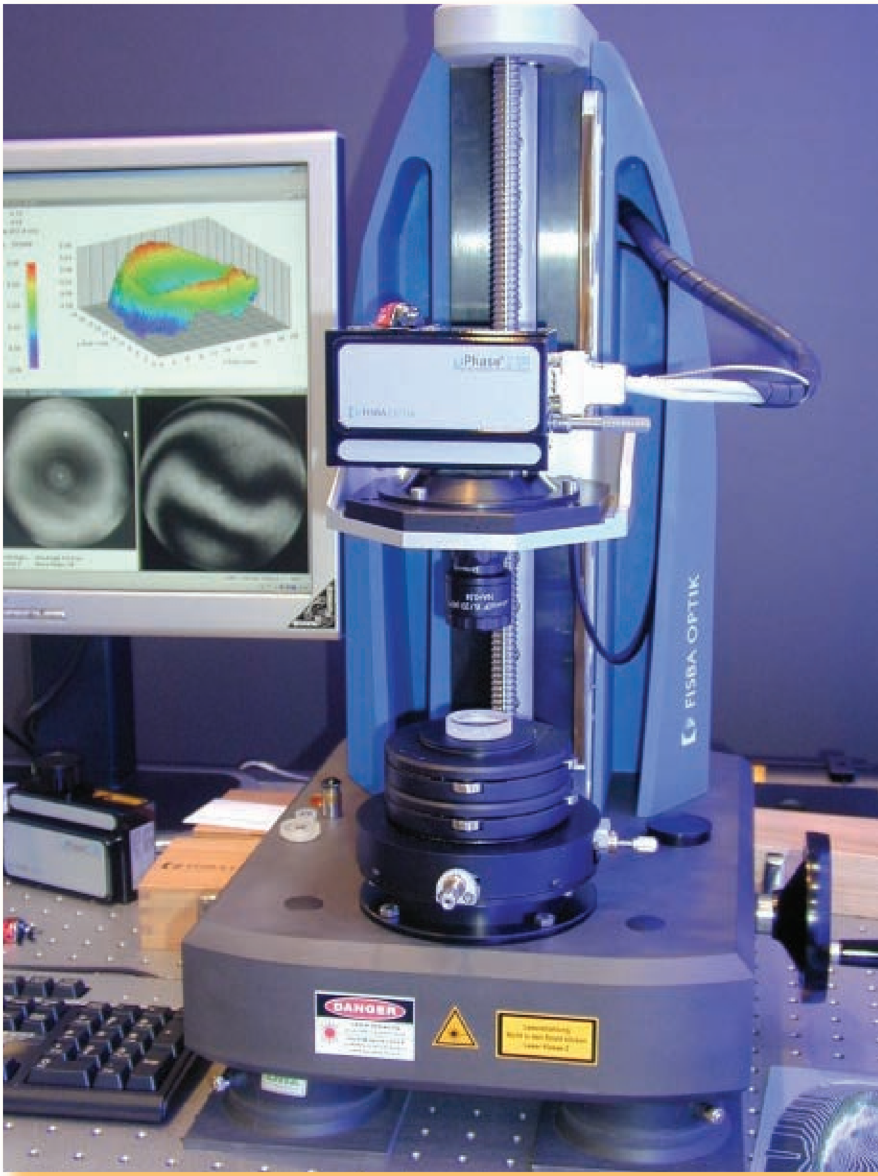

The µPhase manufactured by Fisba Optik is a compact Twyman-Green interferometer.

Old School Versus New in Optical Topology Testing

For components testing, the Twyman-Green interferometer weighs in against the Fizeau.

BY JÖRG SCHWARTZ
EUROPEAN CORRESPONDENT

For the past 100 years or so, makers of optical components have relied on Fizeau interferometers to check surface quality. These devices have allowed manufacturers to detect defects via deviations from regular fringe patterns. However, Fizeau interferometers require very accurate references, which must be tailored for each surface type. Twyman-Green interferometers, however, sidestep this requirement. Not only is the Twyman-Green more flexible, say supporters, but also the need for calibration is no longer relevant. This makes sense for today's systems, in which electronic processing of the test is standard.

So which is the stronger argument? – "I only trust what I see," or "I trust computers in other applications, so why not in optical testing?"

From an optical perspective, the starting point of both devices is the same: a spatially filtered laser source with good coherence properties. In a Fizeau interferometer, the output beam hits a collimating lens that creates a plane wave used for surface testing. Then the beam passes through an angled beamsplitter on the way for coupling out the light on its return path. The key component of a Fizeau interferometer is always the last surface of the test optics, the so-called Fizeau surface, which sits in front of the surface under test. It has a double function: It represents the beamsplitter an interferometer needs, and it defines the reference with which the sample is compared.

This Fizeau surface must be of very good quality (λ/10 peak to valley or better, which sets an upper limit to measurement accuracy). It must also be the same shape as the surface under test. If the intention is to measure the test surface as a whole (which is usually the case), the reference surface must be the same size. A part of the illuminating beam is reflected by this reference, whereas the other part continues on to the surface to be tested. There, a part is reflected that contains information on aberrations introduced by irregularities of the test surface. The two reflected wavefronts (reflected by the reference and the test surface) interfere with each other on the way back to the light source, and the beamsplitter diverts the interfering beam toward a recording medium, typically a CCD camera.

An argument has been made that a Fizeau interferometer does not require high-quality optics. However, standard interferogram analysis is based on the fact that the wavefront from the test object does not experience any changes from the test optics and is imaged directly to the detector. Consequently, low-quality test optics would not meet that requirement – independent of interferometer type. Therefore commercial versions of both types typically use test optics of λ/2 quality or better.

The Fizeau alternative

Fizeau interferometers have no optical elements between the reference and the tested surface, which is key for generating a pristine interferogram; this is not the

Pictured is the VeriFire AT+, a state-of-the-art Fizeau interferometer made by Zygo.

case for Twyman-Green-type devices. These interferometers look very much like the well-known Michelson interferometers but generally use more optical elements in the arms, where the beamsplitter is a separate element that generates two individual light paths that are designed to interfere with each other. The reference beam is reflected by a known – and usually fixed – reference surface, returning to the beamsplitter. And as one would expect, the test beam hits the test part and also returns to the beamsplitter, where the beams are reunited to create the interferogram relayed by an imaging lens to the CCD in the observation plane.

The way the Twyman-Green interferogram is generated suggests that the many optical components in both arms can add unwanted aberrations to the result. However, instead of making sure that these components are of perfect quality, the system is turned on its head. Rather than striving for perfection, the process involves zeroing out all errors by a reference measurement, which is mathematically subtracted from the test result. Although this seems much more cumbersome, it isn't really because in today's interferometers all data is captured and processed electronically anyway. And it comes with another bonus: Since the calibration does not really care how many aberrations are to be taken out, additional optical elements can be added to the interferometer path to support a more compact design or additional features. Also, if contrast is important, it can be achieved more easily in Twyman-Green setups where the reference can be attenuated to produce similar intensity in both interferometer paths – a job much more difficult to achieve in a Fizeau setup.

Twyman-Green flexibility

The size of the high-quality – and hence expensive – reference surface can be reduced to just a few millimeters in Twyman-Green interferometers by adding (size-converting) optics to the reference arm. Due to the calibration, this reference is usable for various types of surfaces – as opposed to Fizeau interferometers, where a particular and full-size reference is needed for every type of application shape. In a strict sense, Fizeau measurements are limited to surface types for which references exist, whereas Twyman-Green also supports other surfaces. This is the case for aspheric lenses, popular in today's optical systems, for which computer-generated holograms can be placed into the Twyman-Green. Although this is also possible for Fizeau interferometers, calibration becomes mandatory, making the test effectively the same as the Twyman-Green test – that is, reliant on software operation.

Software is used in all modern interferometers of both types, so that's not the main difference. However, in the Fizeau case, usually the unprocessed image gives a clue as to how good or bad things are. While this is not the case for the fringe pattern shown by the CCD in a Twyman-Green system, the software has become very fast in yielding the same answer. So how important is this to the user?

"To me, it is not the interferometer type that makes the difference, and whether I can see the result directly or not," said Robert Daddato, scientist at the European Space Agency (ESA) optics laboratory, which runs several interferometers of both types.

To him, in day-to-day operation, other factors are more important, such as software functionality not related to the interferometer type. When choosing an interferometer – rather than using a service lab like ESA's – he considers the main factor to be not performance but, for example, the often significant cost of references for testing large surfaces. Objective lenses for a Twyman-Green, on the other hand, are relatively cheap.

"Nevertheless, although I see this as an open race, I think this is almost a matter of taste, where the many traditionalists in the industry [are] sticking to the Fizeau they are used to, and those happy to try something new [are] giving Twyman-Green a go."

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Villa Solar Set for June in Madrid

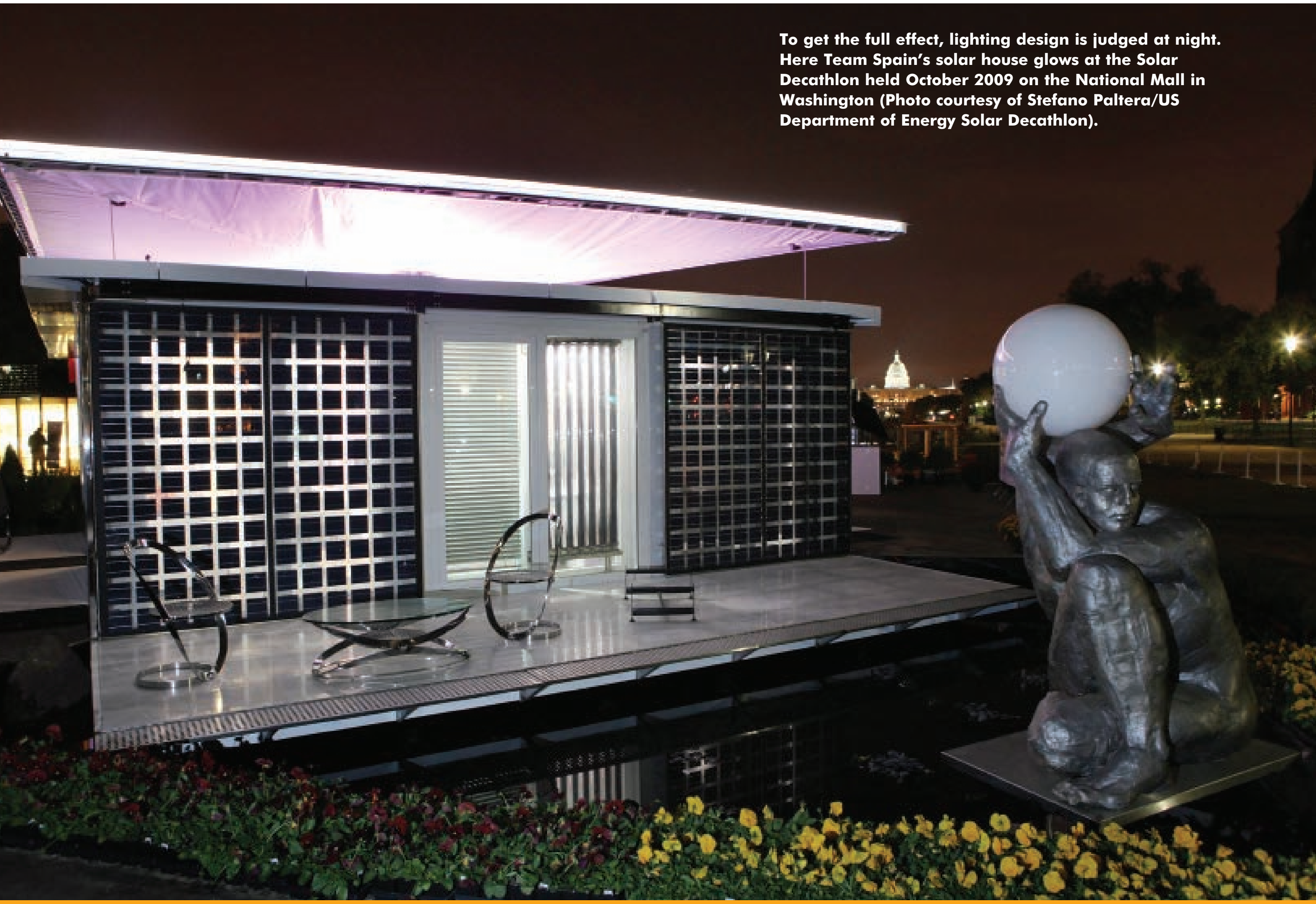
At a time when several European countries are proposing cuts to feed-in tariffs, known in the past as a great motivator for the solar industry, cutting-edge research and innovation in sustainable development and renewable energy are ramping up for a showcase at the Solar Decathlon Europe, which will take place in Madrid. The Solar Decathlon, jointly sponsored by the Spanish Ministry of Housing and the US Department of Energy (DoE), is a competition in which university teams from Europe, America and Asia design and build solar homes that vie for the grand prize of €100,000.

The goal is to construct a 75-sq-m house that relies solely on the sun's energy, has appealing and adequate lighting and is fully livable – with appliances for cooking and cleaning. The houses are given points in 10 areas that fall into five categories: architecture, solar, comfort, social and economic, and strategic.

According to Sergio Vega, project manager for Solar Decathlon Europe 2010, the greatest surprise so far has been the number of interested participants, with teams coming from four continents and nine countries to assemble "Villa Solar" on a site 30,000 sq m on the banks of the River Manzanares. The European decathlon is similar to the American solar decathlon, which was launched in 2002 by the DoE and which is held every other year on the National Mall in Washington. The aim is to share knowledge of renewable energy; to that end, the Spanish and American governments agreed this year to launch the European version of the competition.

Teams that enter the competition are made up of students from a broad range of academic disciplines, including engineering, architecture, urban design and transportation. They use their classroom knowledge to run energy consumption simulations, design lighting, configure multiuse interior spaces, build furniture and communicate through their team Web site.

Each entry has a name. The Armadillo is the house built by the Ecole Nationale Supérieure d'Architecture de Grenoble in partnership with two other French schools (Institut de L'Energie Solaire and Grands Ateliers de I'Isle d'Abeau). The name was chosen because the design of the house is similar to the armor on an armadillo, with a protective shield on the outside that houses the energy collectors. Just as the



To get the full effect, lighting design is judged at night. Here Team Spain's solar house glows at the Solar Decathlon held October 2009 on the National Mall in Washington (Photo courtesy of Stefano Paltera/US Department of Energy Solar Decathlon).

armadillo's outer shield protects the animal, the home's shield protects the underlying thermal envelope.

In many cases, the names are as clever and unique as the designs. The University of Nottingham's house is called, well, H.O.U.S.E., which stands for Home Optimizing the Use of Solar Energy. This two-level home was designed for a family, with walls transformed into storage units. A house called the Eclipse, from Virginia Polytechnic Institute and State University, is one of two entries from US-based universities. It uses the concept of "responsive architecture," with a climate controller accessed through an iPhone interface.

At Grands Ateliers de l'Isle d'Abeau in France, students work on sections of the design of the Armadillo house.

Completing a project for the Solar Decathlon requires cooperation and coordination of students and faculty as well as numerous financial, material and logistical sponsors. Students involved with the Solar Decathlon learn about designing affordable houses that are not only energy-efficient but also adaptable to various climates. The general public is encouraged to view the homes in Villa Solar to gain awareness of the technologies that are available to reduce energy consumption.

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PRODUCT PREVIEW

Optical Vector Analyzer ▼

Luna Technologies has added the OVA 5000 for optical network measurement to its Optical Vector Analyzer platform product line. The device, used for loss, dispersion and polarization measurements of optical networking equipment, has a small footprint and provides single-measurement, all-parameter analysis of fiber optic components and assemblies up to 150 m long. It performs full C- and L-band characterization of all linear optical parameters in less than 3 s and features complete polarization response.

Luna Technologies
solutions@lunainnovations.com

Color Cameras ▲

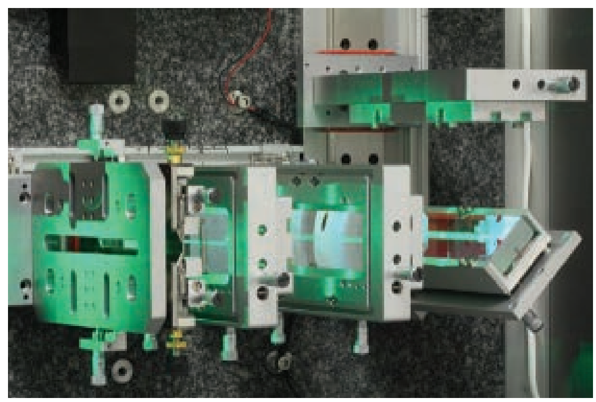
The AT-140CL and AT-200CL represent the latest generation of JAI Inc.'s three-CCD progressive-scan color camera series. They offer a patented prism block process that ensures alignment to within ¼-pixel accuracy, and a larger sensor format and higher resolution than previous models. The AT-140CL features ½-in. CCDs, each with 1392 × 1040-pixel resolution and an individual pixel size of 4.65 μm^2, while the AT-200CL features 1/1.8-in. CCDs, 1628 × 1236-pixel resolution and an individual pixel size of 4.4 μm^2. The series is suitable for use in applications including machine vision, homeland security and medicine.

JAI
camerasales.emea@jai.com

Stereomicroscope ▶

Nikon Instruments Europe has added the SMZ745T trinocular stereomicroscope to its stereo zoom microscope product line. It offers a 7.5× zoom, a built-in camera port and a 115-mm working distance, providing room to access and manipulate a large sample. When the auxiliary objective lens and eyepiece lens are combined, total magnification ranges from 3.35× to 300×. Its optical path switch enables easy switchover between eyepiece and camera, and its zoom body is equipped with a built-in trinocular camera port and a 0.55× C-mount adapter. The microscope is suitable for observation and digital image capture in industrial and biomedical applications.

Nikon
info@nikoninstruments.eu



Laser Optics ▲

Jenoptik's Lasers and Material Processing Div. and its company Innovavent GmbH have released the Innovavent Volcano laser optics module with a uniform 200-mm laser line for solar cell annealing and other applications. Designed for uniform, large-area illumination, the system is driven by the Dual Asama laser module to deliver up to 16 mJ at 10 kHz. It can crystallize silicon films at 50 nm for the manufacture of thin-film transistors for LCD and organic LED displays. A specially adapted version enables laser doping of crystalline solar cells.

Jenoptik
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8-Megapixel Camera ▲

SVS-Vistek GmbH's svs8050 8-megapixel camera with a 2-Gb interface is now available for print and printed circuit board inspection, optical metrology and semiconductor industry applications. The camera's output features two RJ45 connectors and transmits 2 Gb/s via two cables. Working with an interline transfer CCD sensor from Kodak with a diagonal of 22.66 mm, it offers a maximum frame rate of 20 fps with full 3320 × 2496-pixel resolution. In partial-scan mode or when using areas of interest, images with fewer lines can be read out at a higher speed. The Gigabit Ethernet camera is available in monochrome and color versions.

SVS-Vistek
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◀ Abatement System

Edwards Ltd. has unveiled the Spectra ZW abatement system for solar cell and flat panel manufacturing. The compact instrument, which includes an integrated wet scrubbing system, provides particulate and acid gas capture in a high-flow chemical vapor deposition process. It can function as a stand-alone unit, or it can be integrated into the proprietary Zenith for a custom-built vacuum pump/abatement solution, or combined with the optional wet electrostatic precipitation unit. It features standard process flows of greater than 16 standard l/min of silane, 200 standard l/min of hydrogen and 40 standard l/min of nitrogen trifluoride.

Edwards
info@edwardsvacuum.com

Two-Bar Laser Modules

Fiber-coupled two-bar laser modules with a compact footprint and a convenient aiming beam have been announced by Dilas. The devices deliver 808 and 976 nm at 80-W output power and 1550 nm at 30 W through a 400-µm-core-diameter fiber with a numerical aperture of <0.22 and wall plug efficiency of >35%. The bars can be cooled with industrial-grade water or thermo-electrically air-cooled. Custom wavelengths are available upon request. They are suitable for use in direct-diode applications and for fiber and solid-state laser pumping. Optional features include an integrated pilot beam, a power sensor, a fiber interlock and a user-exchangeable protection window.

Dilas
sales@dilas.com

GRIN Rod Lenses

Edmund Optics Inc.'s gradient index (GRIN) rod lenses feature plane optical surfaces and achieve focus using a continuous change of the refractive index within the lens material. The lenses eliminate complex geometries and provide a 0.55 numerical aperture. They are available in two working distance options. Lenses with a 0-mm working distance are suitable for collimation of single- and multimode optical fibers and laser diodes, while the small working distances are for focusing applications or situations where the lens cannot be in direct contact with the emission source.

Edmund Optics
medmund@edmundoptics.com

Smart Camera

FiberVision GmbH has launched the Nano-smart-PoE (Power over Ethernet), a smart camera based on the single board camera VCSBC4012 nano from Vision Components. Interfaces are provided using either an RJ45 and an RJ48 plug. The camera's delay between flash trigger and exposure start is programmable, as is the flashing time, enabling well-defined short exposure times and high-speed input and output for precise camera and flash synchronization. The camera has a CS lens mount, and an adapter for S-mount is available, as are six LEDs to display operational states.

FiberVision
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Electron Microscope

Carl Zeiss SMT AG has introduced its line of corrected Libra 200 transmission electron microscopes (TEMs). Two configurations are now available – the C_S TEM and the STEM (scanning TEM). Based on the energy filter version of the 200-kV Libra TEM, the Libra 200 C_S features a corrector for spherical aberrations of the objective lens. Image resolution below 0.7 Å can be achieved. The STEM model features a corrector for the condenser system and is suitable for imaging in the scanning mode with a resolution below 1 Å. The models are suitable for imaging of interfaces in semiconductors and solar cells, and materials science.

Carl Zeiss
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DPSS Laser

A "greener" MiniGreen diode-pumped solid-state (DPSS) laser has been released by Frankfurt Laser Co. It offers higher electrical-to-optical conversion efficiency than that of previous versions. Designed for applications that require up to 120-mW TEM_{00} output power, it is available with either an integrated photodetector monitor or high polarization. It is suitable for portable and battery-driven applications, including signaling to or guiding individuals by means of aiming, alignment or pointing laser light. The instrument measures 9 mm in diameter and offers a near-diffraction-limited output beam and low power consumption.

Frankfurt Laser
sales@frlaserco.com

Slide Scanners

The NanoZoomer 2.0 series slide scanners from Hamamatsu Corp. can convert a 20 $\times$ 20-mm area on a glass slide into a 1.9-gigapixel color image in less than 2 min. The virtual slides can be viewed on a computer monitor, shared across computer networks, used for software-aided image analysis in research applications and preserved in digital archives. Users can magnify specific areas to inspect fine details and can capture and view multiple focal planes in thick samples. Both the high-throughput and compact models can be fitted with a fluorescence imaging unit.

Hamamatsu
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Vibration Isolation

Kinetic Systems Inc.'s ergonomic low-profile-format (EL_pF) portable benchtop vibration isolation system is suitable for vibration isolation of sensitive devices, including atomic force microscopes, microhardness testers, analytical balances, profilometers and audio equipment. Measuring 410 $\times$ 490 $\times$ 75 mm and weighing 18 kg, it is available in two models. The system can support 45- or 136-kg loads on self-leveling platforms with active-air systems, and it delivers vertical isolation efficiencies of 95% vertical and 92% horizontal at 10 Hz. The top can be ordered with or without mounting holes and is available in aluminum plate, ferromagnetic stainless steel, plastic or antistatic laminate.

Kinetic Systems
sales@kineticsystems.com

Diode Laser

Lissotschenko Mikrooptik (Limo) GmbH has expanded its portfolio of compact and fully equipped diode lasers at 1470 nm. The two standard versions deliver output power of 12 and 25 W, and customized options with output of >100 W also are available. The fiber-coupled devices are packaged in a minimized potential-free housing and integrated with a protection window, fiber contact switch, monitor diode and pilot laser. Suitable for medical applications, the laser features high absorption in water to enable user-friendly operation in surgery. They also are suitable for pumping Er:YAG lasers.

Limo
a.gruetz@limo.de

LED Diagnostics

The Master4Light mobile control unit from Majantys is for characterizing LEDs in various conditions. Measuring 48 $\times$ 36 $\times$ 20 cm, it integrates an adjustable source generator with continuous or pulsed current at various amplitudes and frequencies, plus two thermocouple inputs for real-time temperature probes. A spectrophotometer connected to an 80-mm-diameter integrated sphere measures the optical parameters. The software provides access to the measured spectrum and to parameters such as color coordinates, dominant wavelength, correlated temperature and color rendering index. Applications include component sourcing, product evaluation and quality control.

Majantys
contact@majantys.com

Laser Engraving

The Xbase fume extractor and stainless steel work base for laser engraving is available from Purex International Ltd. The device removes hazardous fumes with automatic electronic flow-controlled blowers connected to the engraving laser with a short length of flexible hose. After fumes are drawn through the patented Labyrinth filter system and submicron particles and gases are removed, clean air is returned to the workplace. The fully mobile device is suitable for applications in engraving workshops and universities.

Purex
purex@purexltd.co.uk

High-Sensitivity Cameras

Dalsa Corp. has extended its Falcon line of high-performance cameras with the introduction of three models suitable for use in applications including electronics and semiconductor inspection, and industrial metrology. The Falcon VGA300 HG, 1M120 HG and 1.4M100 HG feature proprietary CMOS image sensors and are fully programmable. The 1M120 HG offers 1-megapixel resolution and operates at 120 fps, while the 1.4M100 HG delivers 1.4-megapixel resolution at 100 fps. The cameras support the company's Power over Camera Link, eliminating the need for a separate power cable. They feature exposure control, gain and offset adjustment, and flat-field correction. The 44 $\times$ 44 $\times$ 44-mm housing offers users mounting options.

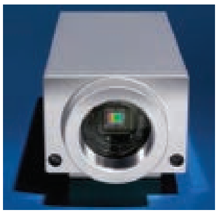
Dalsa
sales.europe@dalsa.com

Point Sensor

STIL SA has added the CCS Prima 4 to its family of CCS "point" sensors for noncontact metrology. This version, with four multiplexed channels, allows users to commute instantaneously from a measurement performed with one optical pen to another measurement without any manual operation. With the ability to run up to four input pens and a fast commutation rate, users can access a multiple measurement range and multipoint measurements with a single controller.

STIL
contact@stilsa.com

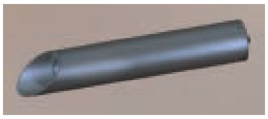
Near-Infrared Camera



The VC4067/NIR camera from Vision Components GmbH is an imaging system for security tasks, including nighttime perimeter protection and access control. With an integrated high-performance processor, it can execute all image processing routines, completely replacing conventional PC-based systems. It measures 110 × 50 × 35 mm and can be integrated easily into small spaces. Optional robust housing provides protection outdoors. The camera can capture images at a distance and is suitable for license plate recognition and motion detection applications.

Vision Components
sales@vision-components.com

Solar Measurement



Avantes BV has released two cosine correctors for solar measurement applications. The CC-UV/VIS/NIR-8MM has an 8-mm active area, while the CC-UV/VIS/NIR-5.0 offers a 5° angular field of view. The spectroradiometric sampling optics are designed to collect light over 180°, eliminating the problems with interface geometry that are associated with other light collection devices. Both versions offer Radin quartz diffusing material optimized for applications from 200 to 2500 nm. When coupled to a miniature fiber optic spectrometer, they can measure UV-A and UV-B solar radiation as well as environmental light and other emissions.

Avantes
carolineb@avantes.com

Feedback Controlyzer

Toptica Photonics AG has announced the DigiLock 110 controlyzer, a digital solution for laser stabilization that can be used to computer control and analyze lasers digitally. The newest software version enables one computer to control up to four DigiLocks. A comprehensive interface is available for remote transmission control protocol and Internet protocol access to all functions. Its basic capabilities include multichannel oscilloscope functionality, control over laser frequency and frequency scans, a lock-in regulator and lock detection. It also offers simulation of controller parameters and network analysis. The device can be integrated easily into complex experiments. It enables lock monitoring, control and adjustment of many parameters, including laser current, temperature and scan offset.

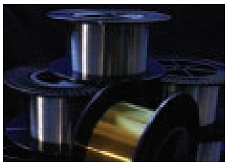
Toptica
info@toptica.com

Optical Amplifier

The R-SOA-EAM-1550 from CIP Technologies monolithically integrates a semiconductor optical amplifier with a reflective electroabsorption modulator to combine high optical gain with high-speed modulation capabilities. The device offers high output power, low power consumption and low sensitivity to input polarization. It is suitable for dense wavelength division multiplexing transmission at speeds of 10 Gb/s over fiber optic links up to 80 km. It is colorless, and a single device may be used across the entire C-band. It can be used as a sensor network source.

CIP Technologies
info@ciphotonics.com

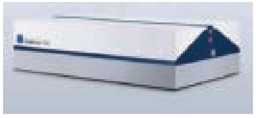
Optical Fibers



Fibertronix AB has launched a range of polyimide-coated optical fibers designed for harsh environments and elevated temperatures. They operate at a spectral range of 800 to 1750 nm and at a temperature from −65 to 300 °C. Suitable for applications where high strength and low bending loss are required, they feature a coating diameter of 145 ±5 µm and a typical core diameter of 8.4 µm. They are available in stainless steel tubes or with other buffer materials and are suitable for sensing, defense and security, and medical applications.

Fibertronix
info@fibertronix.com

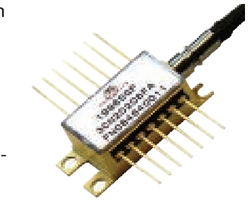
Microprocessing Laser



The TruMicro microprocessing lasers manufactured by Trumpf GmbH + Co. KG are suitable for use in photovoltaic applications. The 5000 series features powers up to 50 W, beam quality of M^2 <1.3 and pulse frequency of 200 kHz. With pulse durations <10 ps and pulse energies up to 250 µJ, the devices can vaporize almost any material quickly so that no heat-affected zone is detectable

Trumpf
info@de.trumpf-laser.com

980-nm Pump Modules



The next-generation 1996 SGP series 980-nm submarine-grade pump modules have been unveiled by 3S Photonics. The coolerless devices provide 600 mW of ex-fiber optical power and operate from 0 to 45 °C in a hermetically sealed 14-pin butterfly package. With ultrahigh reliability, they offer a polarization-maintaining fiber pigtail with a fiber Bragg grating stabilizer. Applications include submarine optical networking and high-power pumping in submerged erbium-doped fiber amplifiers for next-generation dense wavelength division multiplexing repeaters and branching units operating at 10 and 40 Gb/s.

3S Photonics
jphirtz@3sphotonics.com

LED Source

CoolLED has launched the pE-100, a fluorescence LED source. The device offers instant on/off and 0 to 100% intensity controls. It can be used on all microscopes with an external light source port for epifluorescent or transmitted light applications. Users can select their desired wavelength from more than 20 LED wavelengths. An optional cable is available for external transistor-transistor logic trigger. The instrument features quiet operation, fast switching, active cooling and no hazardous materials.

CoolLED
sales@coolled.com

Optical Table

The Kentek table guard barrier system is highly configurable and can be fitted to any standard optical bench or to a customized layout, with options suitable for both imperial and metric optical tables. Its panels are composed of a proprietary Ever-Guard barrier system or acrylic viewing windows, which use techniques for absorbing and diffusing the laser beam with a black anodized surface and light-diffusing texture. The system offers durability and scratch resistance with optical clarity.

Kentek
info@laserphysics.co.uk

Green Laser

Laser Operations LLC has released the BrightLock Ultra-G, a compact, passively cooled green laser based on QPC Lasers' monolithic chip wavelength stabilization technology. The platform delivers continuous-wave output power of 6 W at 532 nm and has a base plate temperature of 20 to 30 °C. It is offered in fiber-coupled and collimated versions. The instrument was designed for military, medical and display applications.

Laser Operations
info@qpclasers.com

Drive Module

ABB Inc.'s ACS850 drive module provides onboard safe-torque-off, a removable memory block, an intelligent user interface, a built-in energy-saving calculator, and modular hardware and software. Designed for industrial machinery and OEM applications, it also includes an advanced adaptation of a proprietary high-performance motor-control platform, the Direct Torque Control. The device delivers from 1.5

to 600 hp at 480 VAC. It is engineered to work with the company's latest generation of high-speed serial interface modules and Drive-Studio software.

ABB
thomas.junger@us.abb.com

Microscope Module

Carl Zeiss MicroImaging GmbH has released a microscope module for analyzing fast processes in living cells. The DirectFRAP imaging system examines processes in cells on the basis of fluorescence-labeled proteins and can study highly dynamic processes in the cell and receive detailed image information simultaneously. Used with a proprietary Axio Observer microscope, the device enables photomanipulation of a region of interest in the specimen with laser light and the direct observation of the subsequent processes. Photomanipulation possibilities include bleaching of GFP, photoactivation of PA-GFP, conversion of Dendra and reversible on/off switching of Dronpa. Laser pulse control and data acquisition are performed by the company's Axio-Vision software.

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Big research on tiny technologies

BY ANNE L. FISCHER
SENIOR EDITOR

IMEC is one busy research center. Headquartered in Leuven, Belgium, the independent research and development center focuses on nanoelectronics and nanotechnology, partnering with companies, universities and other research institutes. One example of the collaborative approach can be seen in the development of technologies and devices for the body and mind.

The Human++ research program, which is operated through IMEC and the Holst Centre in Eindhoven, the Netherlands, focuses on the development of miniaturized devices and technologies that attach to the body to determine a diagnosis or provide feedback on the status of various therapies. Many partners take part in the research. One example is Terepac of Waterloo, Ontario, Canada, which packages the electronics that go into wireless electrocardiogram (ECG) systems.

Terepac brings to the program its expertise in the photochemical printing process, in which thinned silicon dies and passive components are placed on flexible substrates that go into a wireless ECG patch. As with other partnerships within the center, the relationship between IMEC and Terepac is mutually beneficial: IMEC benefits from Terepac's package assembly capabilities, and Terepac has the advantage of being able to test its technology in the final stages of production and application.

Advancing the smart grid

Lowering costs and increasing the performance of power devices such as smart meters, switches, sensors and actuators – all of which play a role in alternative energy – are other areas of focus. Gallium nitride (GaN) devices have shown promise for use on the electrical grid of the future, but making them cost-effectively means producing very large GaN wafers. As a result of collaboration with Aixtron of Crystal Lake, Ill., IMEC launched an industrial affiliation program, with a goal of working toward lowering the cost of GaN technology by using large-diameter GaN-on-silicon. Potential applications include high-power switching in solar converters, motor drives and hybrid electric vehicles.

Aixtron provides the equipment that makes GaN-on-silicon wafers for the solid-state lighting market, among others. With this equipment, researchers at IMEC demonstrated crack-free GaN growth on 200-mm wafers. According to Frank Schulte, vice president of Aixtron Europe, IMEC is a "kind of showroom," where the equipment is in front of a lot of end users, who he said are all potential customers. The benefit to IMEC is the potential development of high-voltage, low-loss, high-power switching devices based on large-diameter GaN-on-silicon technology.

By sharing costs and resources, partners bring in products and technology that become part of the research and development process, and cross-fertilization is the result. While IMEC is headquartered in Belgium, its offices in China, the Netherlands, Japan, Taiwan and the US afford the center the opportunity to have an impact on the technologies of our global future.

anne.fischer@laurin.com

IMEC cooperates with the photovoltaic industry on research and development of highly efficient thin-film crystalline-silicon solar cells and advanced photovoltaic technology, such as organic solar cells and solar concentrators with photovoltaic stacks.

GreenLight

Nonactive solar materials make a difference

In the never-ending quest to lower costs and boost efficiency in solar modules, attention is focused on the active-layer materials such as silicon wafers or copper indium gallium selenide thin films. Nonactive materials, however, can account for nearly half of the module materials cost, and, thus, interest is turning to the development of lower cost/higher efficiency materials such as encapsulants, metallization, antireflection coatings and transparent conducting oxides.

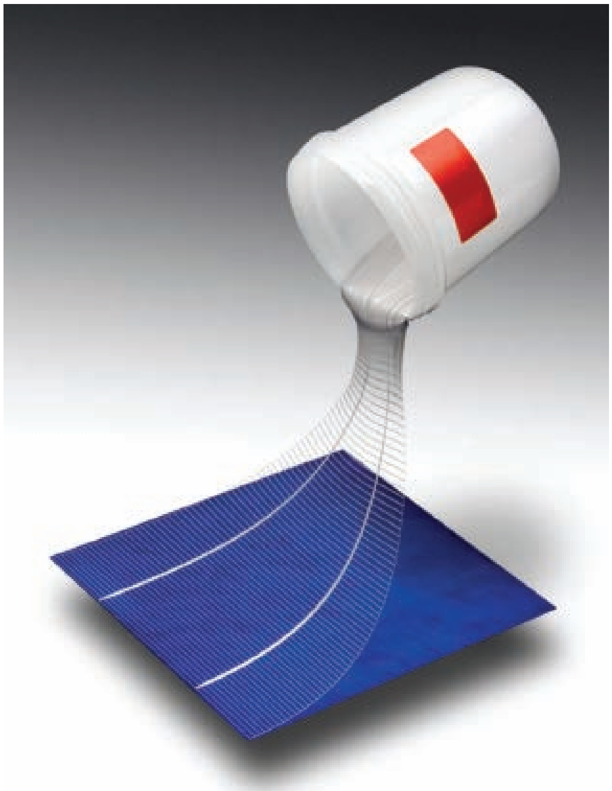
In the report *Driving Down Solar Costs: Non-active Material Opportunities* by Lux Research Inc. of Boston, analysts looked at 21 new nonactive materials for the solar market in terms of their potential effect on the dollar-per-watt cost, factoring in how long it will be before the material is ready for commercialization. When asked how nonactive materials can have much of an effect on cost or efficiency, Johanna Schmidtke, the report's author, said that the goal is to increase efficiency for a relatively small amount of money.

As an example, she cited antireflection coatings for external reflectivity of glass on the module, which she said are quite expensive. But she added, "Once you get to a certain point in module efficiency, the cost per area is low enough to make sense in terms of dollars per watt."

New twist on old tech

Key findings in the report include the fact that tomorrow's nonactive products will be improvements upon today's technologies, and anything that's really new will have to show significant cost savings and efficiency improvement before finding widespread adoption. For example, in metallization, there are new ways of adding grid lines to the front of crystalline silicon solar cells, such as screen printing very fine lines.

Schmidtke pointed out that making the grid lines thinner allows for less shading on the cell and, therefore, greater efficiency. Screen printing is a proven technology in creating fine lines, and adopting processes that are advanced variations on screen printing doesn't require a leap of faith on the part of module manufacturers, but moving to any noncontact printing method will take at least three to five years before it meets market acceptance.



New materials, such as the metallization paste shown here adding grid lines to the front of silicon solar cells, boost their efficiency. Photo courtesy of DuPont.

Two new processes looking to replace screen printing are inkjet printing and aerosol jet printing, but they will have to prove their value before finding wide use in the solar industry. Xjet, a company based in Israel, has an inkjet metallization process for solar cell manufacturing. One company that makes an aerosol jet system for solar manufacturing is Optomec of Albuquerque, N.M. The system is currently installed in an R&D production line at the Fraunhofer Institute for Ceramic Technologies and Systems in Dresden, Germany, the results of which may help get other manufacturers onboard with the new technology.

Typical time to market for any totally new material or process is five years or more, according to Schmidtke. From the solar vendor's point of view, when the module has to "sit out there for 20 years in rain, dust and wind, it has to have a durability and performance that's suitable for its warranty." It's no wonder that the materials in use today are variants of the tried and true. But with some of the newer, more radical materials showing great promise, the makeup of solar modules could look very different five years from now, and a lower cost and more efficient source of energy could be the result.

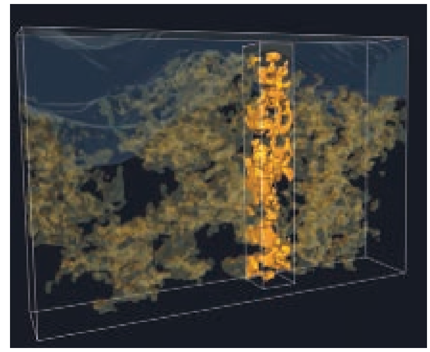
anne.fischer@laurin.com

Peering into a hybrid solar cell

Hybrid polymer solar cells are not as common as silicon cells, nor are the efficiencies as high – currently only about 2 percent. But hybrid polymer cells, which are both organic and inorganic, offer two major advantages that keep researchers seeking ways to boost their efficiency. Most notably, they can be printed in a roll-to-roll process, reducing the cost of their manufacture, and they're flexible and can be applied to a range of objects such as clothes, umbrellas, laptop carrying cases and more.

Hybrid cells are a mixture of a polymer and a metal oxide, a combination that creates charges when the mixture soaks up the sun. Critical to the cells' efficiency is the degree of mixing, which can enhance the area of the interface where the charges are formed. Researchers at the Eindhoven University of Technology in the Netherlands and at the University of Ulm in Germany used 3-D transmission electron microtomography to peer inside these solar cells. They are interested in their structure because it's difficult to control, as a result of the differences between the chemical nature of polymers and metal oxides. The researchers used a precursor compound that mixes with the polymer and then converts into the metal oxide only after is incorporated in the photoactive layer.

A commercial 3-D transmission electron microscope (TEM) from FEI Co., a Tecnai G² 20, was used to visualize the modules. Lead researcher René Janssen, a professor of molecular materials and nanosystems, noted that this is the first time that 3-D tomography has been applied to hybrid solar cells. He said its application is similar to that of a medical CT scanner in that researchers look at the transmission of an electron beam through the sample and take images while rotating it in 1° steps. A series of 2-D TEM projections is then used as input to come up with a 3-D reconstruction, which gives insight into the morphology.



This 3-D electron tomography image of the inside of a polymer-metal oxide solar cell shows the metal oxide network (yellow) in the polymer phase (transparent) below an aluminum top electrode (gray). Most zinc oxide is interconnected and makes contact with the aluminum electrode.

Measuring percolation

"There are quite a few of these bulk heterojunction solar cells, but so far we have very little quantitative information on the morphology. By using 3-D tomography, we have a way to understand how these devices work," he explained.

In general, the challenge is to be careful that the electron beam doesn't influence the sample or damage the very thin film, according to Janssen. However, because of the large difference in density between the polymer and the zinc oxide, the resulting images showed good contrast and demonstrated in three dimensions the importance of mixing.

Researchers from the Institute for Stochastics at the University of Ulm extracted the typical distances between the components that relate to the efficiency of charge formation. Then they analyzed how much of each component is connected to the electrode for charge transport. Through this research, they were able to analyze and quantify the percolation pathways. The next step will be to use this data to develop a detailed operational model of these cells, which they hope will help solar researchers better understand the way organic and inorganic solar cells work.

anne.fischer@laurin.com

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For example, at our global network of Solar Solution Application Centers, we're collaborating with customers to solve material development puzzles, trial new solutions at industrial scale, and test them to be sure they meet industry standards. And through our Hemlock Semiconductor Group joint venture, we're combining our silicon expertise with their industry-leading polycrystalline silicon manufacturing experience to help meet the needs of the growing solar panel market.

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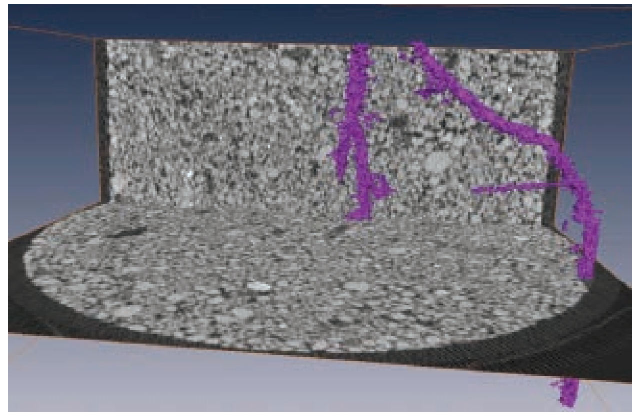
DOW CORNING

GreenLight

CT scanner peers into soil and sustainable materials

Imagine looking at the inner structure of pretty much anything – and getting ultrahigh-quality, high-resolution images that show it changing over time. Researchers at the University of Nottingham in the UK are doing just that with a three-dimensional x-ray micro-CT system.



A CT scan taken at 18 μm shows roots from a wheat plant (in purple) in a sandy loam soil. Image courtesy of Rob Davidson/Sacha Mooney.

Sacha Mooney from the university's division of agricultural and environmental sciences previously had to borrow time on hospital scanners to look at soil structure. By taking an interdisciplinary approach and pooling resources, the university was able to purchase a Nanotom from phoenix x-ray, based in Germany, a division of GE Sensing and Inspection Technologies. Researchers from various departments – including veterinary, geography, archaeology, engineering and biology – all use the Nanotom.

"There's a lot of interest in [seeing] how things look inside without disturbing them," Mooney noted. The scanner can image objects measuring up to 15 × 15 cm and weighing up to 1 kg. It comes with a digital 5-megapixel detector and a 180-kV/15-W nanofocus tube. There are a lot of x-ray tomography systems around, but what's significant with the Nanotom, Mooney said, is that it produces resolution to a half a micron, "and you can scan in a matter of minutes instead of hours."

In the soil studies, the researchers can now scan whole plants. By scanning roots in soil at 10- or 15-minute intervals, they're able to see the growth process. And with the high-resolution capability, they can see the complexity of soil better than they ever have with previous scanners.

The engineering department has had the same results with sustainable building materials. They can see the internal pore structure to better understand heat flow, heat loss and moisture retention.

The output is a series of image slices separated by very fine intervals. Mooney explained that scanner operators can open up a stack of images and examine each in any orientation or level of zoom with VGStudio Max visualization software from Volume Graphics of Heidelberg, Germany. The result is a model of the structure that is useful for studying the transportation process.

For example, looking at sustainable building materials, scanner users can determine the size and shape of pores in a structure and understand the flow of heat or moisture. Or in soil studies, they can see how water flows around roots. "We no longer have to guess," Mooney said.

The greatest challenge with the Nanotom so far has been "just getting it in the building," according to Mooney. During actual use, there's a steep learning curve, as with any type of computed tomography, he noted. He added that a secondary component is image analysis.

"Image quality is everything in image analysis." With many options throughout the scanning process, the researchers have to understand more about it. He indicated that, although the operators are still learning how to get the best results, they've already gotten some that are very good. "We're amazed by the images of some structures that we didn't know even existed." The results of this understanding can be used in food security and sustainable food production, and in developing more energy-efficient building materials.

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Photonics Is Heating Up in India

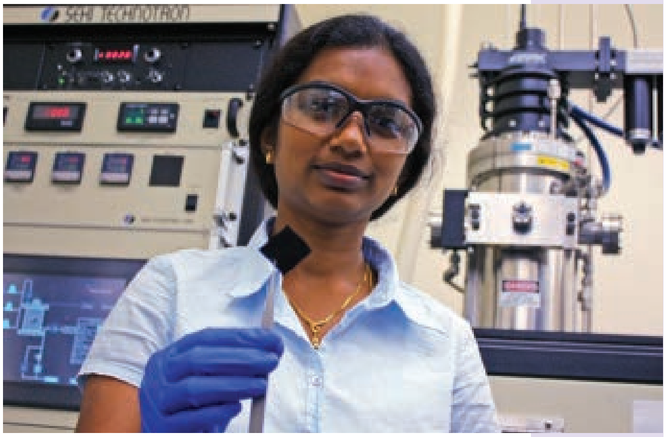
BY MARIE FREEBODY, CONTRIBUTING EDITOR

India is the seventh-largest country by geographical area and the second-most populous in the world. With approximately 1.17 billion people, it is second only to China, which has 1.34 billion. Situated in south Asia, between Pakistan, China and Nepal, India is bounded by the world's highest mountain chain – the snow-covered Himalayas – in the north, stretching southward to tropical rain forests and sandy deserts.

Its economy is as diverse as its landscape, ranging from traditional village farming, modern agriculture and a whole host of services. Photonics is still in its infancy in the country, generating approximately $500 million every year. But thanks to a mushrooming telecommunications sector, many believe that photonics will play a vital role in India's future development.

"Optical communication is an area that is going to drive the Indian economy," said professor Perumal Ramamurthy, director of the National Centre for Ultrafast Processes at the University of Madras in Chennai, India. "With its huge population, India has massive potential for extensive growth in this sector for both general communication as well as broadband Internet."

As seen elsewhere in the photonics industry, biomedical optics, particularly microscopy, endoscopy and skin treatment, as well as photovoltaics are all major areas in India's growing photonics map. Optical computing, defense, new materials for sensors and devices are also sectors to watch in the country.



(Top) Bhuvana Thiruvelu, a postdoctoral research associate at the Birck Nanotechnology Center in Purdue's Discovery Park, demonstrates her research in which carbon nanotubes are grown from palladium nanoparticles on what's called a "buckypaper" sheet. (Purdue News Service photo submitted by Jeff Goecker.) (Bottom) Shown is an LED chip bonding process at Kwality Photonics Pvt. Ltd. in Hyderabad, India. Courtesy of Kwality Photonics.

Photonics hot spots

On the whole, India's photonics companies are clustered around universities and research institutes, which are in Bangalore, Cochin and Hyderabad, all in southern India.

With only about 24 photonics companies in the country, employing about 200 engineers and between 800 and 1000 technicians/operators, jobs still are limited in the industry.

Arguably the biggest home-grown photonics players are SFO Technologies of Cochin, Sterlite Optical Technologies Ltd. of Pune, Tejas Networks India Ltd. and Optocircuits (India) Ltd., both of Bangalore, and Kwality Photonics Pvt. Ltd. of Hyderabad. These companies, as well as India's industry as a whole, benefit from proximity to important Indian Ocean trade routes, providing vital links to Africa, East Asia, Europe and the Americas.

SFO Technologies, part of the NeST Group, operates in software development, hardware manufacturing, optoelectronics, fiber optics and broadband solutions. Dr. Suresh Nair, chief technology officer for the NeST Group and executive council member of the Optical Society of India (OSI), attributes the company's success to the high-level tech-nical skill of its staff and to its ability to communicate in English.

Vijaya Kumar Gupta Kopuri, managing director of LED manufacturer Kwality Photonics, agrees. "India offers a huge market as well as a massive workforce, both at the factory floor and engineering level. This is a great advantage for Indian firms."

Besides the country's domestic companies, India is home to the design centers of global companies such as US giant IPG Photonics Corp. of Oxford, Mass., the French-formed Alcatel-Lucent, Honeywell, Cisco, Cienna, Tyco Electronics and Alphion, to name a few.

Nair said that the attractions for foreign companies are government subsidies and low interest rates. The government also recently stipulated that a minimum 40 percent of system contribution must come from local sources, which means that many industry giants are keen to partner with local photonics companies.

The workforce

There are only a handful of universities and institutes that specialize in optics and photonics research, and the limited job opportunities have had a secondary effect on these academic centers, which often find that attracting photonics students can be a problem.

"We find that not many students are coming forward to enroll in photonics courses, compared with other courses, because there aren't enough industrial openings available in the country," Ramamurthy said. "Students prefer to pursue higher education within the country or go abroad looking for work."

But Reji Philip, assistant professor at the Raman Research Institute, disagrees. "We don't find any particular difficulty in attracting students into the optics/photonics stream. In the doctoral program at the Raman Research Institute, we currently have around 20 percent enrolled in the Light and Matter Physics Group."

OSI was formed in 1965 in a bid to promote photonics in the country. The society organizes regular national conferences and publishes the *Journal of Optics*, which enjoys a wide circulation in India.

The Photonics Society of India was formed more recently, in 2000. Its main objective is to create a network of researchers, scientists, educators and industrialists who are interested in taking part in photonics-related programs in the country. Most of its committee members are made up of scientists at India's leading research institutes and national laboratories, including the Raman Research Institute and the International School of Photonics at Cochin University of Science and Technology.

Government support

For the most part, the photonics industry receives minimum support from the Indian government. "The Department of Information Technology supports industries as well as academic institutes by sponsoring projects in thrust areas, but there is no special consideration for photonics industries," Nair said.

Recently, however, the government recognized the potential of optical communication and reduced some of its controls on foreign trade and investment. By permitting higher limits on foreign direct investment in a few key areas, such as telecommunications, the government has helped strengthen this sector.

A major challenge facing Indian photonics companies is competing with Chinese vendors, who often undercut Indian manufacturers. "Many fiber components are imported from China with no duty – the product descriptions are carefully worded so as to avoid this tax – and they are dumped on the local market," Nair said. "While Indian component manufacturers provide high-quality goods, the customers or installers will often look for the lowest quote. There are even instances where you purchase two couplers, and another one is given free of charge just in case one fails."

Another issue, Nair said, is Chinese companies, such as Huawei Technologies Co. Ltd. of Shenzhen, that participate in Indian government tenders. Indian counterparts cannot match the cost competency.

What now?

Quality does not seem to be the issue for Indian photonics. Many of the country's designs and products are privately labeled and can be found in telecommunications, health care and other industries around the globe. For example, SFO Technologies' fiber distribution systems for multidwelling units are now being used by US broadband and telecommunications specialist Verizon.

According to Kwality Photonics' Kopuri, the country appears to be on the verge of a photonics explosion. Despite entering the LED industry early in the 1970s, India has yet to see large-scale manufacturing or a proliferation of entrepreneurs in the field. But this may all be about to change.

"I predict sizable investments to be made in LED chip and LED packaging lines in anticipation of exploding demand in India for LED-based lamps," he said. "Kwality Photonics is ready to partner with forward-looking technology firms to produce 120-lumen-per-watt LEDs."

But the photonics industry in India has a long way to go before it reaches its peak. A bottleneck in its growth is the limited component and material base. This makes the industry reliant on foreign sources. To ensure the industry's success, Ramamurthy believes that huge investments are required.

The Raman Research Institute's Philip agrees. "I don't foresee any quantum jump in industry revenues in the near future. To ensure success, the foreign export component first needs to be strengthened."

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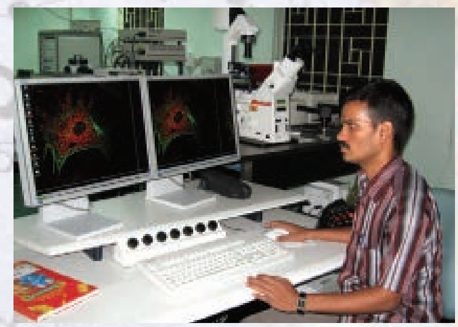


(Clockwise from right)
A research scholar at the National Centre for Ultrafast Processes performs a fluorescence confocal experiment. Courtesy of the National Centre for Ultrafast Processes.

Inside SFO Technologies, engineers manufacture active photonics systems. Courtesy of the NeST Group.

Students at Raman Research Institute set up a nonlinear light absorption experiment. Courtesy of Manoj Sudhakaran.

A student at the Raman Research Institute aligns an ultrafast laser system. Courtesy of Manoj Sudhakaran.

This thermal image obtained with a 1024 × 768 a-Si microbolometer detector shows both high sensitivity and high resolution. Courtesy of ULIS (sister company to Sofradir).

Uncooled infrared detectors:
Better performance, lower cost

BY ART STOUT, SOFRADIR EC INC.

Infrared camera manufacturers can choose from a wide variety of uncooled IR detectors to make different model designs for a variety of commercial, industrial and military products.

Uncooled infrared detectors have seen many significant technology advances – improved reliability, better manufacturability and lower costs – that have fueled the availability of a wide variety of IR cameras. Low-cost portable and fixed infrared cameras as well as high-performance systems have been introduced for a variety of thermal imaging applications.

Thanks to new price points and better overall performance, traditional markets for infrared cameras have exploded, while new markets have been created.

Uncooled detectors go mainstream

There are two classes of infrared detectors that can be used to manufacture IR cameras: cooled and uncooled. Cooled detectors – named for their reliance on a cryogenic cooling mechanism – are considered extraordinarily sensitive to infrared radiation. The cryocooler substantially reduces thermal noise (infrared radiation from sources other than the objects being observed) down to very low levels. Mercury cadmium telluride and indium antimonide are the most common materials used in cooled detectors. Because the cryocooler unit is a mechanical device with moving parts, cooled detectors usually require maintenance after a period of time, often for every 8000 to 10,000 hours of operation.

Uncooled infrared detectors have become an excellent alternative and are much more commonly used in many commercial, industrial and military IR camera products. Because they do not require the use of a cryogenic cooling unit, infrared cameras that use uncooled detectors enjoy substantial advantages in maintainability as well as a significant reduction in size, complexity and cost.

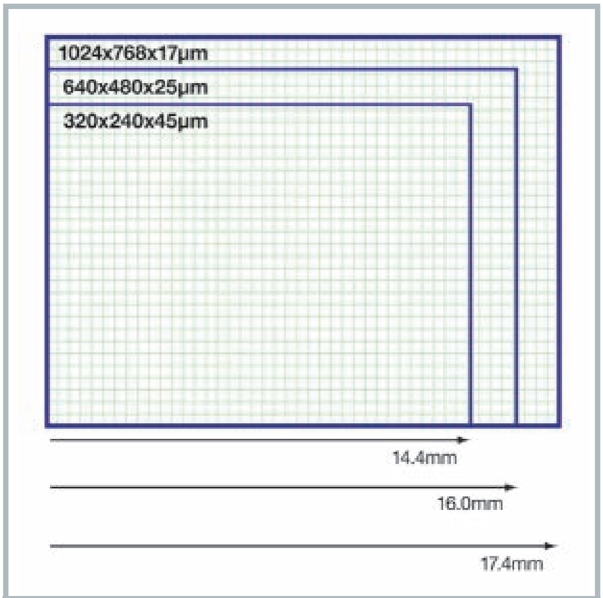
The primary type of uncooled detector today is the microbolometer, a device based on microelectromechanical systems technology. When infrared radiation in the wavelength range between 7 and 13 µm strikes the microbolometer's detector material and is absorbed, it heats up, and the resulting change in its electrical resistance is the basic sensing technique. These changes are processed by separate core electronics to create a thermal image. These detectors are quite sensitive and can sense heat radiated from objects, depending upon their temperature.

The two most common microbolometer detector materials are amorphous silicon (a-Si) and vanadium oxide, referring to the material on the outermost thin-film layer. While the two materials function in a similar manner, there are many differences between them.

Microbolometers having a-Si as the thermometer material have been developed using sophisticated surface micromachining techniques to produce very thin, very sensitive membranes. These detectors can be economically used in an extremely thin ceramic package specifically designed for the detector. The array is integrated and subsequently sealed under vacuum without the need for any pinch-off tube.

The design of the detector package allows for a 15-year storage lifetime at room temperature.

These detectors have become widely integrated into many commercial and military products. Because of the use of a-Si, they have benefited from widely available silicon manufacturing processes. They also have benefited from a great deal of research on improving the performance of similar silicon-based devices, such as solar cells and flat panel displays, with particular attention to pixel operability and uniformity. Although other detector materials such as vanadium oxide have shown slightly better noise figures, the technological benefits of a-Si pixels and high-yield silicon manufacturing processes have rapidly popularized this technology.



As pixel pitch decreases and pixel counts increase, the detector active area stays fairly stable.

Technological advancements

Technological breakthroughs in a-Si microbolometers have occurred at a constant pace, resulting in performance improvements such as resolution and sensitivity as well as in better detector packaging. Pixel uniformity and operability due to production changes have continued to improve as well.

1. Reduced pixel geometries

Because a-Si is inherently stiff, microbolometers manufactured with this material can be made with very small bridge structures. As a result of these thinner membranes, a-Si microbolometers exhibit higher effective thermal insulation than devices based on vanadium oxide. Reduced bridge size allows also for the development of small pixels and therefore more pixels per area, smaller physical sizes and lower costs. The a-Si microbolometer pixel is quite simple in structure, so reducing pixel size does not require a complex microbridge, since the structure scales appropriately. As a result, the number of fabrication operations in the manufacturing process is optimized.

Over the past 10 years, a-Si infrared detector arrays have seen a steady reduction in pixel pitch from 45 µm back in 2000 to 17 µm in 2008. Next-generation arrays are projected to have a 12-µm-pixel pitch geometry, further reducing the size of detectors and optics as well as the size of infrared cameras.

In conjunction with pixel pitch reductions, arrays offering higher resolution have been introduced. Many microbolometer array sizes are available, from a low-resolution 160 × 120 array to a large-format 1024 × 768 array. In light of the reduction in pixel size and the increase in resolution, the active detection area for these arrays remains nearly constant for certain comparative array sizes. The width of a detector having 320 × 240 pixels with 45-µm pixels (14.4 mm) is quite similar to the width of a detector having 640 × 480 pixels with 25-µm pixels (16.0 mm) and also to the width of a detector having 1024 × 768 pixels with 17-µm pixels (17.4 mm). With similar detection areas, production and packaging costs are maintained, and the size and cost of infrared camera housings and optics can be stabilized.

2. Thermal time constant and sensitivity

Thermal time constant is one of the most important parameters in the design of an infrared imaging detector, exceeding the importance of other parameters. Again, because of the intrinsic properties of silicon, a-Si pixels can be produced with very thin microstructures because of their rigid behavior. With these thin microstructures, pixels exhibit a very low thermal conductance between the pixel and substrate, and low suspended thermal pixel mass. This results in pixels having a very short time constant and very fast response time, which is an enormous benefit for any infrared detector. It is commonly accepted that pixel response times should not exceed one-third of the reciprocal of the frame time (i.e., 10 ms for an array operating at 30 Hz). This is easily achieved with a-Si pixels.

As pixel pitch decreases, other parameters must be appropriately modified to keep pixel sensitivity from decreasing as the active detection area becomes smaller. Because sensitivity has a great impact on image quality, certain design changes are important to ensure that detector sensitivity remains at the desired level. For example, when the pixel pitch of a-Si microbolometers was reduced from 45 to 25 µm, the photolithographic resolution improved with no adverse impact on fill factor. While 1.5-µm minimum design rules were used for 45-µm pitch detectors, 25-µm detectors required 0.8-µm minimum design rules, and 0.5 µm for 17-µm pitch detectors. However, improvements in the design of the support legs as well as a reduction in both the width and thickness of the patterned legs resulted in higher thermal insulation. The result was a microbolometer array having the same sensitivity but with all the advantages of smaller pixels.

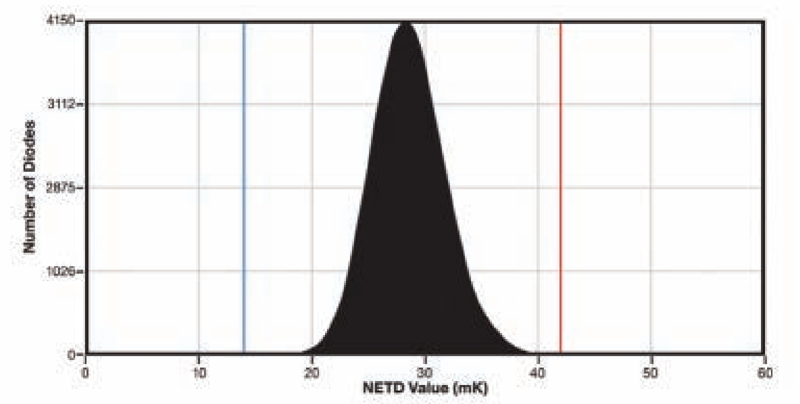
To further reduce the pixel pitch while maintaining pixel time constant and detector sensitivity, pixel design modifications were required. It was necessary to reduce the thickness of the microbridge films to

	Temporal NETD	Pixel Time Constant	Intrascene Dynamic Range
Standard Design	30 mK	7 ms	200 K
MERTIS Design	11 mK	13.6 ms	19 K

NETD = Noise-Equivalent Temperature Difference
MERTIS = Mercury Thermal Infrared Imaging Spectrometer

reduce their thermal mass. To maintain good noise immunity, the microbridge was thinned down at the same rate of decrease as the detector active area. At the same time (but more challenging), the thermal conductance also had to be reduced at a rate corresponding to the square of the pixel area. Because of the simplicity of the silicon substrate, the thickness of the a-Si microbridge could be easily reduced with very few restrictions.

As an example of the importance of pixel time constant, compare the results of different a-Si focal planes as shown in the table: One is standard in design, and another is designed for high-sensitivity, narrow intra-scene dynamic range applications such as would be required in astronomical missions.



Amorphous silicon detectors are well-known for their excellent array uniformity, resulting in improved image quality, reduced system complexity and lower overall costs.

3. Image uniformity and operability

As with other imaging arrays, each microbolometer pixel has a slightly different response given by the pixel gain and pixel offset. During the manufacturing process, each array has a resulting distribution of gain and offset values from each pixel. Because of well-established silicon manufacturing methods and the simplicity of the a-Si microbolometer's structure, the device exhibits excellent image uniformity, as shown by the similar behavior of all the pixels. Excellent array uniformity means that the array gain can be increased before digitization to improve overall system signal-to-noise performance.

The operability of an IR detector array is defined by the number, or percentage, of defective pixels in the array. Highly uniform arrays have a smaller number of bad pixels since pixels are defined as defective if their characteristics are significantly different from the average. To achieve the best image, array pixel response should be as uniform as possible across the surface of the device prior to any nonuniformity correction. Amorphous silicon detectors traditionally offer high operability rates because of the simplicity of silicon technology and the benefits of established processes. Operability of better than 99.5 percent is standard in a-Si detectors, and rates as high as 99.9 percent are not uncommon.

Because of their intrinsic uniformity, a-Si detectors have other important advantages over other types of microbolometer detectors. For example, they can be operated quite easily without a thermoelectric cooler. Since a-Si pixels have only one activation energy that defines the bolometer resistance as a function of temperature, knowing the pixel resistance at one temperature is sufficient for predicting the resistance at other temperatures.

Microbolometer arrays manufactured with a composite of materials (e.g., vanadium oxide) have numerous factors that affect the response of the pixels in the array and are not so easily characterized. Consequently, they exhibit higher nonuniformity characteristics and are more difficult to operate in a mode without a thermoelectric cooler since the wide variation in response cannot be easily predicted. In addition, if not appropriately compensated, some of the pixels in the array may appear saturated, having a response outside the detector digitization range. Because of the high uniformity of a-Si detector arrays, the raw signal delivered by the detector is sufficiently uniform to be processed without any additional electronics, which reduces system complexity, calibration, yield, power consumption, size and cost.

Applications

High performance, high reliability and lower cost make a-Si detectors ideally suited for many IR applications in both commercial and military sectors. IR detectors and cameras are now becoming standard in automobiles as night-vision systems. Thermal imaging cameras also have been used to find victims in live fires and for airport "fever screening."

Because of technological advances such as 17-µm pixel pitch and large-format detectors, a-Si microbolometers are finding their way into many more military and commercial night-vision applications, including security and basic surveillance. For example, unmanned aerial vehicles require lightweight and reliable IR detectors that can stand physical punishment including high vibrations and high *g* force loads. These requirements make uncooled a-Si microbolometers ideally suited for this application.

Certain IR cameras can be calibrated to provide noncontact measurement of object temperature. These can be used for industrial inspection, especially in environments with high power usage. Inspectors use IR cameras for thermal analysis to detect and prevent problems with electrical and mechanical components. In these systems, excess heat can be a sign of a potential problem, so noninvasive infrared cameras scan for issues including loose or dirty connections, overloaded circuits and plugged cooling lines in transformers.

IR detectors and thermal imaging provide an easy-to-use tool for conducting energy audits. These focus primarily on insulation and seals around exterior doors and windows as well as on gaps or cracks that are leaking energy. In addition, thermal imaging cameras can save time and money in detecting pipe leaks: A quick scan can eliminate the need for destroying a wall or digging up a pipe.

Meet the author

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Adaptive Optics in Biological Imaging with Two-Photon Microscopy

BY MICHAEL FEINBERG AND PAUL BIERDEN, BOSTON MICROMACHINES CORP.

Cutting-edge biological microscopy has enabled researchers to explore tissue at the subcellular level in vivo. Having the ability to observe physiological processes in vivo has led to breakthroughs in our understanding of cancer, eye disease and brain disorders and is paving the way for earlier diagnoses and more effective treatment.

Until recently, biological imaging devices have had resolution limitations that restrict the ability of researchers and clinicians to detect critical detail in vivo mainly because of tissue type, density and lighting. As light passes through tissue to reach the object of interest, the tissue induces wavefront aberrations in the light, causing images to be blurred and distorted and significantly reducing the contrast.

In vivo imaging also has struggled with a fundamental problem: using enough light to illuminate a sample while not using too much light, which can cause tissue damage. The use of adaptive optics has reduced the effects of optical distortion, providing clearer images down to the cellular level and minimizing potential damage to the tissue.

Fluorescence microscopy is a form of biological imaging that can benefit from improvements in adaptive optics, which may well become a fundamental component in this core instrument in biomedical research. When certain molecules are illuminated with high-energy light, they emit light of a lower frequency. This effect is known as fluorescence. Two-photon (also known as multiphoton) laser scanning microscopy (TPLSM) is a form of fluorescence microscopy that is being used in all major areas of biological research, from stem cells to cancer and heart studies.

TPLSM allows researchers to study changes in the physiological state of cells and tissues by combining laser scanning microscopy with long-wavelength multiphoton fluorescence excitation to enable deep, three-dimensional images for depths of up to 2 mm with submicron resolution obtained in vivo with minimal damage. With the technique, the imaging challenge is difficult because the images depend nonlinearly on laser power for excitation and, as researchers move farther into the tissue, because the fluorescent signals decrease rapidly.

Increasing the laser power partly compensates for the signal loss, but this adjustment is limited by the increased likelihood of phototoxicity to the sample. Adaptive optics solves this challenge by allowing research on thick, living tissue specimens that would not be possible using conventional imaging techniques.

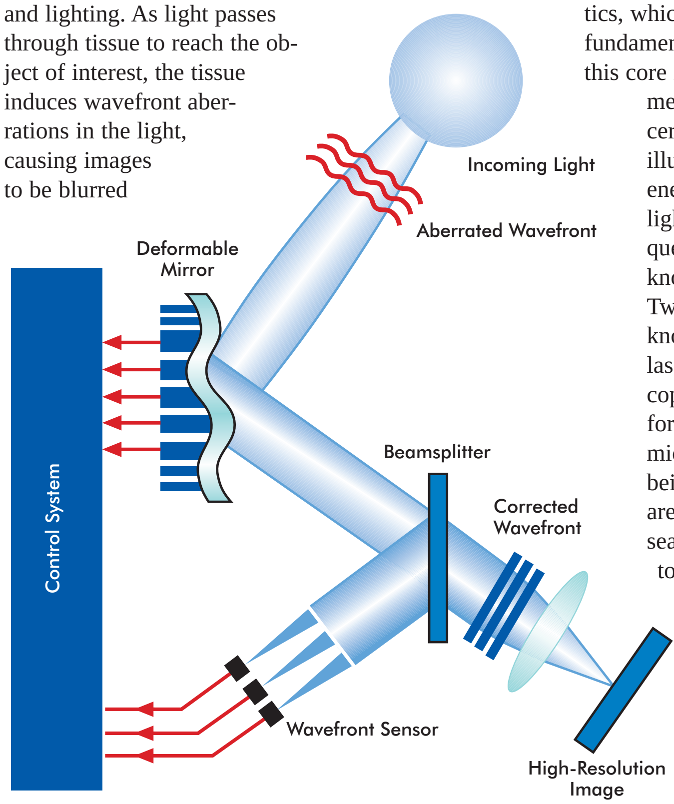

Figure 1. There are three main components of an adaptive optics system: a sensor to measure wavefront aberrations, a deformable mirror that can correct for the aberration, and a control system that takes measurements from the sensor and calculates the necessary movement of the mirror. Adapted from Professor Claire Max, director of the Center for Adaptive Optics, University of California, Santa Cruz.

Adaptive optics mature

Currently, the addition of adaptive optics aids TPLSM instruments in having consistent imaging capabilities, so that distortion is minimized and detail enhanced by helping to remove aberrations and misalignments present in the instrument as well as sample-induced aberrations. There are three main components of adaptive optics systems: a sensor that can measure wavefront aberrations, a wavefront corrector that can correct for the aberration, and a control system that takes measurements from the sensor and calculates the necessary movement of the wavefront corrector (Figure 1).

A deformable mirror is the most commonly used wavefront corrector and the adaptive element of the adaptive optics system. Based on information provided by the controller, the mirror will change its shape to correct for the aberration in the wavefront, thus “cleaning up” the image. The deformable mirror is thin and flexible, with a number of control points behind it to adjust its shape. Microelectromechanical systems (MEMS) deformable mirrors are currently the most widely used tech-

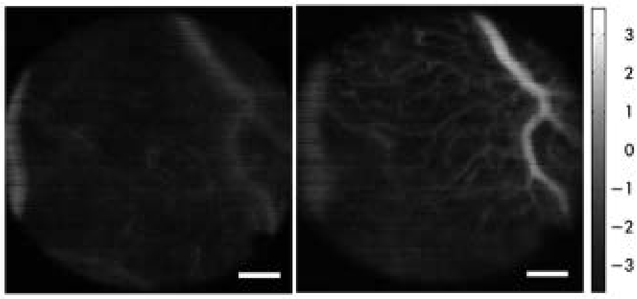

Figure 2. Mouse retinal imaging benefits from the addition of adaptive optics. Images taken without adaptive optics enabled (left) and with adaptive optics enabled (right) are shown. The scale bar represents −3 to 3 µm. (From David P. Biss, Daniel Sumorok, Stephen A. Burns, Robert H. Webb, Yaopeng Zhou, Thomas G. Bifano, Daniel Côté, Israel Veilleux, Parisa Zamiri and Charles P. Lin, "In vivo fluorescent imaging of the mouse retina using adaptive optics," *Optics Letters*, Vol. 32, No. 6, March 15, 2007.)

nology in wavefront shaping applications because of their versatility and cost, the maturity of the technology and their ability to correct high-resolution wavefronts. Liquid-crystal spatial light modulators as well as macroscale deformable mirrors also have been used in this application.

Recently, the addition of adaptive optics to TPLSM has enabled scientists to see great detail in vivo of the anatomy of animals, shedding light on the exact makeup of biological structures. For example, Figure 2 illustrates in vivo fluorescence imaging of mouse retinal blood vessels before and after adding adaptive optics elements. As can be seen, the use of adaptive optics increases the resolution to the point that finer capillaries are visible; without its use, these capillaries are not visible. In addition, the use of adaptive optics increases the overall contrast in the image.

Another example of this enhanced capability is shown in Figure 3. A bone cavity in a mouse skull was imaged using TPLSM both with and without adaptive optics. Clearly, the bone cavity image acquired with adaptive optics shows improved intensity and resolution.

TPLSM and neuroscience

Recently, TPLSM has enabled groundbreaking advances in neuroscience that help researchers increase their understanding of brain disorders by studying neural dendritic spines and the relationship between blood flow and neuronal activity.

Dendritic spines are small protrusions or appendages that are present on neurons and are believed to help transmit and receive electronic signals from other neurons. Before the introduction of TPLSM, the basic physiological properties of dendritic spines could not be measured or observed because the volume of dendritic spines is 1 µm^3 or less.

Researchers using TPLSM have learned that, by using time-lapse studies in the brains of living animals, spines can change significantly in shape, volume and number and can affect brain functions including motivation, learning and memory. Numerous brain disorders – such as autism, mental retardation and schizophrenia – are associated with abnormal dendritic spines.

Adaptive optics can play an important role in ensuring that the TPLSM instrument is always working at peak performance levels by correcting for misalignment in the optical system. This is critical during time-lapse studies and during research that depends on

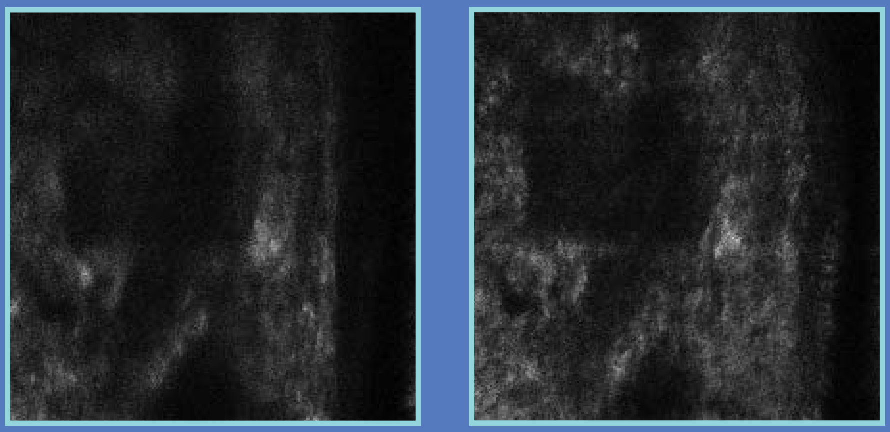

Figure 3. TPLSM images of mouse skull bone cavity show enhanced detail and contrast with adaptive optics (right). Bone imaging of mouse skull was taken at 180 m into the bone. (From Y. Zhou, T. Bifano and C. Lin, "Adaptive optics two-photon fluorescence microscopy," *Proc. SPIE*, Vol. 6467, MEMS Adaptive Optics, Scot S. Olivier, Thomas G. Bifano and Joel A. Kubby, eds., January 2007.)

observing changes to tissue matter, particularly at the molecular level. Distortion can skew or influence results.

Discovery using TPLSM

New research using TPLSM from Northwestern University Feinberg School of Medicine in Chicago has revealed how schizophrenia works in the brain. Using a genetically engineered mouse model, investigators discovered that schizophrenia symptoms are triggered by a low level of kalirin in the frontal cortex of the brain, the part responsible for problem solving, planning and reasoning. Kalirin is a brain protein necessary for the development of dendritic spines.

With fewer dendritic spines, there are fewer neural pathways for information to travel, so the information becomes bottlenecked (Figure 4). This traffic jam results in hallucinations, memory loss and social withdrawal, the symptoms associated with schizophrenia (Cahill et al, 2009).

Michelle Day, a research assistant professor at Northwestern University in Chicago who acquired all TPLSM images for this research, said the instrument was found to be difficult to calibrate, requiring hours each month for alignment. With the addition of adaptive optics, calibration issues would be significantly reduced, increasing the availability of the instrument. By implementing adaptive optics, the need for expertise in calibrating the instrument on a regular basis would also be reduced, leading to lower cost of operation. Day believes that this could lead to more widespread use of the instrument because users such as biologists and practitioners of medicine would not need to be experts in the inner workings of the instrument to take advantage of the technology.

The examples listed can benefit from the use of adaptive optics. Introducing it into each of the optical setups renders the ability to capture images more dependable. Wider use of this technology could lead to new discoveries and advancement in the detection of disease and therapeutic treatment. TPLSM has become an important tool for learning more about brain function and its impact on disease. Adaptive optics greatly enhances TPLSM so that the instrument always works at peak performance levels and reduces optical distortion that could affect research results.

Discoveries such as those noted in this article are enabling researchers to make unprecedented medical research breakthroughs in diagnostics and therapeutic treatment for brain disorders and mental illness. With the use of adaptive optics, these discoveries no doubt will continue, leading to new discoveries as they have in other biological disciplines.

Meet the authors

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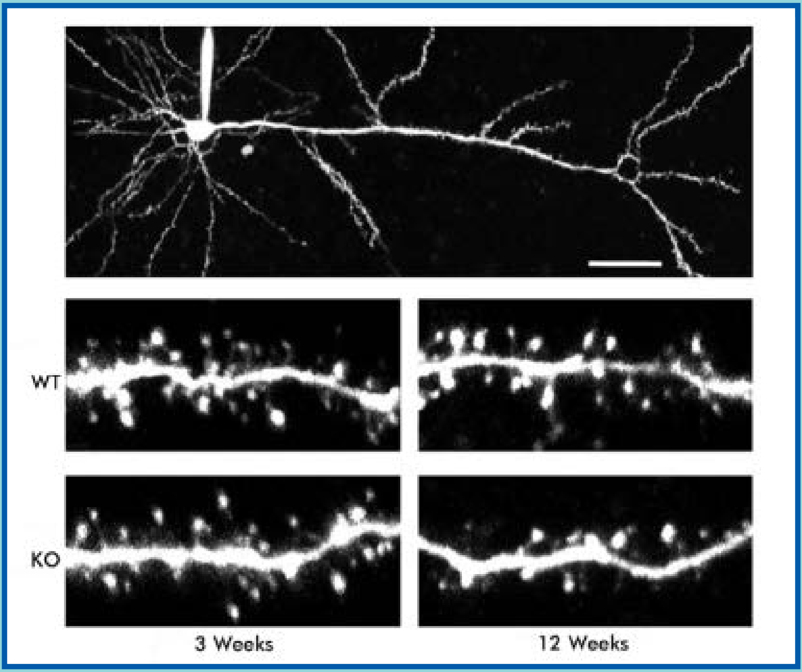

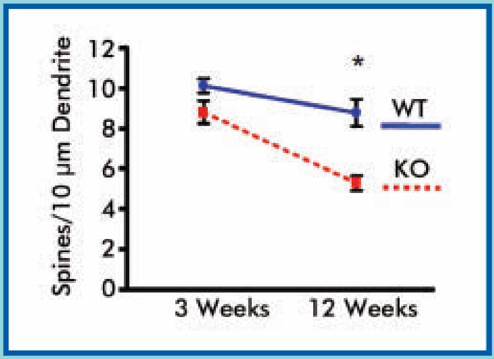

Figure 4. The images on the left show that, after 12 weeks, fewer dendritic spines are present in a genetically engineered kalirin knockout mouse (KO) as compared with an unaltered mouse (WT). This is found to be significant, as shown in the graph on the right. The reduction in spine density results in the symptoms associated with schizophrenia. Images are by Michelle Day using TPLSM. (From Michael E. Cahill et al, "Kalirin regulates cortical spine morphogenesis and disease-related behavioral phenotypes," *PNAS*, Vol. 106, No. 31, pp. 13058-13063, Aug. 4, 2009.)

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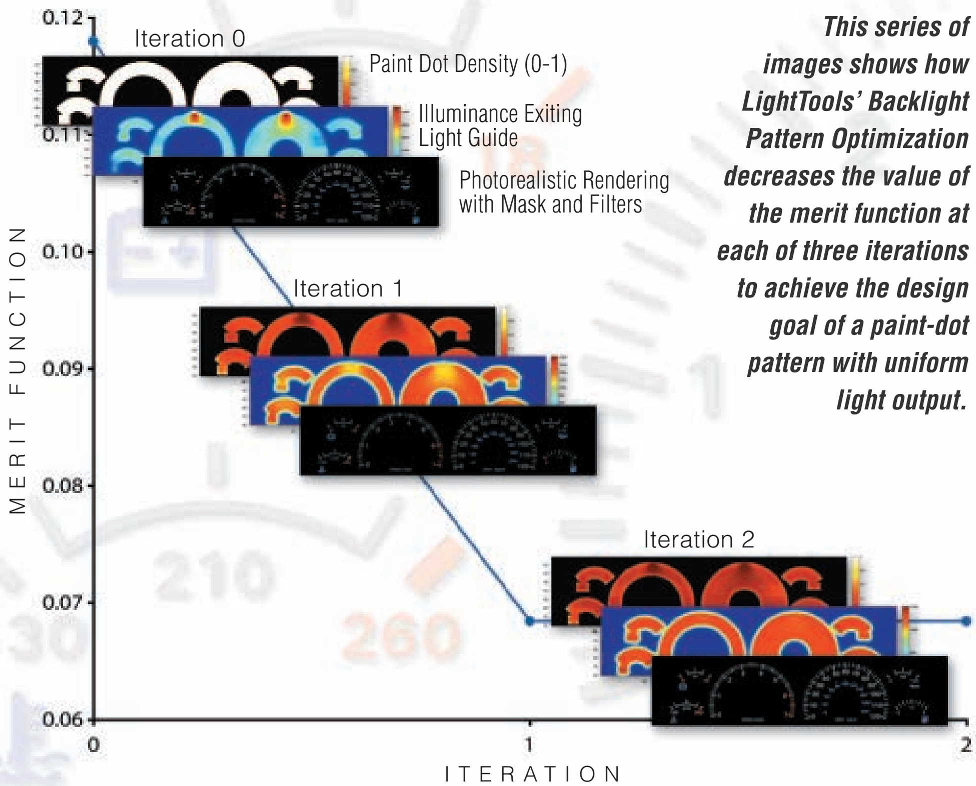
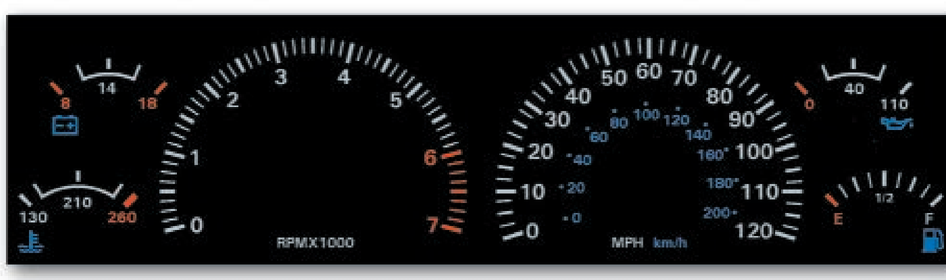


This series of images shows how LightTools' Backlight Pattern Optimization decreases the value of the merit function at each of three iterations to achieve the design goal of a paint-dot pattern with uniform light output.



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Under an Unblinking Eye:

The Demands of LCD Quality Control Push the Laws of Physics

BY LYNN SAVAGE
FEATURES EDITOR

Used for displays in all manner of electronic gadgets, LCD panels are a mainstay of everyday life. Dozens of manufacturers – mainly in China, Taiwan, Japan and South Korea – produce a seemingly endless stream of these liquid crystal attention-getters, and consumer demand for products that incorporate LCD screens just keeps growing. But while the manufacturing process has been standardized, with little if any room for improvement, a major roadblock has appeared: rapid, accurate inspection of LCDs during the manufacturing process.

Not very long ago, LCD systems were inspected on the manufacturing line by people – human eyes attempting to spot black, dead pixels on the fly in newly made displays. LCD producers, including Samsung, Sony, Panasonic, LG and their competitors, eventually moved to advanced machine vision systems to replace eyeballs but now are in a continual race to improve the speed and resolution of these systems.

"The state of the art is a moving target," said Greg Hollows, director of machine vision solutions at Edmund Optics Inc. in Barrington, N.J. "The industry moves as fast as any I've ever seen – including semiconductors."

LCD inspection systems face targets that are shrinking as well as growing. Currently, the individual pixels that comprise an LCD panel are 5 μm across – down from 10 to 15 μm a few years ago. That equates to millions of pixels, each of which must be tested under power several times during the manufacturing process. On the other hand, the arrays of pixels in television panels continue to grow to enormous sizes: 42-, 50- and 60-in. devices are becoming the norm, and larger still are fast approaching.

The mantra has become "early and often" – defects in any LCD product must be discovered as quickly as possible so as not to waste time and resources on bad products. In the worst case, there may be a problematic machine or process used in the steps leading to the first test that must be rooted out.

At Edmund Optics, Hollows and his team design specialized lenses for machine vision inspection systems. Their customers continuously seek to make the inspection process faster, but with higher resolution. Therein lies the problem: Smaller pixels demand lenses with smaller fields of view, which in turn puts an end to much hope for speed.

"Our customers want us to design, prototype, build and ship lenses in eight to 12 weeks, but that's hard when you keep pushing the laws of physics," Hollows said.

At camera maker Imperx Inc., president and CEO Petko Dinev agrees about what LCD manufacturers want: "The faster the better, the higher-res the better." But where Edmund Optics sees mostly line-scan cameras being used, Dinev believes that cameras that cover broader regions of LCD products are the future.

"LCD inspection must be as precise as possible over a large area," he said. "Area-scan cameras are best for high-speed glass-defect inspections."

It takes numerous cameras in a system to test every pixel at high speed, whether the system uses line- or area-scan cameras. Dinev noted that a dozen 11-megapixel area-scan cameras are needed to look over a 4 × 8-ft LCD panel. He sees larger, faster cameras coming, but at a cost to users – and not just price. Cameras that work at 10 fps and 20 to 30 megapixels may come, he suggested, but the amount of data they produce will expand too much to be processable.

"Cameras have to be smarter," Dinev said. "Small, incremental changes will help."

Zero defects

Some industry wishful thinkers say that a "zero defect" policy is possible, which would leave inspection systems with nothing to do. With screens getting bigger, however, millions of pixels lined up in great rows would seem to be resistant to such a utopian vision. Manufacturing defect-free panels – even if possible – would be horrendously expensive, thus jacking up consumer prices and suppressing sales. Some LCD makers at the bottom end of the market already sell products, including televisions, with a relatively large number of dead pixels, just to keep prices down for one segment of the buying public.

In fact, researchers at the corporate level as well as in academia – including places such as Korea Advanced Institute of Science and Technology in Daejon and Feng Chia University in Taichung, Taiwan – continue working to improve inspection techniques. According to Chern-Sheng Lin, a researcher in the automatic control engineering group at Feng Chia University, "zero defect" is an impossible dream. However, he continues to work on improving inspection techniques, such as developing algorithms for more precise alignment of LCD components during scans.

New software algorithms are being developed to speed up LCD inspection without sacrificing manufacturing speed. Courtesy of Chern-Sheng Lin, Feng Chia University, Taiwan.

Next on the line

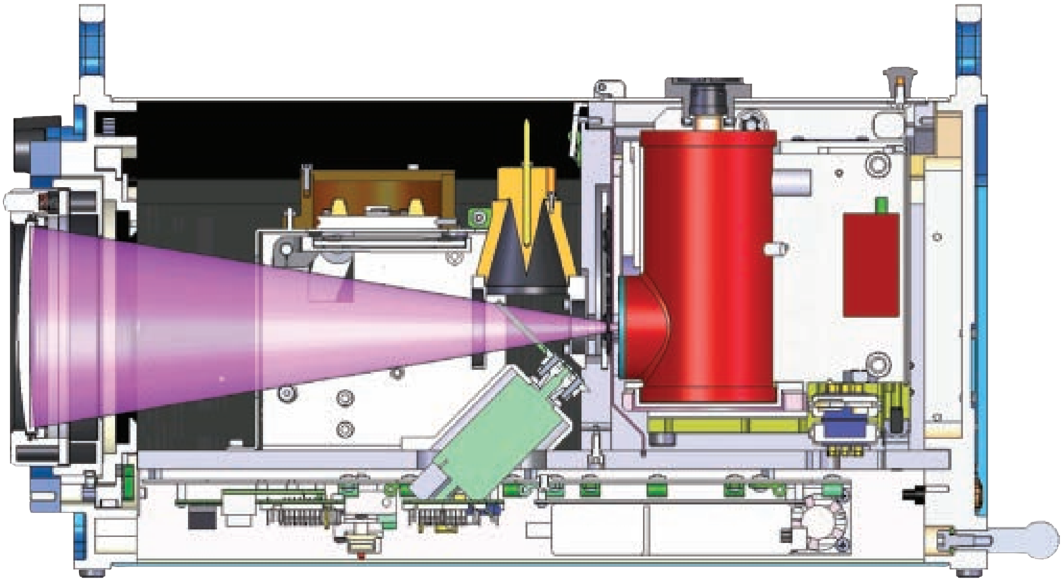
LCD manufacturers find themselves in a bit of a bind. Consumers want bigger and better, which means that faster and more exact inspection systems are required. Developing real-time inspection systems that can classify defects on the fly and pull bad panels out of the line as quickly as possible is the goal. Cameras, lenses and analytical software can move only so fast until the laws of physics start to get in the way.

"A lot of things will change [in the LCD industry] in five years, but not so much in six months," said Imperx's Dinev. "There will be more demand for different types of displays."

New demand for flexible, low-power display types such as organic LEDs will challenge LCD makers even more in the next few years. That push, which will come for a market desire for more elegant wall-hanging televisions and slim, easy-to-adapt e-readers, will have their own quality control issues. Machine vision pioneers who helped shape LCD production will no doubt translate their expertise to those display needs when the time comes.

From digital cameras to giant high-definition TV monitors, no matter what size they come in, LCDs have become commodity products that nevertheless demand high quality control measures.

lynn.savage@laurin.com



Radiation is focused by the objective lens onto an LN2-cooled detector. The path to the detector is interrupted by a reflective chopper wheel (shown in green), which alternately exposes the detector to the incident radiation and to the radiation from the internal blackbody source (shown in orange).

Calibrating the Thermal Camera

As thermal cameras gain ground in the commercial market, testing becomes critical

BY DR. DAVID A. IMRIE, OPTIKOS CORP.

Thermal imaging, once the domain of the defense sector, is finding applications in a number of commercial and medical fields. As more manufacturers join the thermal camera business, the need to test these devices to recognized standards is becoming increasingly important. After all, they can be fairly tricky instruments to design and build.

Both cooled and uncooled focal plane arrays are sensitive to manufacturing process variations, and thermal camera bodies and lenses are constructed from materials that emit radiation visible to these instruments. The defense sector knows all too well that testing of production units is just as important as the initial qualification of the design.

As thermal cameras find a broader market, the defense industry continues to push the limits of detectable and resolvable temperature differences. Frequently, the subjects of greatest interest have only a small temperature difference compared with the background against which they are viewed. A broadly adopted set of performance metrics exists for thermal imagers. Noise equivalent temperature difference, subjective and objective minimum resolvable temperature difference, minimum detectable temperature difference and modulation transfer function are typical parameters that may need to be measured in a testing laboratory.

Of particular importance are those metrics that require the presentation of a target with a precisely known thermal contrast. Four-bar targets, for example, are frequently used to determine the minimum resolvable temperature difference for a thermal imaging system. In these systems, the target, consisting of apertures cut into a target plate, is passively held at ambient temperature, while the temperature of an extended thermal source mounted behind the target plate is actively servoed so as to maintain the desired *radiometric temperature difference*.

In this case, the radiometric temperature of a target is the temperature of a perfect blackbody that produces the same in-band flux as the target. Using embedded sensors such as platinum resistance thermometers, it is possible to measure the physical temperature of the target and source plates to within a few millikelvin. Knowing the physical temperature difference, however, does not provide us with the precise radiometric temperature contrast of the target.

Two variables to consider

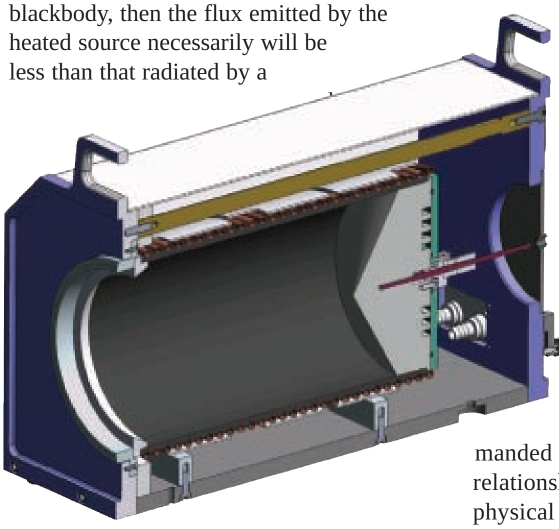
One problem is that the intensity of radiation leaving the target surfaces not only depends on the temperature of the target but also on the *emissivity* of the surfaces. For an opaque object in thermodynamic equilibrium with its surroundings, the spectral emissivity, ϵ, is equal to the spectral absorption, α. Many of the coatings applied to thermal target generators have emissivities that approach 1, but none attains it. To a thermal camera, a target with a surface emissivity less than unity appears cooler than an ideal blackbody at the same physical temperature.

Most tests are performed with the target located at an infinite conjugate, and additional losses in target flux occur at the mirrors and lenses used in the collimation system. For the target plate, nonunity emissivity and collimation losses are generally unimportant. To a good approximation, the whole room or enclosure is essentially an isothermal cavity bathing the test apparatus in background radiation at the same temperature as the ambient target plate. For an opaque object in thermal equilibrium, the reflectivity r and the absorption a are related by $\alpha + \rho = 1$.

Because the target plate emissivity (absorption) departs from 1 by an amount equal to its reflectivity, and because the temperature of the radiation that it reflects is the same as the temperature of the target, the shortfall in emitted radiation is compensated by the reflected background radiation. To a thermal camera, the target plate appears to radiate the same flux as an ideal blackbody at the same temperature. Even when collimated using mirrors with less than perfect reflectivity, the small portion of the flux absorbed by the mirror is replaced by the flux radiated by the mirror, again at the same ambient temperature as the target plate.

The same is not true for the background source plate. If the source is not an ideal blackbody, then the flux emitted by the heated source necessarily will be less than that radiated by a body at the same temperature. The "missing" flux is only partially replaced by the ambient background radiation. At the surfaces of collimating mirrors, photons are absorbed by less than perfect reflectors but are replaced only by radiation at the temperature of the mirror.

The result is that the heated target appears to be cooler than it really is. In most thermal target projector systems, the source control electronics usually compensate for these effects by setting a physical temperature difference between the foreground and background temperatures that is greater than the radiometric temperature difference demanded by the operator. To do this, the relationship between the radiometric and physical temperature differences for the entire target projection system must be known. One approach sometimes used is to combine the individual component contributions – the source emissivity, the transmission of lenses and windows, and the reflectivity of mirrors in the collimating system. Often, the emissivity values given by manufacturers of thermal target generators are simply the nominal values suggested by paint manufacturers and not actual emissivity measurements for the system that is shipped to the customer.



The temperature of the blackbody is held constant by circulating water at the required temperature through the coils wrapped around the cylinder and through the channels cut into the back of the reentrant cone. Winding two sets of coils in a double-helix arrangement and circulating water in opposite directions in each set minimizes thermal gradients.

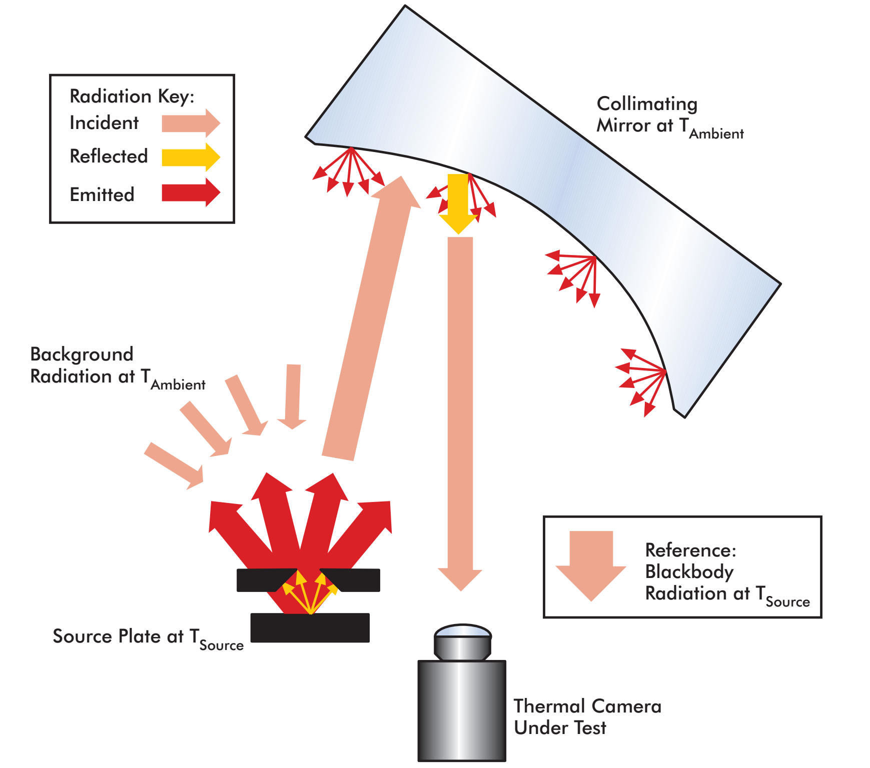
A more direct method is to perform a radiometric system calibration using a scanning infrared radiometer, such as the RAD-900 model offered by Optikos. Usually the preferred method for establishing the radiometric calibration of a projection system, it produces a result with less uncertainty than that introduced by the stackup of error bars associated with combining individual contributions. It also is often the only feasible manner in which the radiometric calibration may be maintained as part of an annual cycle because of the impracticability of disassembling the system to measure the performance of individual components.

An enigmatic position

At its most basic, a low-temperature (<100 °C) infrared radiometer is a transfer standard from the nearly ideal blackbody source used to calibrate it to the target projection system. It is a noncontact thermometer that occupies a somewhat enigmatic position in the field of temperature measurement instruments. The measurement of temperature at low-to-moderate temperatures is most accurately carried out by measuring the change in a physical material property, such as that in resistance of a platinum resistance thermometer. At elevated temperatures, where material phase changes start to occur and materials begin to glow, the preferred method changes to optical pyrometry and radiometry.

Such devices are concerned with remotely determining the physical temperature of very hot objects. The low-temperature infrared radiometer, on the other hand, does not seek to measure how warm a target actually is, but instead how warm it appears to be. Only if the target is an ideal blackbody are these two things the same.

The essential elements of the radiometer are an objective lens to collect and focus the incident radiation, filters to select the spectral region of interest, a reflective chopper wheel, an internal reference blackbody source, and a cooled detector and as-



The cooler background radiation does not compensate entirely for the imperfect emissivity of the target, and the radiation from the ambient temperature mirror does not fully compensate for its imperfect reflectivity. The result is that the radiation presented to the camera under test appears to have originated from a blackbody at a temperature less than the physical temperature of the source.

sociated amplification and signal processing electronics. Modern radiometers no longer are tethered to bulky racks of electronics but can be controlled from a laptop computer using a single USB connection.

Other features to look for are operator aids to aiming the instrument, such as an integral boresighted video camera and a visible laser tracer beam.

The purpose of the reflective chopper wheel is to expose the detector alternately to incident radiation collected by the objective lens and the radiation from the internal blackbody reference source. Usually, the internal reference blackbody is held passively at ambient temperature, ensuring that the interior of the instrument behaves as an isothermal cavity.

Using small signal measurement techniques, the instrument determines the physical temperature of the internal blackbody source and the magnitude of the rectified detector signal. The radiometer software combines these measurements with a set of calibration data obtained using a reference cavity blackbody to establish the radiometric temperature of the object being viewed.

Relatively low-cost infrared thermometers expose a detector to infrared radiation and then display the temperature of an object with an assumed emissivity that produces the same signal level. Besides the superior accuracy and thermal resolution of the measurement made using the radiometer, the chief difference between the two instruments is the radiometer’s far smaller field of view.

The RAD-900, for example, has a 300-mm-long focal length lens and a 0.25-mm square detector, giving it an instantaneous field of view on the order of 0.05°. The instrument’s utility is increased by scanning it across the target in angular space. Linear scans of edge targets enable the radiometric calibration coefficients for the target projection system to be extracted, and two-dimensional scans are helpful in verifying the spatial uniformity of sources.

When plotted over a range of target temperature differences spanning approximately 80 °C, the relationship between radiometric and physical temperature difference first appears to be linear. It is not uncommon for some testing facilities to assume that the relationship is simply proportional and to characterize it with a single proportionality constant, which they loosely refer to as the “system emissivity.”

In fact, because it is flux and not temperature that is attenuated by the combined contributions from emissivity and reflectance, and because temperature is not linearly related to flux, the relationship between physical and radiometric temperature is not strictly linear. The departure from linearity may be accounted for using higher-order polynomial terms, and over a relatively modest range of, say, 80 °C, the inclusion of a second-order term usually is adequate to characterize the relationship.

All thermal camera-testing laboratories should be concerned with maintaining an annual calibration of the radiometric temperature contrasts generated by their equipment. Although many laboratories are scrupulous about calibrating the thermal probes used in the target generation equipment, they often are less aware of the importance of maintaining radiometric calibration.

Meet the author

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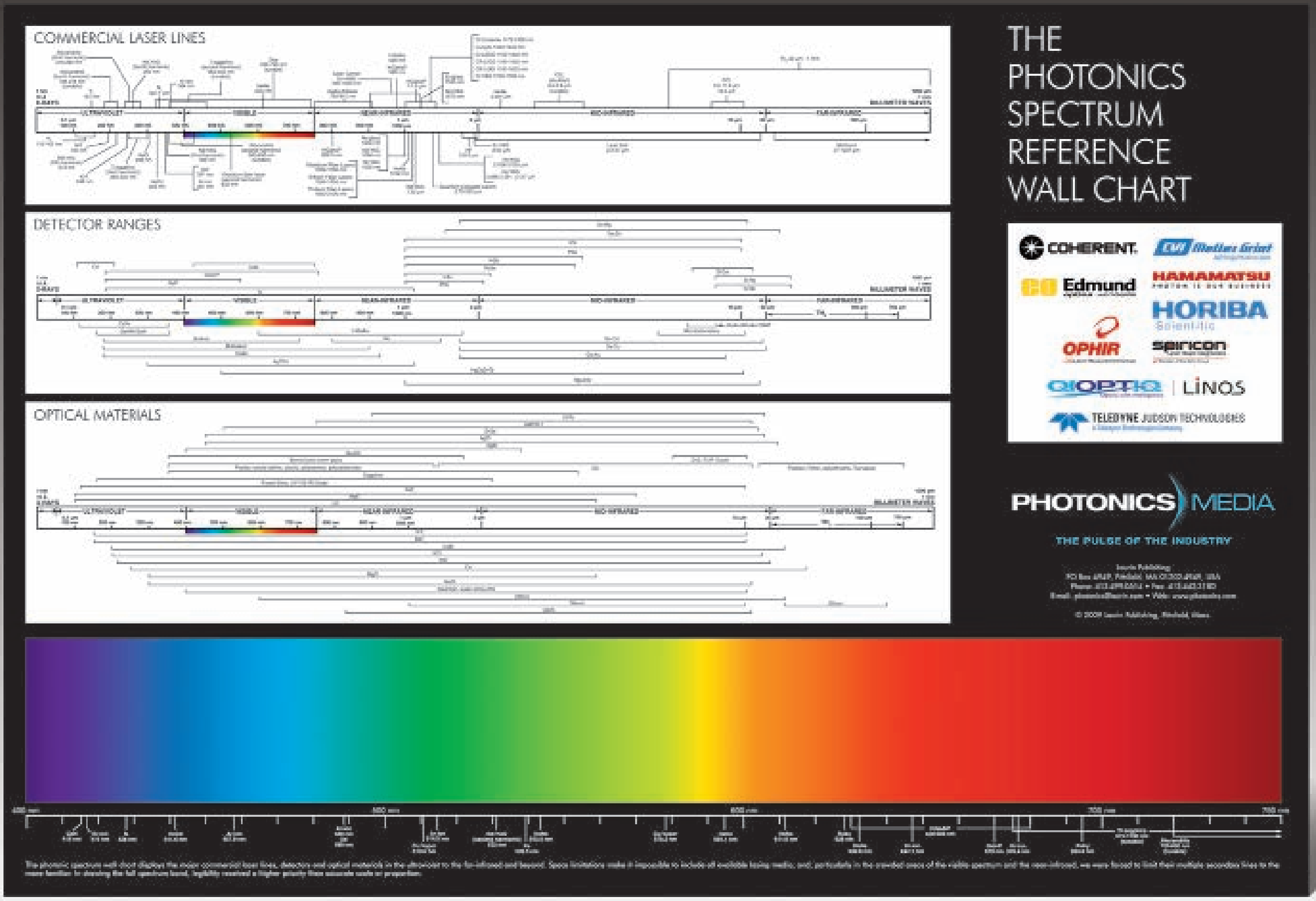
THE PHOTONICS SPECTRUM REFERENCE WALL CHART

FROM LAURIN PUBLISHING

The updated Photonics Spectrum Reference Wall Chart reflects the changing technologies in the photonics industry. New lasers at new wavelengths are represented, as are detectors and materials. The chart includes commercial laser lines, and wavelength ranges for detectors and optical materials. Also, a new format makes it easier to use and to quickly find the information you need.



Actual Size: 30″ x 20½″

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12/09

Sniffing out threats WITH LIGHT

BY HANK HOGAN
CONTRIBUTING EDITOR

It isn't time to retire bomb-sniffing dogs – yet. However, that scenario is closer to happening, thanks to advances in surface-enhanced Raman spectroscopy, hyperspectral imaging and other photonics technologies. Armed with these, police and military personnel will be able to do quick checks to uncover explosives and chemical or biological agents from a distance and up close.

Photonics at the core

Adam Bingham, a research scientist at ICx Technologies Inc. in Arlington, Va., noted that the company's explosive-, narcotic- and chemical agent-detecting products have something in common. "All of our Fido products have a photonic backbone in them."

For trace detection, ICx employs a proprietary amplifying fluorescent polymer that quenches its emission in the presence of a chemical of interest. The approach works for the telltale vapors given off by a chemical as well as for the solid particulates containing it. By measuring the decline in fluorescence, the technique enables detection of nitroaromatic explosives in the parts-per-quadrillion range. That sensitivity, the company says, is comparable to that of a highly trained dog.

A different approach is found in a handheld unit designed to identify explosives, liquid threats and narcotics. These devices exploit Raman spectroscopy, using a diode laser operating at 785 nm to excite a response from the unknown material. By looking at the spectral signature from just above 785 nm to about 930 nm and comparing that to a library of known agents, the device can identify the unknown substance.

The method is not for trace detection, and it works only on solids and liquids. It does not require touching the unknown, but the container must be transparent to the laser and the Raman signal.

Bingham noted that improved matching algorithms would make identification more certain. A second area of possible improvement involves photonics technologies, particularly detectors. ICx currently uses silicon-based CCDs, but these work only to approximately 1 μm, and their response falls off as that limit is approached.

"If you had a better detector, you could either use less laser power or you could extend your spectral bandwidth. That would definitely be an area that could give you a lot of advantages in capability," Bingham said.

Tiny particles, big sensitivity

Another type of photonics-based test is being developed by researchers at Queen's University Belfast in Northern Ireland, UK. The idea is to bring the benefits of surface-enhanced Raman spectroscopy to the field through the application of techniques originally investigated by Queen's pharmacy professors for drug delivery.

Steven E.J. Bell, research director of the innovative molecular materials group in Queen's School of Chemistry and Chemical Engineering, heads the development team. He noted that surface effects can boost a Raman signal a million times or more, making it suitable for detecting trace amounts of an explosive or narcotic. The challenge has been turning that potential into something suitable for use by laypeople outside a lab.

The proposed solution at Queen's begins with a special gel loaded with colloidal gold or silver nanoparticles. These will be chemically functionalized so that they preferentially absorb particles containing the compound of interest. The nanoparticles will produce a surface-enhanced Raman signal, making trace detection possible.

In use, the gel will be loaded onto pads that will be swiped across suspect surfaces and read by a field Raman instrument.

It is important that the gel be transparent to both the excitation laser and the Raman signal. It also is important that the specificity of the test be high.

The researchers are aware of the capabilities of current Raman instruments and what should be possible in the next few years, Bell said. "We're trying to develop chemistry that will fit with the performance levels that we believe will be available."

He expects to have a working prototype within a year or so. It's too early to know what the detection limits might be, but the technique must be only sensitive enough for the job.

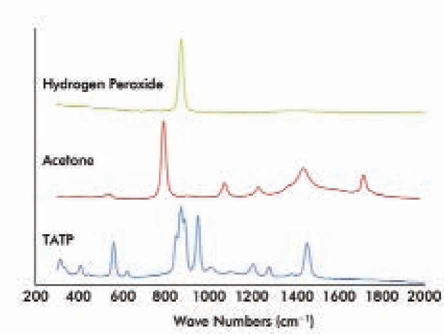
In the hole

A different detection tactic is being taken by a group from the Missouri University of Science and Technology in Rolla, working in conjunction with researchers from the University of Cincinnati. The team is working with zeolite, aluminosilicate crystals with subnanometer-scale pores that can absorb molecules. The absorption causes a change in the zeolite's properties. Among the characteristics that change is the material's refractive index or its reflectivity (see "Fiber Sensor Provides Real-Time, Continuous Monitoring," *Photonics Spectra*, December 2005, page 92).

Hai Xiao, an associate professor of electrical and computer engineering who heads up the Missouri group, noted that the selectivity for specific molecules depends upon geometry and chemistry. "You can design a different size of the pore, and then you can design the absorption property."

As for the readout, that can be done either optically or electrically. For the latter, what the researchers look for is a change

A National Guardsman samples a spill, using a handheld device and Raman spectroscopy to identify the liquid. Courtesy of ICx Technologies.



The Raman spectrum of the explosive triacetone triperoxide (TATP) is clearly different from those of its two main constituents. The difference enables the explosive to be identified by matching spectra against a library. Courtesy of ICx Technologies.

in capacitance. For the former, various optical methods, including refractometry and spectroscopy, are possible.

The group currently is developing sensors for the military that are tiny enough for portable, battery-powered devices. These wirelessly networked instruments then would be deployed on a battlefield or in an urban setting and would report on current environmental conditions.

Xiao noted that, for such an application, an all-electrical detection method offers integration advantages, largely because no laser or detector is required. However, a photonics method may offer better selectivity and results. Further research and development is needed before a decision about the best approach can be made.

Researchers at Queen's University Belfast want to use gold nanoparticles in a gel as part of an explosives detector based on surface-enhanced Raman spectroscopy. Courtesy of Steven E.J. Bell, Queen's University Belfast.

At a distance

Finally, there are photonics techniques that offer the ability to detect explosives or other dangerous agents at some standoff distance. This capability is particularly important when a wide area must be quickly searched or when conditions are unsafe for personnel.

One method involves hyperspectral imaging, an approach that captures a signal across a wide swath of spectrum. The signal then can be compared to a known library for identification or used to spot anomalies.

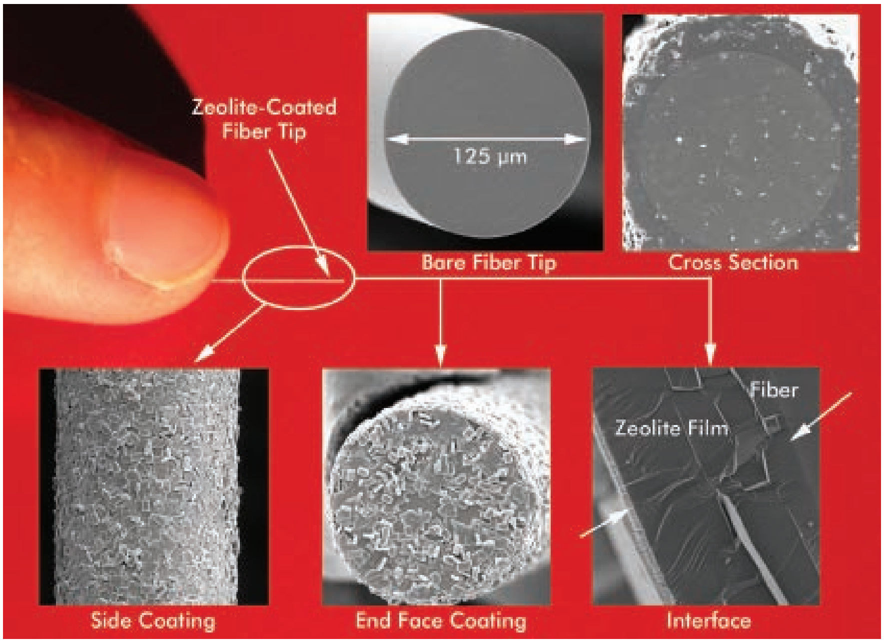
ICx is developing a thermal infrared method, working in conjunction with the privately held Spectrum Photonics Inc. of Honolulu. The technique is passive, since everything glows in the 8- to 12-μm spectral range that is being used. In addition, these wavelengths yield information specifically related to chemical bonds, enabling classification of the compounds present. Plans call for a product based on the technique to be available within a year.

Edward T. Knobbe, president of Spectrum Photonics, noted that the technique works best for chemical agents. He said more work is needed before it becomes practical for biological ones because, at present, their spectral signature is not distinct enough.

Because everything emits at these wavelengths, it is necessary to filter out the background signal. But once that is done, hyperspectral imaging offers some benefits, he said. "One of the big advantages of the hyperspectral is very, very wide angular range of detection and very fast search time."

He noted that it also can be combined with and complement other techniques, such as active lidar. To be useful, however, hyperspectral imaging systems will have to be much lighter, smaller and less costly than current technology. For that reason, Spectrum Photonics is concentrating on dramatically improving those areas, Knobbe said.

hank@hankhogan.com



Zeolite's subnanometer-size pores trap molecules, enabling detection of explosives via an optical fiber. Courtesy of Hai Xiao, Missouri University of Science and Technology.

Thermal Imager

L-3 Communications Corp.'s Infrared Products Div. has launched the high-resolution Thermal-Eye Series 17-640 thermal imager. The device has an amorphous-silicon uncooled infrared sensor with a fast response time. Available in three configurations (analog, digital, dual-mini), it can be purchased with or without a lens. The dual mini no-lens configuration is suitable for applications that require a small form factor. Optics are available in 14°, 28° and 55° fields of view. The user interface has a programmable electronic zoom sequence, an expansion port for video processing and real-time control of touch-up parameters. Wafer-level packaging enables the small detector size of 17 μm. The 640 × 480-pixel focal plane array offers a spectral response of 7.5 to 13.5 μm, thermal sensitivity of ≤50 mK and a refresh rate of 30 Hz.

L-3 Communications
irp.info@l-3com.com

Ultracompact Diode Laser

The iBeam smart, an ultracompact OEM diode laser manufactured by Toptica Photonics Inc., measures 100 × 40 × 40 mm and delivers 150-mW single-mode power at 660 nm. The feedback-induced noise eraser function protects against optical feedback, and the RS-232 serial interface and a standard software package control all laser parameters and generate status reports. The one-box module has a beam diameter of ~1.1 mm $1/e^2$, beam quality of $M^2 < 1.2$, wavefront error of <0.05 λ and drift of <0.5% over 48 h. Applications include flow cytometry, confocal microscopy, microlithography, retina scanning, fluorescein angiography and microplate readout.

Toptica Photonics
info@toptica.com

Bar-Code Scanners

Sick Inc. has unveiled its CLV650 bar-code scanner with autofocus technology and the CLV640 with dynamic focus. The 1-D scanners use the company's modular advanced recognition technology (SMART) code reconstruction algorithms and microprocessors to read damaged and dirty bar codes. The 650 model is suitable for use in applications where space is limited and a large depth of field is required. The 640 reads high-density codes and provides an increased depth of field in applications that require an external input to change the focus position. Proprietary Sopas software reduces programming and processing requirements of the host system.

Sick
info@sick.com

LED Measurement Tester

The BTS256-LED Tester manufactured by Gigahertz-Optik Inc. measures the luminous flux, color and spectral characteristics of printed circuit board-mounted LEDs, discrete LEDs within a module, miniature lamps, endoscopes and any narrow beam-emitting light source. Larger light sources can be measured by attaching the tester to a larger integrating sphere, and illuminance can be measured with the optional diffuser window attachment. The portable handheld device measures spectral flux distribution in watts per nanometer, peak and dominant wavelength, color temperature, color rendering index and color coordinates (X,Y and u′ v′). The built-in 50-mm-diameter integrating sphere has an exchangeable input optic nozzle to minimize positional error. Other features include an auxiliary LED for test sample absorption factor correction, a remote-controlled shutter for online offset compensation of the diode array and a proprietary bi-tech sensor.

Gigahertz-Optik
b.angelo@gigahertz-optik.com

Bandpass Filters

Near-IR hard-coated bandpass filters have been announced by Semrock. Keyed to popular laser lines in the 1500- to 1600-nm spectral region, they are suitable for use as laser source cleanup filters and as detection filters that pass particular laser wavelengths and that virtually eliminate background noise over the full InGaAs detector range from 850 to 1750 nm. They are optimized for retina-safe lasers in the 1.5-μm range. The filters match well with erbium-doped fiber and glass lasers at 1535 nm, erbium-doped fiber and InGaAsP semiconductor lasers at 1550 nm and Nd:YAG-pumped optical parametric oscillators at 1570 nm. Applications include laser radar, remote sensing, rangefinding and laser-induced breakdown spectroscopy. Standard filters are 25 mm in diameter, and custom sizes can be ordered.

Semrock
filters@semrock.com

Green Lasers

Coherent Inc. has introduced two continuous-wave green 532-nm lasers for use in life sciences applications. They deliver low noise of <0.1% rms and a TEM_{00} beam with $M^2 < 1.1$. The Genesis 532-1000 S models produce >1 W of output power and the Genesis 532-500 S models, >0.5 W. Both are air-cooled, available in OEM packaging and can be directly modulated. Based on proprietary optically pumped semiconductor laser technology, they are scalable in wavelength and output power. Linewidth is <30 GHz FWHM, pointing stability is <10 μrad/°C, polarization ratio is >100:1, horizontal, and operating diode current is <10 A.

Coherent
tech.sales@coherent.com

Optical Attenuators

Agilent Technologies Inc. has added five models to its high-density 77xx family of integrated optical multichannel attenuators and power meters. Designed for testing optical transceiver modules and their subcomponents and for optical network integration tests, they provide high-speed attenuation and power setting, and fast power measurement. They are supplied with USB, LAN and GPIB interfaces. The N7751A and N7752A are hybrids that combine one or two variable single-mode fiber optical attenuators and two power meter channels in one unit. The N7761A, N7762A and N7764A have granularities of one, two and four attenuator channels in one unit. Settling time is 20 ms, and transition speed is selectable from 0.1 to 1000 dB/s.

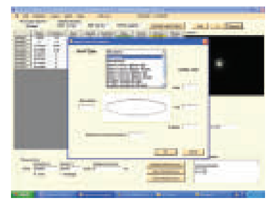
Agilent
janet_smith@agilent.com

Vision Tools

The VisionPro Solar Toolbox manufactured by Cognex Corp. includes preconfigured software tools for alignment and inspection applications in photovoltaic solar production. Users can work with the basic VisionPro software library or use the preconfigured tool sets to set up vision inspection and alignment applications. The tools for location, identification and inspection ensure wafer-to-panel traceability. The hardware-independent VisionPro software can be used by solar equipment suppliers and line builders with any camera, frame grabber or direct-connect digital standard.

Cognex
john.lewis@cognex.com

Measurement Software



For multielement optical lens assembly, Opto-Alignment Technology has introduced CalcuLens 2.1.0, optical centration measurement software that calculates real-time total indicated runout, with high-speed automatic centroid capture, eliminating user error and improving uniformity and repeatability. It performs noncontact and instant submicron measurements for any lens surface, including cylindrical and parabolic, and coated or uncoated optics. It accommodates radius of curvature from ±2 mm to infinity. The user can perform inspection and quality control of centrations and wedges, import Zemax files, generate and save quality assurance reports for traceability, share files over the local network and receive live technical support via the Virtual Network. Features include tolerance zone recognition for repeatable productivity and unit conversion between English, metric and ISO/DIN.

Opto-Alignment Technology
steve.bohuczky@optoalignment.com

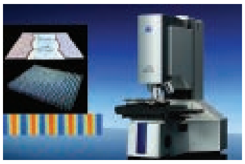
Complex Shaping Services

Using CAD, CAM and CMM software, Optimax Systems Inc. offers complex shaping/machining services for optical lenses and nonoptical components made from glass, crystals and other brittle materials. The company adds through holes, contoured perimeters and other geometric features to enable nontypical optical assembly and packaging. It also fabricates nontraditional optical surfaces such as toroids and off-axis parabolics, and it performs deterministic polishing and correction of these surfaces to fractional wave tolerances. With multiple high-precision five-axis machining centers, the company can create almost any shape to machine code and metrology routines.

Optimax Systems
rick@optimaxsi.com

Confocal Light Microscope

Carl Zeiss MicroImaging Inc. has added new functions to its Axio CSM 700 confocal light microscope. Materials scientists now can measure 3-D topography over large sample areas more



easily. Scanning stage control is integrated into the software and allows large sample areas to be captured in a mosaic fashion. The stitching algorithm ensures that no transitions are perceived between the single images in the final mosaic. The encoded and motorized objective nosepiece facilitates operation. English units such as inches and microinches have been integrated into the software, resulting in improved compliance with the material microscopy standards valid in parts of North America. The software's newly programmed filter improves image processing.
Carl Zeiss MicroImaging
ksalerno@zeiss.com

Deformable Mirror

The Hi-Speed DM37 manufactured by Alpao is a 7.5-mm deformable mirror designed for beam-shaping and vision-sciences applications, and for others that require correction of large aberrations. The low-surface-error, large-stroke (more than 35 μm for astigmatism and focus wavefront correction) mirror has an optical silver-protected coating. It is supplied with certified drive electronics for precise control. Drivers for Matlab, LabView and C/C++ are included. Nonlinearity errors are <3%, and settling time is 1 ms at ±5%.
Alpao
contact@alpao.fr

Spectrometer

Released by B&W Tek Inc. for use in near-IR applications, the Sol 2.5 InGaAs linear array spectrometer covers the wavelength range from 1700 to 2500 nm and features enhanced thermoelectric cooling and low-noise readout electronics for longer integration times. It offers four sensitivity and dynamic-range settings and a built-in 16-bit digitizer, and it delivers 9-nm FWHM spectral resolution. Readout speed is 1 MHz, data transfer speed is 3 ms per spectrum in fast acquisition mode, integration time is from 10 μs to >64 ms, and operating temperature is from 0 to 30 °C. The system is supplied with a USB 2.0 interface, with RS-232C available as an option. Applications include composition analysis and moisture content.
B&W Tek
megk@bwtek.com

Near-IR Photodetectors

Amplification Technologies Inc. mounted its NIRDAPD TEC series photodetectors on a two-stage thermoelectric cooler in a TO8 package designed for extremely low light level signals. Available in active areas ranging from 50 to 210 μm, they feature high-speed, near-infrared spectral response from 1000 to 1700 nm, operating temperature from −30 to 25 °C and high gain. The devices are suitable for applications in homeland security, night vision, quantum communications, biological sensing, lidar and environmental monitoring, 3-D imaging and fluorescence detection.
Amplification Technologies
info@amplificationtechnologies.com

Gigabit Ethernet Cameras

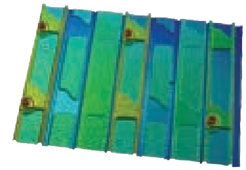
The Genie C1280 (color) and Genie M1280 (monochrome) GigE Vision-compliant cameras introduced by Dalsa Corp. have 1.2-megapixel image sensors for industrial imaging in the semiconductor, robotics and traffic-control industries. The cameras feature a $\frac{1}{3}$-in. Sony sensor and operate at 24 fps. Features include global electronic shutter with exposure control, and onboard flat-field correction. The C1280 has onboard color conversion to produce clear images. Both have an RJ45 screw mount cable connector that is suitable for robotic applications. They transmit data to distances of up to

100 m and are supported by proprietary Sapera Essential software.
Dalsa
sales.americas@dalsa.com

Raman Spectrometers

Designed for high-resolution field measurement and validation of unknown substances, BaySpec Inc.'s Portability Raman spectrometer line uses proprietary volume phase gratings and fast optics to perform high-throughput and low-light-level spectroscopic measurements. The systems include a noncontact point-and-shoot fiber optic probe and Windows-based Spec 2020 software with a touch-screen display. The instruments have no moving parts, and no sample preparation is required. Battery operation and a wireless interface are included to facilitate data logging and reporting.
BaySpec
sales@bayspec.com

Imaging and Analysis Software



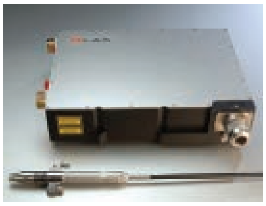
Digital Surf SARL has released the latest version of its surface imaging and analysis software. Mountains 5.1 includes features for 3-D optical microscopy, dimensional analysis of 2-D component geometry, dynamic statistics for near-line monitoring of surface parameters and Cpk capability parameters. Multicore and 64-bit technologies accelerate analysis, and video tutorials with audio and subtitles minimize the learning curve. The Z-RGB-I function provides imaging and analysis of multichannel topography, color and intensity information acquired by 3-D confocal microscopes. All three types of information can be manipulated simultaneously. The optional Advanced Contour module provides intelligent dimensional analysis of component geometry.
Digital Surf
contact@digitalsurf.fr

Photovoltaic Measurement

Newport Corp.'s Oriel Instruments division has announced the Oriel IQE-200, an instrument that performs simultaneous measurement of external and internal quantum efficiency of solar cells, detectors and any photon-to-charge converting device. Wavelength is from 300 to 1100 nm, working distance is 50 mm, resolution is 5 nm (adjustable), and repeatability is

<±0.5. The system combines a 250-W quartz tungsten halogen light source, a monochromator, advanced sensor technology, and related electronics and software. The preconfigured and calibrated assembly with four-channel data acquisition for rapid measurement is a turnkey solution. The system measures silicon-based and thin-film cells, copper indium gallium diselenide and cadmium telluride.
Newport
ed.manke@newport.com

Fiber-Coupled Multibar Modules



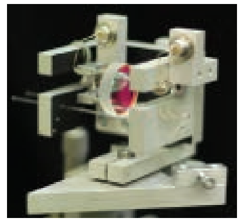
Dilas has released fiber-coupled multibar modules that deliver up to 300-W output from a 200-μm core diameter fiber at 976 nm. Featuring high brightness and power, they have a compact footprint and a convenient aiming beam and have demonstrated a lifetime of >10,000 h at 300-W CW operation. Their cladding mode-free high-power fiber has a numerical aperture of <0.20 and wall plug efficiency of >35%. Packaged in up to 10-bar configurations, the modules are based on conductively cooled bars that are optically stacked and polarization-coupled. They operate from 20 to 35 °C and require only industrial water for cooling. Center wavelength tolerance is ±3 mm, spectral width is 5 nm FWHM, slope efficiency is >7 W/A, and power conversion efficiency is >35%. The devices are suitable for direct-diode applications and for fiber- and solid-state laser pumping.
Dilas
sales@dilas.com

Near-IR Camera

Flir Systems Inc.'s Model SC2500-NIR, a near-infrared fully integrated camera, covers the spectral range from 0.9 to 1.7 μm and combines thermal imaging and noncontact temperature measurements with advanced data acquisition capabilities. All image processing electronics are embedded in the camera. Features include flexible integration times, lock-in signal processing, spectral filtering and a Gigabit Ethernet digital interface. The analog-to-digital electronics enable integration times from 400 ns up to 1 s in 1-μs steps. The InGaAs detector has a 320 × 256-pixel array that, combined with the electronics, enables full-frame acquisition rates up to 340 Hz. The adjustable image windowing

down to 128 × 8 pixels enables frame rates as high as 15 kHz.
Flir Systems
sales@flir.com

Laser Calorimeter



Laser Zentrum Hannover eV has developed a laser calorimeter that measures the absorption of light in optical materials used in the production of functional laser optics. Such measurement determines the purity and quality of the material. Using a precise temperature measurement, the device can detect an absolute absorption of <1 part per million, determining the smallest absorption data deriving from surfaces, coatings and impurities in quartz glasses and crystals. Absorption measurements can be made between 193 and 2000 nm, and the range from 670 to 2200 nm is accessible.
Laser Zentrum Hannover
info@lzh.de

Spectrometers

Edmund Optics Inc. has launched a series of thermoelectrically cooled CCD-based spectrometers for low-light-level detection and long-term monitoring applications. They have 2048 pixels, a 16-bit digitizer and a USB 2.0/1.1 interface. The cooler reduces dark noise, improves dynamic range and provides operational stability. Included is intuitive Spectral Data Acquisition software that is compatible with Windows 2000, NT, XP and Vista. The spectrometers feature an SMA fiber input, measure 0.11 × 0.10 × 0.04 m and weigh 0.54 kg. They are available in UV/VIS, VIS, UV/VIS/NIR and NIR versions.
Edmund Optics
medmund@edmundoptics.com

Spectrophotometer

For wavelength-dispersive spectral measurements from 120 to 350 nm, McPherson Inc. has released the Vacuum Ultraviolet Analytical Spectrophotometer. It provides results as percent transmission or reflection, with 0.05% precision. It works with solid samples and can be equipped with gas or liquid sample cells. In reflectance mode, the angle of incidence can be easily adjusted to the sample surface. It also is suitable for inert gas purge requiring parts-per-million levels of O_2 and H_2O. The system includes a tight and particulate-free enclosure, sources, detectors, UV-enhanced optics and a computer-optimized optical system. Cryogenic

or heated sample mounts and raster-mapping attachments are available as options.
McPherson
mcp@mcphersoninc.com

Power/Energy Sensor

Ophir-Spiricon Inc. has introduced the 3A-P-FS, a very low power/energy sensor designed to measure very low power and energy light sources and divergent beams such as LEDs and diode lasers. It features a 12-mm numerical aperture and a fused silica window in front of the detector. The window is 7 mm from the sensor surface and keeps out air currents and long-wavelength background heat, enabling accurate measurements. The sensor measures divergent beams up to ±40° and pulsed or continuous-wave lasers in the 0.19- to 20-μm range. Its *p*-type absorber provides a larger aperture and a flatter spectral response than do broadband devices. Optical power can be measured from 60 μW to 3 W and energy, from 20 μJ to 2 J.
Ophir-Spiricon
sales@ophir-spiricon.com

Photoelectric Sensors

The ML8 series miniature PCB (printed circuit board) photoelectric sensors unveiled by Pepperl+Fuchs Inc. are available with 30- or 50-mm detection ranges. They provide reliable printed circuit board detection in semiconductor applications, regardless of holes, indentations and components on the circuit board. Customized light beam patterns enable precise detection of board edges. They are plug-and-play devices that are supplied with factory-optimized settings, eliminating the need for sensitivity adjustments. They feature a slotted mounting pattern and two-position-status LEDs and are available in convergent mode with a narrow sensing strip and in background suppression mode with an array of two or three light spots. They are suitable for use in solar, packaging and materials handling applications.
Pepperl+Fuchs
sales@us.pepperl-fuchs.com

Gigabit Ethernet Camera

For vision applications that require speed and resistance to blooming, Toshiba Teli America Inc. has launched the CSGV90BCS GiantDragon monochrome Gigabit Ethernet camera. It runs 90 fps uncompressed images at VGA resolution. Applications include high-speed robotics, industrial inspection, optical character recognition, traffic monitoring, machine vision and OEM integration. The progressive-scan camera provides

high-quality images for full-motion video and still image capture. Features include a random shutter mode, scalable region-of-interest partial scanning for faster frames per second, and compact dimensions of 44 × 29 × 70 mm for easy interchange of older analog cameras in existing systems.
Toshiba Teli America
doug.freck@ttai.toshiba.com

Photodetector

The ET-5000 series 2-μm photodetectors manufactured by Electro-Optics Technology Inc. feature rise and fall times of <35 ps and a cutoff frequency of >10 GHz. They have a spectral response range from 900 to 2200 nm and include an internal bias supply. Free-space and fiber-coupled models are offered. The InGaAs PIN detectors have a photodiode active area diameter of 60 μm and responsivity of 0.9 A/W at 2100 nm. Running on a 3-V battery, they enable monitoring of thulium and holmium lasers, and perform pulse width measurement of subnanosecond lasers.
Electro-Optics Technology
sales@eotech.com

Color Camera

Lumenera Corp. has introduced a color microscopy camera designed for clinical, life and materials sciences, and educational applications. The Infinity 1-2 features a 2-megapixel ½-in. CMOS sensor and operates at up to 96 fps. The camera is equipped with an adjustable C-mount and is suitable for use with all microscope configurations, including upright, inverted and stereo. It offers 1600 × 1200 resolution, onboard processing, subsampling for rapid focus at full field of view and increased pixel intensities in challenging light conditions.
Lumenera
industrialsales@lumenera.com

Laser Diode Drivers

Lumina Power Inc. has released a line of DC-input laser diode drivers for the medical and industrial laser markets. The RoHS-compliant LDPC drivers are available with power levels up to 300 W and output currents of 70 A. They require 12- to 24-VDC from a battery or an AC to DC power supply. Features include reverse input voltage, input overvoltage and thermal protection, and an easy-to-use analog interface. A protective case and an internal fan are available as options. Typical rise/fall

time is 50 μs, and operating temperature is from 0 to 40 °C.
Lumina Power
sales@luminapower.com

Stereomicroscope

Developed by Vision Engineering Inc., the Mantis stereomicroscope includes the permanently engaged digital Mantis Elite-Cam camera to allow users to capture images for reporting, cataloging and communicating with colleagues and customers. It also enables simultaneous optical and digital viewing. The camera comprises a Mantis Elite head and a factory-integrated and -sealed digital camera. Image capture options include bmp, jpeg and png. Connectivity is through USB 2.0 with PC-based software. The system offers 2× and 20× magnification options and true-color LED illumination that provides up to 10,000 h of shadow-free viewing. It has a long working distance and a large field of view. Its ergonomic design yields fatigue-free viewing.
Vision Engineering
info@visioneng.com

Two-Axis System

The LT490-450-EDLM, manufactured by Steinmeyer Inc., is a two-axis system for laser ma-

chining and other extended travel applications that require precision positioning. The fully enclosed stage has a 450-mm stroke. The system comprises iron-core linear motors, linear guideways, a linear measuring system and E chain cable carriers. Maximum speed is 500 mm/s with acceleration of 5 m/s². Accuracy in each direction is 1 μm with ±0.5-μm repeatability.
Steinmeyer
jskaltsas@steinmeyer.com

3-D Scanner

Creaform has expanded its Handyscan line of 3-D handheld, self-positioning, portable laser scanners with the introduction of the UNIscan. Applications include 3-D archiving, complex shape acquisition, damage assessment, digital models and mock-ups creation, multimedia contents creation, packaging design, rapid prototyping and ergonomic studies. The Class 2 laser performs 18,000 measurements per second, with resolution in the Z-axis of 0.1 mm and accuracy of up to 80 μm. Depth of field is 30 cm. The system measures 160 × 260 × 210 mm and weighs 980 g. It is supplied with proprietary data acquisition software.
Creaform
info@creaform3d.com

Immersion Oil

Cargille Laboratories designed its immersion oil type 37DF to provide optical values at 37 °C for a sharp image. Immersion oil standardized for room temperature at 23 °C may cause a decrease in resolution when used at 37 °C because critical optical values of the oil change with temperature. The 37DF, as does the DF at 23 °C, offers very low background fluorescence, making it suitable for fluorescence microscopy applications. The oil is available in 1-, 4- and 16-oz bottles.
Cargille
cargillelabs@aol.com

Gigabit Ethernet Cameras

Basler Vision Technologies AG has introduced the Gigabit Ethernet ace series cameras. The four CCD camera models are in monochrome and color, with resolutions from VGA to 2 megapixels. All have a footprint measuring 29 × 29 × 48 mm. Users can choose between a Power-over-Ethernet version with the camera power and data on a single cable, or one where power is supplied through a separate Hirose input/output connector. The cameras transmit >100 MB of data per second and have up to 100-m cable lengths and a proprietary pylon driver package with filter and performance drivers. Maximum frame rate is 20/, 30/ or 100/s, depending upon the model. All have a C-mount lens and a Sony sensor.
Basler Vision Technologies
vc.sales@baslerweb.com

JANUARY

IS&T/SPIE Electronic Imaging (Jan. 17-21) San Jose, Calif. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org/electronic-imaging.xml.

Automated Imaging Association Business Conference 2010 (Jan. 20-22) Orlando, Fla. Contact AIA, +1 (734) 994-6088; info@machinevision.org; www.automated-imaging.org.

Photonics Japan (Jan. 20-22) Tokyo. Includes Internepcon Japan; Electrotest Japan; IC Packaging Technology Expo; International Electronic Components Trade Show; Printed Wiring Boards Expo; Material Japan 2010; International Automotive Electronics Technology Expo; and EV Japan 2010. Contact Hajime Suzuki, Reed Exhibitions Japan Ltd., +81 3 3349 8502; photonics@reedexpo.co.jp; www.photonicsjapan.jp.

SPIE Photonics West (Jan. 23-28) San Francisco. Encompasses the conferences BiOS: Biomedical Optics; LASE: Lasers and Applications in Science and Engineering; OPTO: Integrated Optoelectronic Devices; and MOEMS-MEMS: Micro- and Nanofabrication. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org/photonicswest.

PAPERS

SPIE Optics+Photonics (August 1-5) San Diego
Deadline: abstracts, January 18
Researchers are invited to contribute papers to this conference, which encompasses meetings on nanoscience, solar energy, photonic devices, and optical engineering and related applications. Topics to be considered include carbon nanotubes, thin films, IR detectors, remote sensing and solid-state lighting. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

Optical Interference Coatings (June 6-11) Tucson, Ariz.
Deadline: submissions, January 28, noon EST (17:00 GMT)
Papers on the latest results in the development and application of optical coatings are encouraged for this topical meeting of the Optical Society of America. Areas to be addressed include coatings design and applications, deposition process technologies, substrate materials, and characterization and properties. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org.

Imaging and Applied Optics (June 7-10) Tucson, Ariz.
Deadline: submissions, February 1, noon EST (17:00 GMT)
Submissions are encouraged for this Optical Society of America Optics & Photonics Congress, which consists of the meetings Applied Industrial Optics: Spectroscopy, Imaging and Metrology (AIO); Digital Image Processing and Analysis (DIPA); Imaging Systems (IS); Integrated Photonics Research, Silicon and Nanophotonics (IPR); Optical Remote Sensing of the Environment (ORS); Optics for Solar Energy; and Photonic Metamaterials and Plasmonics (Meta). Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org.

Advanced Solid-State Photonics (Jan. 31-Feb. 3) San Diego. Part of the OSA 2010 Optics & Photonics Congress: Lasers, Sources and Related Photonic Devices, and collocated with Applications of Lasers for Sensing and Free-Space Communications, and Laser Applications to Chemical, Security and Environmental Analysis. Contact Kristin Mirabal, kmirab@osa.org; www.osa.org.

Applications of Lasers for Sensing and Free-Space Communications: Topical Meeting and Tabletop Exhibit (Jan. 31-Feb. 4) San Diego. Contact Optical Society of America,

+1 (202) 223-8130; info@osa.org; www.osa.org.

Laser Applications to Chemical, Security and Environmental Analysis: Topical Meeting and Tabletop Exhibit (Jan. 31-Feb. 4) San Diego. Contact Optical Society of America, +1 (202) 223-8130; info@osa.org; www.osa.org.

IFPAC Annual Meeting/International Forum: Process Analytical Technology (Jan. 31-Feb. 4) Baltimore. Contact IFPAC Committee, +1 (847) 543-6800; info@ifpacnet.org; www.ifpac.com.

FEBRUARY

OPTRO 2010: Optronics in Defense and Security (Feb. 3-5) Paris. Contact Tom Pearsall, +331 45 05 72 63; pearsall@epic-assoc.com; www.epic-assoc.com.

Winter College on Optics and Energy (Feb. 8-19) Trieste, Italy. Contact V. Lakshminarayanan, +1 (202) 223-8130; custserv@osa.org; www.osa.org.

The Waterborne Symposium: Advances in Sustainable Coating Technologies (Feb. 10-12) New Orleans. Contact Laura M. Fosselman, +1 (601) 266-4475; www.psrc.usm.edu/waterborne.

SPIE Medical Imaging (Feb. 13-18) San Diego. Contact SPIE, +1 (360) 676-3290; www.spie.org.

SPIE Advanced Lithography (Feb. 21-26) San Jose, Calif. Contact SPIE, +1 (360) 676-3290; www.spie.org.

META'10: Second International Conference on Metamaterials, Photonic Crystals and Plasmonics (Feb. 22-25) Cairo, Egypt. Contact Said Zouhdi, +33 1 698 51660; said.zouhdi@supelec.fr.

PITTCON 2010 (Feb. 28-March 5) Orlando, Fla. Contact The Pittsburgh Conference, +1 (800) 825-3221; info@pittcon.org; www.pittcon.org.

MARCH

SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring (March 7-11) San Diego. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

Lighting Quality & Energy Efficiency (March 14-17) Vienna, Austria. Contact CIE-International Commission on Illumination, +43 1 409 56 31 0; cie2010@dm-and-c.at; vienna2010.cie.co.at.

Laser World of Photonics China 2010 (March 16-18) Shanghai, China. Contact Messe München, +49 89 9 49 2 07 20; www.messe-muenchen.de.

Conference on Optical Fiber Communication/National Fiber Optic Engineers Conference (OFC/NFOEC) (March 21-25) San Diego. Contact Optical Society of America, +1 (202) 223-8130; info@osa.org; www.osa.org.

Laser Optics Berlin 2010 (March 22-24) Berlin. Contact Dorothea Baxter at Messe Berlin GmbH, +49 30 3038 2159; US: +1 (540) 372-3777; dbaxter@exhibitpro.com; www.messeberlin.de

Picalo: Pacific International Conference on Applications of Lasers & Optics (March 23-25) Wuhan, China. Contact Laser Institute of America, +1 (407) 380-1553; conferences@laserinstitute.org; www.laserinstitute.org.

MEDTEC Europe (March 23-25) Stuttgart, Germany. Contact Canon Communications, +1 (310) 445-4200; info@cancom.com; Mr. Alison Trebble, +44 1458 835 955.

Intertech Image Sensors Europe 2010 (March 23-25) London. Contact Stacey Ludlow at IntertechPira, +44 1372 802 052; stacey.ludlow@pira-international.com.

23rd International Conference on 3-D Image Processing in Microscopy/22nd International Conference on Confocal Microscopy (March 28-31) Shanghai, China. Contact Qiushi Ren, +86 21 3420 4080; fax: +86 21 3420 4078; www.focusonmicroscopy.org.

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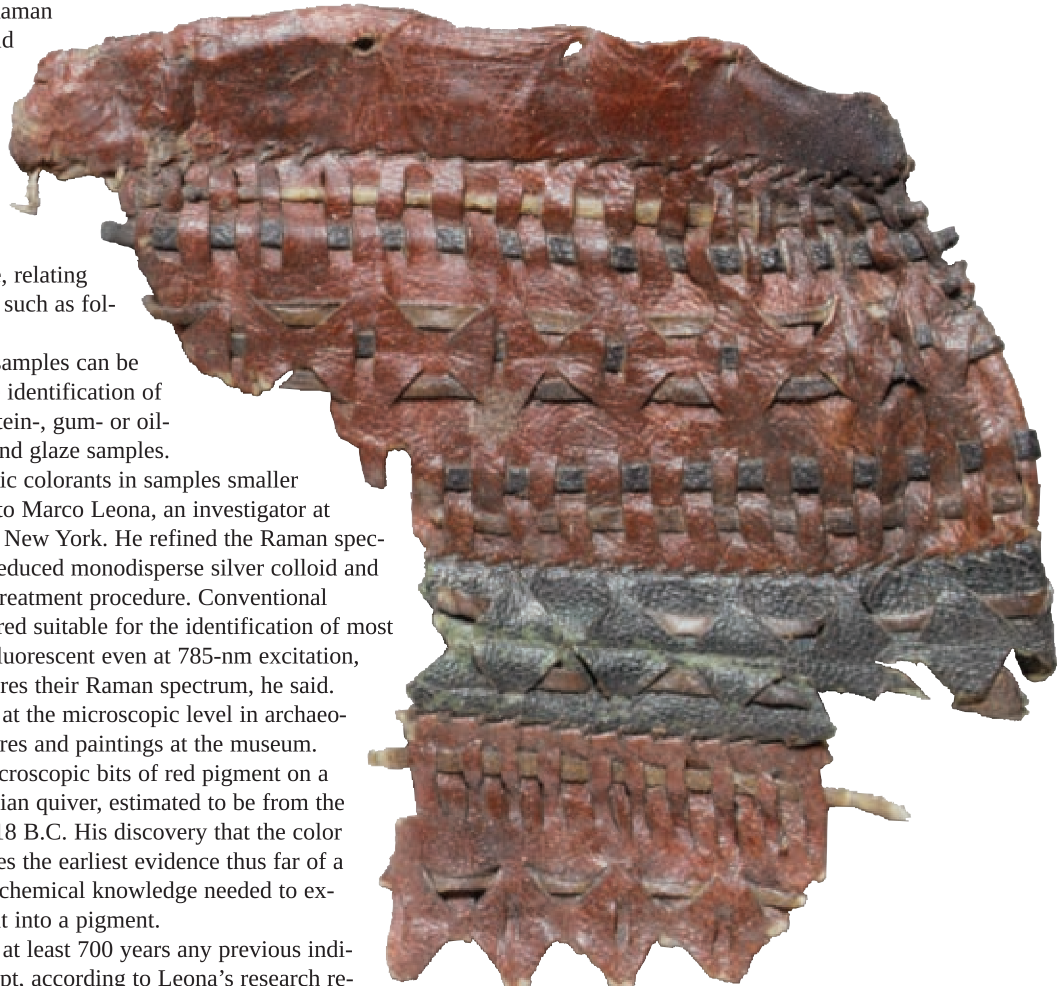
Visions of Cultures Past



Surface-enhanced resonance Raman scattering has provided a rapid and unobtrusive way of analyzing organic pigments and glazes in works of art. Analysis of organic colorants could lead to a deeper understanding of past cultures and societies, providing key information to art historians in terms of attribution and provenance, relating works of art and historical interests such as following trade routes.

Typically, only extremely small samples can be removed from works of art, and the identification of colorants is complicated by the protein-, gum- or oil-binding media present in pigment and glaze samples.

The technique can identify organic colorants in samples smaller than 25 µm in diameter, according to Marco Leona, an investigator at the Metropolitan Museum of Art in New York. He refined the Raman spectroscopy method with microwave-reduced monodisperse silver colloid and a nonextractive hydrolysis sample treatment procedure. Conventional Raman spectroscopy is not considered suitable for the identification of most organic dyes, which are generally fluorescent even at 785-nm excitation, and the resulting background obscures their Raman spectrum, he said.

The method identified colorants at the microscopic level in archaeological objects, polychrome sculptures and paintings at the museum.

For example, Leona analyzed microscopic bits of red pigment on a fragment of a painted leather Egyptian quiver, estimated to be from the Middle Kingdom, circa 2124 to 1918 B.C. His discovery that the color was madder lake, a red dye, provides the earliest evidence thus far of a culture that possessed the complex chemical knowledge needed to extract the dye from a plant and turn it into a pigment.

The quiver fragment predates by at least 700 years any previous indication for the use of madder in Egypt, according to Leona's research report, which was published in the journal *Proceedings of the National Academy of Sciences (PNAS)* in September 2009.

Leona's method also identified kermes, a dye made from the bodies of insects, as the red coloring in the painting "St. John the Baptist Bearing Witness" from the workshop of Francesco Granacci in the early 1500s in Florence, Italy. Before the dyestuff cochineal was imported from the New World, kermes and other insect dyes were popular in Europe. They were used much more commonly than madder in the preparation of glazes, which are translucent red or crimson paints prepared by dispersing lake pigments in oil, according to the report.

The technique documented the red coloring in the polychrome wood sculpture "Morgan Madonna" ("Virgin and Child in Majesty"), dated 1150 to 1200, as the insect dye lac, which originated in South Asia and which may have been imported to southern Europe by Muslim traders. The sculpture originally was housed in a church near the Provence region of France. Leona said that this is the first direct evidence of lac dye in European art before the 15th century.

The technique also identified lac dye in the French Romanesque sculpture the "Montvianeix Madonna," (1150 to 1200), which was thought to be similar in style and from the same region as the Morgan Madonna. The identification of lac dye in both sculptures provides strong evidence that they originated from the same workshop.

Caren B. Les
caren.les@laurin.com

Top: A refined spectroscopy technique called surface-enhanced resonance Raman scattering was used to analyze the red painted area on this ancient Egyptian artifact titled "Fragment of a Quiver," Accession No. 28.3.5, at the Metropolitan Museum of Art. Photos courtesy of the Metropolitan Museum of Art.

Left: Analyses of the red coloring on the sculptures "Morgan Madonna" ("Virgin and Child in Majesty"), Accession No. 16.32.94 (shown), and the "Montvianeix Madonna" (1967.153, not shown), both at the Metropolitan Museum of Art, identified it as lac dye, providing strong evidence that the sculptures may have originated from the same workshop.