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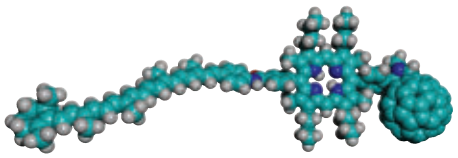

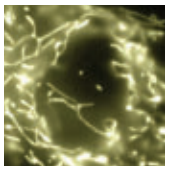

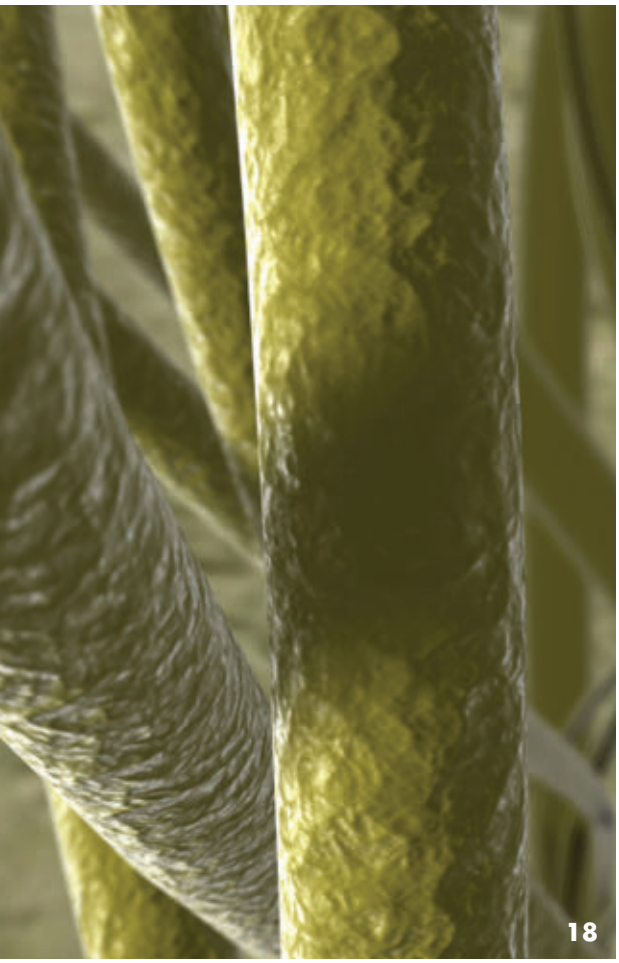

THE COVER
This month's cover is inspired by the artificial photosynthesis feature on page 34; designed by Senior Art Director Lisa N. Comstock.

DEPARTMENTS

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 8
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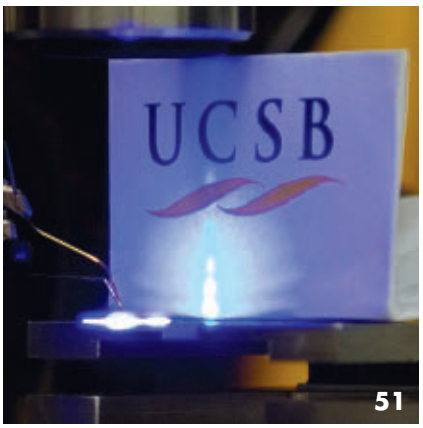
FEATURES



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Special EuroPhotonics Supplement

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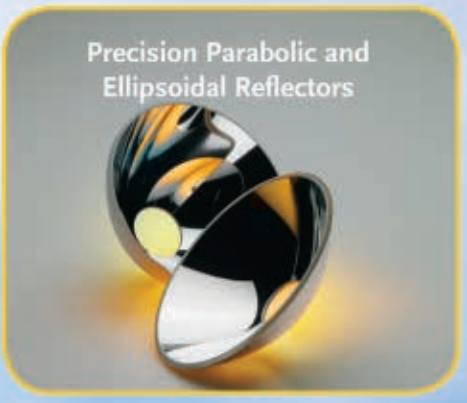

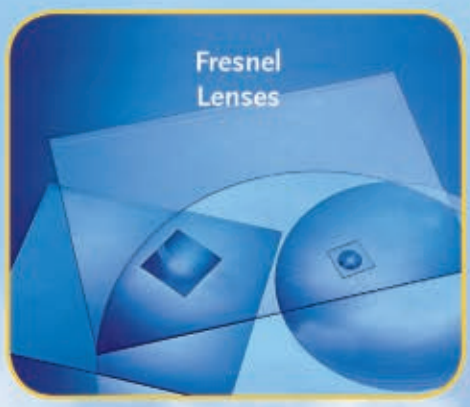

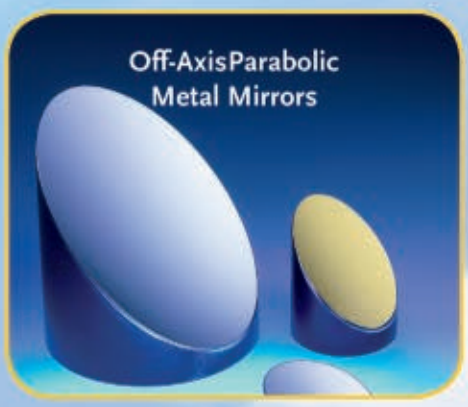

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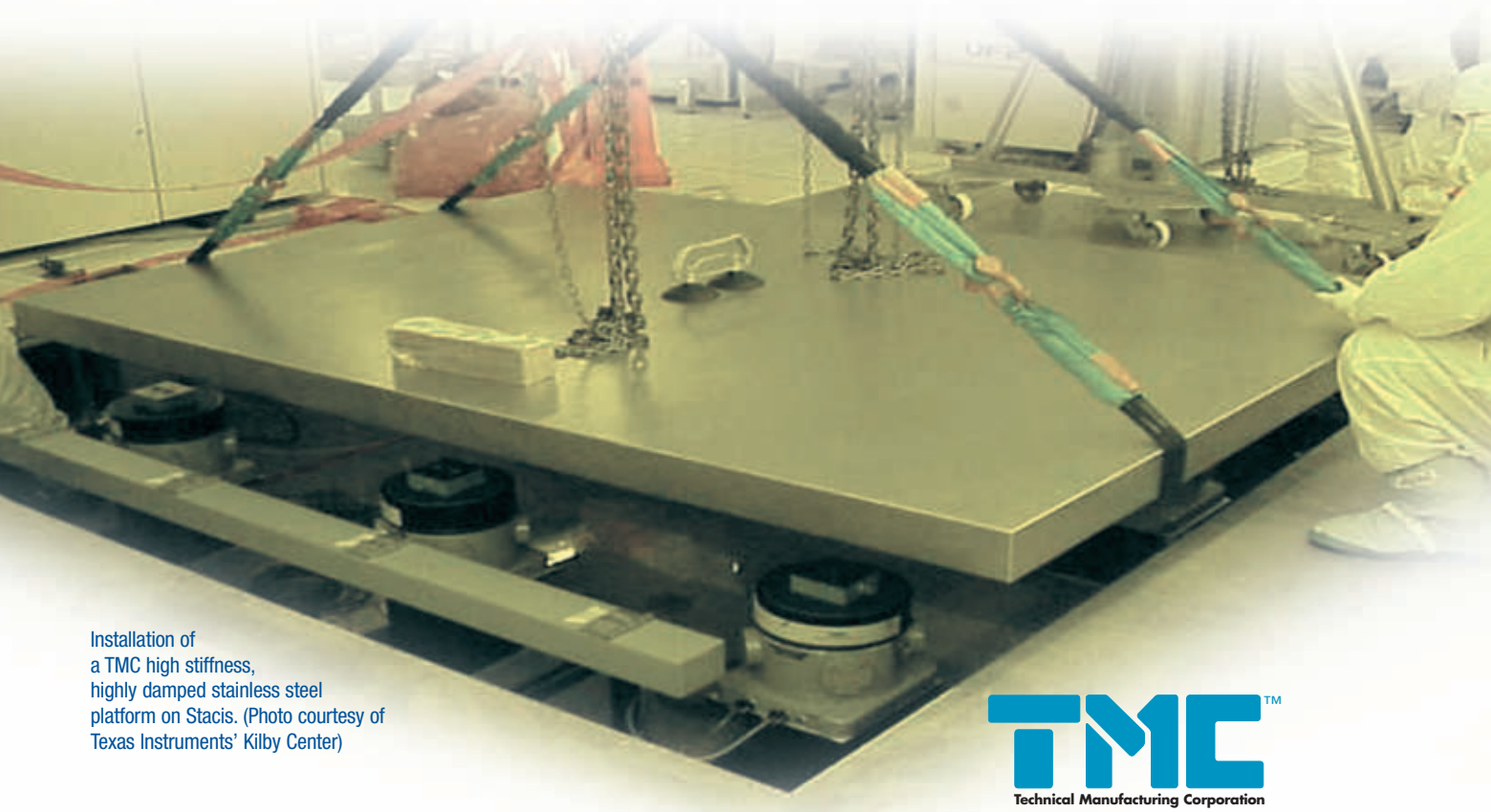

Installation of a TMC high stiffness, highly damped stainless steel platform on Stacis. (Photo courtesy of Texas Instruments' Kilby Center)

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Biting the hand that feeds you

When 300 highly esteemed members of the science community write to protest Gov. Arnold Schwarzenegger's proposed cuts to the University of California budget, their distress resounds throughout all research and technology sectors in the US, including our own.

The letter, signed by UC faculty who are members of the National Academy of Sciences, the National Academy of Engineering or the Institute of Medicine, was also sent to members of the state Legislature and UC leadership. The cuts are severe: 19 percent down from 2007-08 levels in state support for UC, or an $800 million shortfall in the UC budget for fiscal 2009-10.

"Further cuts of the magnitude being contemplated in the latest round of budget proposals are likely to destroy UC's status as the leading public university in the United States," the letter said. "This would undermine prospects for economic recovery and damage California's competitiveness for decades."

As the reports unfold, this seems likely. To begin with, cuts such as these would have a grisly effect on enrollment. According to the Los Angeles Times, an additional student fee hike of 15 to 20 percent for this fall has already been proposed by California State Chancellor Charles Reed. Even more chilling is the predicted enrollment reduction of 32,000 that UC predicts for the following year.

And it gets worse. UC's Board of Regents voted overwhelmingly to implement furlough days for most professors and staff that would reduce their pay between 4 and 10 percent for the year starting Sept.1.

One signatory, UC Santa Cruz astronomy professor Sandra Faber, said the cuts would undoubtedly affect science and technology in the state by draining UC's science elite.

"It's this retention and hiring issue," Faber said. "Why would a person who is a world-class scientist want to come work for a UC and make 20 percent less? What we're looking at is not being competitive anymore."

Why, indeed? In this economic climate, most of us can feel for states forced to enact severe cost reductions, but in this case, the expense is too dear. The alarming fiscal condition of California notwithstanding, it's foolhardy to cut the expenditures responsible for developing innovative technologies and creating new companies and jobs – the very lack of which contributed to the shortfall in the first place.

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Solar coffee shop?

I was intrigued by your articles on solar power in the May issue and have a question I hope you can help me with. I am a member of a Hewlett-Packard survey group that discusses topics such as various aspects of technology. One discussion broached the subject of solar-powered technology; e.g., laptops and cell phones.

Although not as practical as it is expensive, it occurred to me that perhaps one could use solar to provide the needed power for laptops and the like at a Wi-Fi hot spot such as a coffee shop. Is solar technology far enough along that one could deploy panels – say, at a coffee shop – to provide power to outlets for such a hot-spot locale? Better yet, is it cost-effective?

Jaime Sanchez
Albuquerque, N.M.

Editor's response:

Solar-powered consumer products such as laptops and cell phone chargers are available online, in stores and through popular mail-order catalogs. Solar Wi-Fi spots currently exist in several cities, and many of these types of applications are in use in underdeveloped areas of India and Africa to bring electricity and connectivity to those for whom it is intermittent or unavailable. We are eager to learn of more stand-alone solar applications and welcome input from readers.

What's with the battery?

I read Anne Fischer's article "Lighting up the Underdeveloped World" on page 35 of the November 2008 issue of *Photonics Spectra* and was wondering about one thing: the battery. There was not much information about the most vulnerable item in the solar setup regarding life expectancy, recharge cycles, type of battery and how all those batteries could be replaced/recycled.

Ome Willem
Los Angeles

Editor's response:

We focused on the photonics technology, which is why we didn't go into detail on the batteries. However, there is much ongoing research into faster-charging, longer-life batteries that are cleaner and safer for the environment. IEEE, for example, has an Emerging Battery Technology Working Group; information can be found on the association's Web site. You may also be interested in the follow-on article in the July issue ("Lighting up lives," page 39), which describes how solar lighting in India has had a social and economic impact.

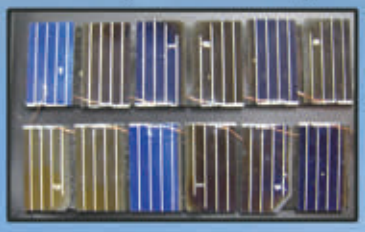
About bin Laden

I enjoyed David L. Shenkenberg's review of the University of California, Los Angeles, study on the location of Osama bin Laden ("Can Remote Sensing Find bin Laden?" May, p. 48). One error should be noted: bin Laden was credited with the 9/11 attacks by our government but denied involvement.

I tend to believe his denial because, traditionally, terrorists trip over themselves to claim responsibility for attacks. And according to the FBI, he is not connected to the 9/11 attacks because there is no mention of them on his page. Take nothing for granted.

Mark Morey, Senior Scientist
Optical Systems Development Group
Special Technologies Laboratory
Santa Barbara, Calif.

Visible image shows only color variations, resulting from the AR coating



Thermal microbolometer image exposes little or no detail

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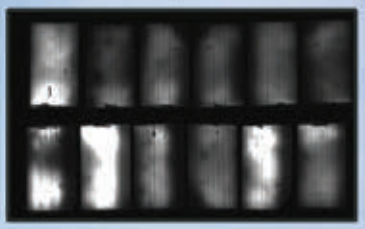

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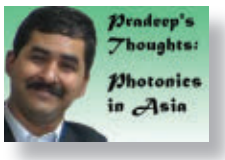

Pradeep's Thoughts – a regular column by blogger Pradeep Chakraborty detailing the photonics industry in Asia. Pradeep is a semicon/telecom consultant at PC Mediaworks.

WEB EXCLUSIVES:

Evaluating and Comparing Camera Performance
Cameras are being used in products such as PDAs, automotive rear viewing systems, medical devices and military applications including thermal imaging and ranging systems, which is why a team from Optikos Corp. has taken a close look at some of the most important evaluation metrics used to assess overall camera performance.

Check out a sample of the new digital version of *Photonics Spectra* magazine at www.photonics.com/DigitalSample. It's a whole new way to stay informed about the global photonics industry.

Plus all the latest news, products and industry information you need each day.

Coming in September …

Update on Display Technology: Displays can never be too thin, as evidenced by the rise of flat-panel displays of all varieties. The latest enhancements promise to bring high brightness yet thinness and low-power consumption to mobile devices.

Report on Canada: Photonics is big in Canada. A look at the depth of the collaboration between photonics research and industry in Canada, profiling a number of big and small companies in the Ontario and Québec clusters and elsewhere in the country.

The Gender Gap in Science and Math: A recent study of gender attitudes around the world has shown that implicit stereotypes associating males with science and math predict sex differences in eighth-grade achievement in these areas.

Interactive Eyeglasses
Ever want to be a secret agent? Well, here's your chance. Researchers have developed eyeglasses that not only display information, but also incorporate interactive eye tracking that enables the wearer to change the display by fixating on an object.

GreenLight will include stories on the Solar Decathlon competition in October; the greening of the campus at Butte College in Oroville, Calif.; a partnership between Arizona State University and Advent Solar of Albuquerque, N.M., to advance solar photovoltaic technology; and an off-the-grid bus shelter at McMaster University in Canada.

Plus all the regular features you look for month after month.

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The CSI Effect

TV shows are inspiring kids to learn about science, but are they sending the wrong message?

BY GARY BOAS, CONTRIBUTING EDITOR

In the fall of 2000, CBS introduced a show about a bunch of attractive, stylish crime scene investigators who, using an array of high-tech, sometimes science fiction-y tools, crack cases with ironclad, incontrovertible evidence and then – just as breezily, it seems – nab the bad guys. All within a span of about 42 minutes.

The show, of course, was *CSI*, and before long it had become a veritable phenomenon, spawning two spin-offs and inspiring a clutch of other such "procedural" programs: *Criminal Minds*, *Bones*, *Crossing Jordan*, *Without a Trace*, *NCIS*, *Cold Case Files* and *Forensic Files*, to name a few.

CSI has brought a new awareness to the field of forensics, especially in the educational arena. Some observers fear, however, that the show is leaving viewers with a somewhat erroneous understanding of the field. In real life, they say, forensics is neither as glamorous nor as effortless as it appears on television. At the same time, the format of the show – the nature of television, generally – has created unrealistic expectations of what science can achieve in the courtroom. The results from forensics tests are rarely as unambiguous – as conclusive – as on *CSI* and are almost never available before the hour is up.

This phenomenon, this combination of misunderstandings about and increased expectations of forensics, has been described as the "*CSI* Effect." And whether it outweighs the positives of the show – the increased awareness of the field and the newfound cachet of science in general – is still up for debate.

Fact and fiction

There is a considerable disconnect between the world of forensics as seen on TV and the real world of forensics. Brad Brown, vice president of Arrowhead Forensics, which supplies instruments and other products to the law enforcement market, said, "We've been doing this for years, and I can tell you, it's not all about fancy cars and high heels."

Arrowhead Forensics has partnered with Coherent Inc. and the law enforcement market to provide a 532-nm forensic laser called the TracER, a new lightweight, battery-operated device that investigators can carry from the laboratory to the crime scene to find latent prints, and biological and other trace evidence.

He also points out the speed and relative ease with which "one guy does it all" on some of the shows. State crime labs have many sections within the laboratory: trace evidence analysis, photo documentation, chemistry, firearms, DNA analysis and so on. A team will work together to complete an investigation and, even then, it needs a considerable amount of time to arrive at any conclusions. "In real life," Brown said, "it sometimes can take longer to solve a crime than it takes to produce a whole series."

And then there is the technology itself. Much of the technology used by crime scene investigators on television exists in the real world – DNA sequencers and mass spectrometers, for example. However, as noted in a 2006 commentary in the *Journal of Chemical Education* by Elisa T. Bergslien, associate professor of earth sciences and science education at Buffalo State College in New York, the manner in which the technology is used is often "far-fetched." "Few chemists would be willing to grind up maggots and inject the resultant pulp into their gas chromatographs," she explained, "an act that would almost certainly destroy the column."

CSI meets the Ivory Tower

Fact or fiction, the popularity of *CSI* has led to the introduction of forensics courses at the junior high and high school levels and to increased enrollments at the college level. In many cases, faculties are scrambling to create new courses – especially "forensics for nonscience majors" – to meet the burgeoning demand.

Bergslien, who teaches a forensic geology course at Buffalo State, welcomes the spike in interest – likening it to the increased currency of environmental courses in recent years, as media attention has focused on global warming, for example. *CSI* has clearly had a positive effect on education, she said recently, helping to popularize science. Students are now more interested in finding out how things work. Oftentimes, they are disappointed that forensic investigation is not quite as effortless as it appears to be on television – a realization that can be a

"significant deal-breaker," she said. At the end of the day, however, there are more students in her program than there were previously.

If Bergslien has any concerns about the newfound popularity of forensics education, it is that forensics is occasionally dumbed down for the sake of the lesson plan. As an example, she refers to curricula created for junior high and high school classes in forensics. "One of the things I've struggled against is matching exercises," she said. "'Here's your crime, here are your four or five suspects.'" Because of the total lack of ambiguity on *CSI* and other such shows, students assume that there is always going to be some obvious solution to the crime, a notion supported by these exercises. Actual crime scene investigations are never so accommodating, however.

Even when she sets up labs in which none of the suspects is linked to the crime scene, she said, students will "jump through hoops to make things match," so certain that the answer is within easy reach.

If *CSI*-inspired courses don't always convey the realities of forensic investigation, they still help to introduce the fundamentals and many of the concepts of scientific inquiry: essentially, what questions to ask and how to ask them. And if forensics courses at the college and university level don't always meet students' expectations of sexy work and a glamorous lifestyle, they might still grab them in some other way.

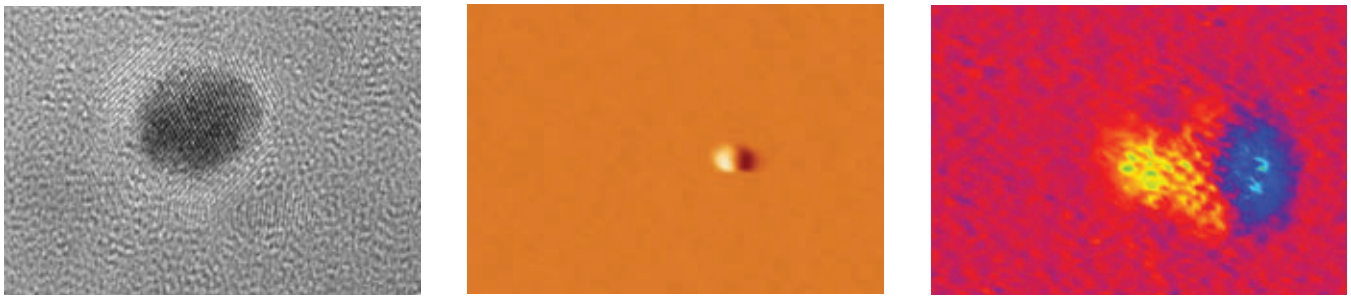
Bergslien sees a number of students who may never have taken a forensics course were it not for *CSI* and other such shows. Some fall away when they realize the classes bear little or no resemblance to what they have seen on TV. Others stay on, however, having discovered something new and exciting in the study of forensics – something they need to explore further.

gboas@eggship-media.com

The "*CSI* Effect" also has played out in the courtroom, as jurors and potential jurors are now armed with greater understandings – and misunderstandings – of how evidence is collected and tested using forensics. "Jurors now want to see the science," said Brad Brown, vice president of Arrowhead Forensics. "They ask questions like, 'Why didn't you run a test that I saw on TV?' Sometimes they know what they're talking about. Other times they don't."

The effect is so pervasive that, at times, attorneys will address it in their opening statements and closing arguments, reminding jurors that forensic investigation in real life is generally more ambiguous than what they see on television. Some reportedly will even ask potential jurors whether they watch fictional crime scene-related shows to assess whether they might have preconceived notions from what they have seen on television.

A cheaper path to nanodiamonds



Left: High-resolution transmission electron microscopy reveals the form of a diamond nanoparticle that was produced by milling. Courtesy of M. Sennour and A. Thorel, Material Centre of Mines-ParisTech. Center: A diamond nanoparticle is viewed using atomic force microscopy. Right: A nanosize diamond fluoresces brightly. Courtesy of F. Jelezko and G. Balasubramanian, Physics Institute, Stuttgart, Germany.

EVRY, France – They don't photobleach, they don't blink, and they are very bright and biologically inert. So why are fluorescent nanodiamonds still not widely used in research? Because they are exceptionally difficult and expensive to produce, making them impractical for many applications.

Researchers at Université d'Evry, in collaboration with scientists from the Physics Institute of the University of Stuttgart in Germany and from the Material Centre of Mines-ParisTech and Technology University of Belfort-Montbéliard, have developed a process to create fluorescent nanodiamonds that could change the way they are viewed and used. According to the investigators, milling the particles from diamond microcrystals preserves their unique properties, making it possible to produce them industrially on a large scale.

Up to now, fluorescent nanodiamonds could only be created by irradiating substitutional nitrogen-containing diamond nanocrystals, obtained as expensive and poorly characterized industrial wastes of the diamond industry, with electron or ion beams to create vacancies in the crystal lattice. The particles then are annealed, causing the substitutional nitrogen atoms to trap moving vacancies and to create a fluorescent nitrogen-vacancy center. However, amorphization and the loss of moving vacancies to the surface of the diamond during processing greatly reduce the efficiency and yield of this procedure.

Top-down processing of fluorescent diamond microcrystals, which are more stable than their smaller counterparts, theoretically could provide an industrially scalable procedure. But the practicality of irradiating large amounts of material – and the problem of converting microdiamonds to nanocrystals without compromising their fluorescence or structure – had kept the plan from being realized.

The investigators surmounted these problems by creating a two-step process to mill the diamonds. They used perfect synthetic diamond crystals – measuring ~0.2 mm – that had been irradiated with a high-energy electron beam and annealed at 800 °C. The crystals were mechanically ground using a jet milling system, which used a stream of inert gas to energetically knock them together. Once the diamonds were small enough that the machine's exit filter could no longer contain them, the particles were transferred to a planetary mill, where they were mixed with dense tungsten carbide beads to continue being ground. The process produced rounded nanodiamonds as small as 4 nm with bright, stable photoluminescent centers.

Researcher Dr. Patrick Curmi of Université d'Evry said that mass production of fluorescent nanodiamonds could lead to breakthroughs in a wide range of fields. The particles could be used as single-photon sources for quantum information processing, as high-resolution magnetometers in nanotechnology and electronics, and as labels to track organic and nonorganic materials.

For more information about fluorescent nanodiamonds, see "Twinkle, Twinkle, Little Diamond" at photonics.com.

Rebecca C. Jernigan
rebecca.jernigan@laurin.com

Radios broadcast into the ultraviolet

ADELPHI, Md. – Ultraviolet communications has been on the US military's agenda since the 1960s, but only recently has the Army been able to perform small-scale, short-range, nonline-of-sight UV radio experiments that could lead to a novel communications model.

Facilitated by developments in semiconductor detectors and optical sources in the deep-UV or ultraviolet C band, the military is determined to stay ahead of the game by improving UV-C systems it can use for short-range broadcasting.

Dr. Brian M. Sadler, a scientist at the Army Research Laboratory, has been working to develop this technology for unattended ground sensors. He also hopes to uncover the complex way in which ultraviolet light scatters throughout the atmosphere and to model the signal for use in UV communications.

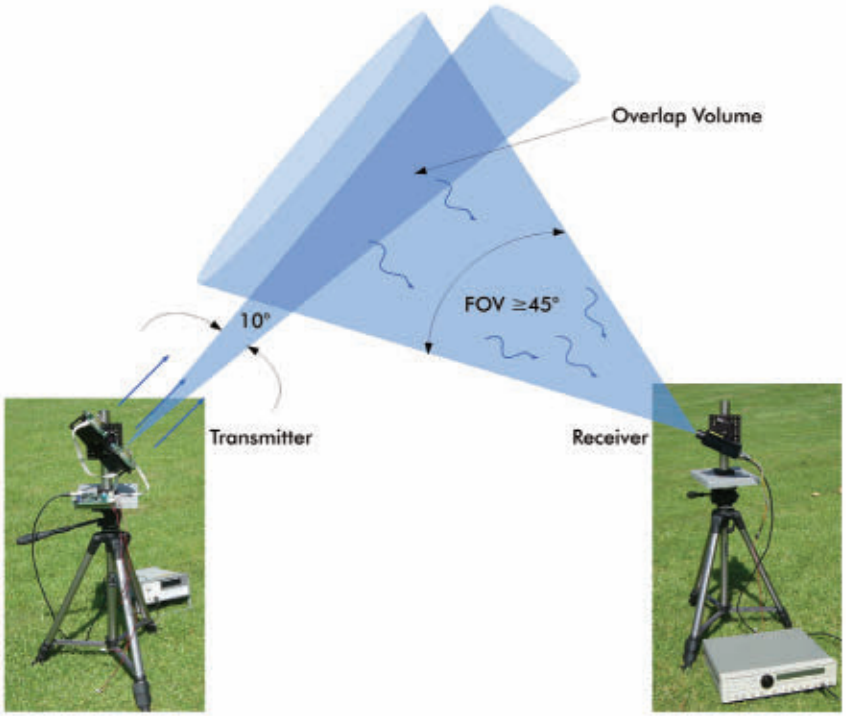
"My primary goal is to understand the basic science," Sadler said.

Over and out

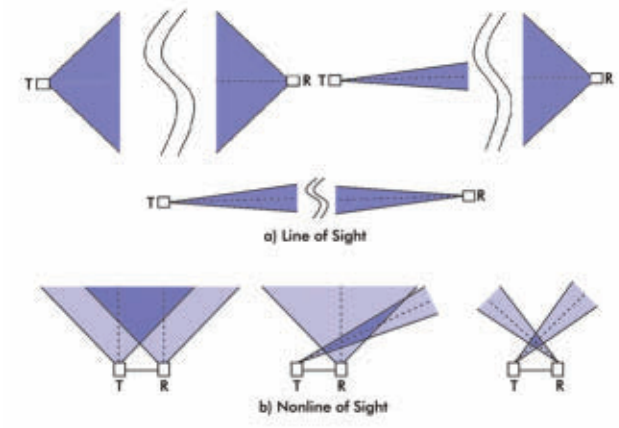
The components of a UV test bed radio system include a transmitter consisting of

seven ultraviolet LEDs with a radiated optical power of 0.3 mW. Each LED yields its own beam divergence gauged at 17°, which projects a cone-shaped beam toward the sky. A solid-state avalanche photodiode, or receiver, generates numerous electrons from a single photon. The device contains a solar-blind filter placed on a PerkinElmer Inc. photomultiplier tube that manages photon detection and counting. When propagated into the atmosphere, photons scatter into the receiver's field of view, and the detector measures the optical power emitted by the LEDs.

An advantage to the technology is that the signal scatters, enabling the nonline-of-sight communication. In addition, the radios operate in the solar-blind portion of the UV-C band, where light emits at a wavelength of 200 to 280 nm. In this band, according to Sadler, when solar radiation propagates through the environment, it is strongly attenuated by the Earth's atmosphere. This means that, as it gets closer to the ground, the amount of background noise radiation drops dramatically, and low-power communications link operation is possible. On the other hand, environmental elements such as oxygen, ozone and water can weaken or interrupt the



A transmitter equipped with an array of ultraviolet LEDs broadcasts a beam toward the sky at an optimal angle. A receiver, placed a short distance away and positioned at a similar angle, emits large amounts of electrons that detect and count scattered photons. Upon propagation into the atmosphere, the photons scatter into the receiver's field of view, and the detector measures the optical power produced by the LEDs.



Depicted are line-of-sight (a) and nonline-of-sight (b) arrangements that differ in bandwidth sizes. Ultraviolet communication greatly relies on the transmitter's beam position and the receiver's field of view. As a result, researchers are refining the pointing apex angle by experimenting with supplementary equipment to enhance the UV-C signal.

communications broadcast, limiting usage to short-range applications.

Early experimental versions of UV radios were not economical because the transmitters depended on lamp technology, and the receiver was a large and cumbersome photodetector based on a vacuum tube. “Back then, the technology they had was extremely bulky by today’s standards,” Sadler said. Now the equipment is smaller and less expensive.

Understanding UV scattering

When UV waves spread throughout the atmosphere, they are strongly scattered into a variety of signal paths. Signal scattering is essential to UV systems operating in nonline-of-sight conditions, and the communications performance is highly dependent on the transmission beam pointing and the receiver’s field of view.

Sadler and his collaborator, Zhengyuan Xu from the University of California, Riverside, are trying to understand the process of UV scattering. If successful, they could create a new approach to optical communications. “A lot of that comes down to the physics of transmission and the physics of the atmosphere,” Sadler said.

Moreover, they are testing the UV-C radios by placing the receiver and transmitter at various distances apart, comparing their performance during day and night operations and observing efficiency during low-to-medium- and high-solar noise. The investigators also are experimenting with assorted transmitting and receiving equipment to refine the pointing apex angle, which can enhance the signal.

“The goal of the research is to have models and equations to be able to predict performance,” Sadler said.

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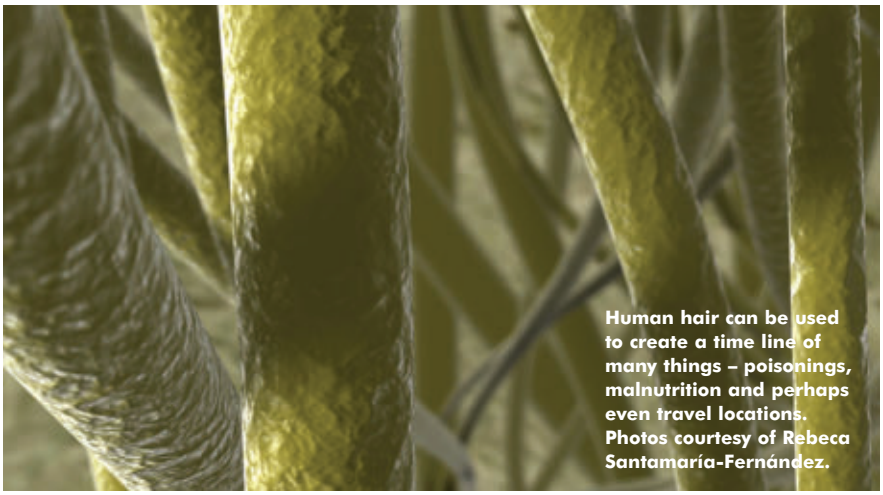
Solution to a hairy problem



Human hair can be used to create a time line of many things – poisonings, malnutrition and perhaps even travel locations. Photos courtesy of Rebeca Santamaría-Fernández.

TEDDINGTON, UK – A single strand of hair can reveal much about a person, especially if you know how to look. Proper investigation can determine diet as well as any drugs or poisons the person may have been exposed to, and the hair’s growth keeps this information in a fairly accurate time line.

Researchers from LGC Chemical Metrology Laboratory and from the University of Oviedo in Spain are investigating the details of this time line. By identifying the proportions of specific sulfur isotopes in hair samples, they believe that they may be able to track the geographical movements of a person. This information could be useful when pinpointing the movements and locations of international crime suspects and victims.

By combining a laser ablation system from the New Wave Research Div. of ESI Electro Scientific Industries of Portland, Ore., with a multicollector inductively coupled plasma mass spectrometer from Thermo Fisher Scientific GmbH of Bremen, Germany, the investigators sampled sections along the length of the hair with a higher resolution than that available using isotope ratio mass spectrometry coupled to an elemental analyzer – the conventional method for analyzing stable isotopic variations.

Rebeca Santamaría-Fernández uses a laser ablation system attached to a multicollector inductively coupled plasma mass spectrometer (LA-MC-ICP-MS) to examine the sulfur isotopes in strands of human hair.

They focused on the most abundant isotopes found in hair keratin, sulfur-32 and -34, which account for 95 and 4 percent of the sulfur total present in keratin, respectively. The proportion of the isotopes varies slightly in response to the diet and geographical location of the hair’s owner, and this technique can measure and record these tiny changes.

By testing hair samples longer than 4 cm from three volunteers – two permanent residents of the UK and one who had spent six months traveling between Croatia, Austria, the UK and Australia – the researchers determined that, although sulfur isotopic variations in the nontravelers’ hair were very small, there were significant variations in the traveler’s hair sample.

The lead investigator of the study, Rebeca Santamaría-Fernández, believes that the technique could be used in forensic investigations and health-related studies, although a comprehensive database for the isotopes would have to be in place for users to make sense of the information.

To further their research, the scientists plan to perform a larger study involving 100 volunteers, gathering information on the participants’ diet, lifestyle, geographic origin and recent travels, and investigating the correlation with the sulfur, carbon and nitrogen isotopic variations found in their hair samples to give them a better understanding of the factors that influence the variations.

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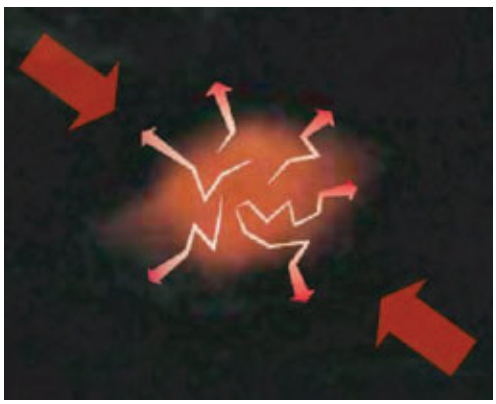
Scientists are creating unusual type of laser from a strange material

NICE, France – Just what the heck is a random laser? Because lasers are supposed to produce coherent, linear beams of light, the notion of randomness in a laser beam seems at first to be an oxymoron.

As in an ordinary laser, light in a random laser is amplified by passing through a special material – the "gain medium," but a random laser lacks one feature that most lasers have – a "microcavity," or a narrow channel that confines the light into a linear beam. Instead of traveling as a linear beam, the light from a random laser radiates outward.



A random laser shoots light outward in multiple directions. Courtesy of William Guerin.

Not only does the laser lack a microcavity, but its gain medium also has been altered such that, besides amplifying light, the laser scatters it in multiple directions. This multiple scattering is the hallmark of the random laser. For example, laser dye can be encapsulated in particles that scatter the light amplified by the dye. In another example, a laser crystal is ground into a powder that amplifies and scatters the light.

Random lasers are interesting from a basic physics standpoint because the light moves randomly and not just in a straight line. Random movement notably has been characterized by P.W. Anderson who, in 1977, won one-third of the Nobel Prize in physics, and his "Anderson localization" can be used to describe the physics of random lasers.

Random lasers also could have various practical applications. Because the light shoots out in all directions in a unique array of colors, random lasers could be used for displays and also for street and home lighting. The unique array of colors also can be used for identifying objects spectroscopically.

Recently, a group of researchers decided to develop a random laser out of cold atoms. "The fact that the medium is very different from other random lasers – atoms versus condensed matter – makes the realization of a random laser with cold atoms both very interesting and very challenging," said William Guerin, a researcher affiliated with the project.

Guerin and Robin Kaiser worked on this project at the University of Nice Sophia-Antipolis in France, and they also are both members of the National Center for Scientific Research. They collaborated with Luis Froufe-Pérez at the Materials Science Institute of Madrid in Spain and with Rémi Carminati at the Optical Physics Laboratory in Paris.

They used the simplest mathematical model of gain, Mollow gain, to calculate the diameter of the cloud in units of the typical distance a photon travels before scattering. This is the "optical thickness," a measure of the opacity of the atom cloud.

As reported in the May 1, 2009, issue of *Physical Review Letters*, they found that they need an optical thickness ranging from approximately 200 to 250 to create the random laser out of the atom cloud. "We found a quite large optical thickness, but we think this is within reach of present cold atoms experiments," Guerin said.

The researchers plan to use magnets and lasers to confine the atoms, slowing their motion and cooling them down to within a few micro-Kelvin. Then they will use tricks such as compressing the cloud to achieve the necessary opacity value. Finally, they will focus a pump laser on the cloud and, theoretically, will at last have their random laser developed out of cold atoms.

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State Department addresses delays in obtaining visas

The US State Department has announced efforts to address issues with the visa application process. Foreign investigators have experienced significant delays in the past year when trying to enter or re-enter the US.

WASHINGTON – In the past year, researchers and students hoping to enter or re-enter the US have faced sometimes months-long delays in obtaining visas. Now, however, after a chorus of complaints from university groups and scientific organizations, the US Department of State has promised to address the problem.

According to a *New York Times* report, David Donahue, deputy assistant secretary of state for consular services, said in early June that the department had already begun to tackle the backlog of applications. He noted that additional staff had been enlisted to do so and that new procedures had been put into place to reduce the wait time for visas. Eventually, he said, routine requests should be handled within two weeks.

The delays have created trouble for university research centers and technology companies alike. Many of the top graduate schools are populated by foreign students and postdocs, and research projects have languished as they wait for weeks or even months to be allowed back into the States. Similarly, many companies employ foreign talent and, when those workers are stuck abroad, the companies suffer as well. This is of concern especially in tough economic times, when continued innovation in science and technology is needed to keep the US competitive (See "Just How Dangerous Are Foreign Researchers?" June 2009 *Photonics Spectra*, p. 62).

A week after the State Department's announcement, a group of science, academic and engineering organizations, including the Association of American Universities, the National Academy of Sciences and SPIE – The International Society for Optics and Photonics, issued a statement praising the department's stepped-up efforts but urging the federal government to do more to improve the visa process for foreign researchers.

"Talent in knowledge-based companies must be able to move freely across international borders for these companies to maintain competitiveness," said M.J. Soileau, vice president for research and commercialization at the University of Central Florida in Orlando and chairman of the SPIE Committee on Engineering, Science and Technology Policy. "Easy, efficient, sensible visa processes and policies are absolutely critical."

The statement also included recommendations on improving the visa process and, thus, building upon the "positive actions" by the federal government. The signing organizations suggested, for example, reducing repetitive processing of applications for established scientists who visit the US regularly to attend conferences and to conduct research with collaborators here. Also, efforts to renegotiate visa reciprocity agreements between the US and certain key countries should be expanded and a high-level interagency panel convened to review all visa-related policies and procedures implemented since the Sept. 11 attacks in 2001.

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THE PULSE OF THE INDUSTRY

The good – and bad – news on gender differences among science faculty

WASHINGTON – Women who apply for tenure-track positions at research universities are more likely than men to be interviewed and offered a job, but the number of women who apply for the positions is still lower than the number who earn doctorates in the sciences, according to a congressionally mandated report by the National Academies looking at the fortunes of women at research-intensive universities with respect to men at the same key transition points in their careers.

The report is based on the results of two surveys of tenure-track and tenured faculty at 89 institutions across the US, in six disciplines: biology, chemistry, mathematics, civil engineering, electrical engineering and physics. It also reflects testimony and data from various federal agencies, professional societies, individual university studies and academic articles.

For example, the report found that, although only 20 percent of those who applied for tenure-track positions in mathematics were women, women accounted for 28 percent of those interviewed and a full 32 percent of those offered jobs.

Women are still underrepresented in the applicant pool, however, and the discrepancy is greater in those fields where higher percentages of women are earning doctorates. For instance, while women were awarded 45 percent of the doctorates conferred in biology by research-intensive universities between 1999 and 2003, only 26 percent of those who applied for tenure-track positions were women.

What accounts for this discrepancy? "Our data suggests that, on average, institutions have become more effective in using the means under their direct control to promote faculty diversity, including hiring and promoting women and providing resources," said study committee co-chairman Claude Canizares, Bruno Rossi professor of physics and vice president for research at MIT in Cambridge.

The proportion of women in the applicant pool is not under their direct control, however. Many institutions have sought to increase the number of women who apply for tenure-track positions – through targeting advertising and recruiting at conferences, for example – but these efforts have not proved especially effective.

A recent congressionally mandated study assessed gender differences among faculty at research universities across the US. The study found that women are faring well in some areas, but that inequalities still exist in others.

The report looked at other areas as well, hoping to assess gender differences in the various corners of research institutions. The other areas included access to institutional resources, such as startup packages, travel funds and numbers of postdocs and research assistants; tenure; salary; climate and interaction with colleagues; and outcomes, with respect to grant funding, nominations for awards and honors, and job offers by other institutions. The study committee found varying degrees of gender difference in these additional areas.

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Environmental sensing market upwardly mobile

WELLESLEY, Mass. – The global market for environmental sensing and monitoring technologies is expected to increase to $13 billion in 2014, with a compound annual growth rate (CAGR) of 5.2 percent, up from $9.1 billion in 2008 and an estimated $10.1 billion in 2009, according to a report published in June 2009 by BCC Research.

Titled *Environmental Sensing and Monitoring Technologies: Global Markets (IAS030A)*, the report discusses application areas for the largest share of the market: radon, GPS, remote sensing and new technologies. Worth $4.9 billion in 2008, this segment is estimated to grow to $5.1 billion in 2009 and to $6.8 billion in 2014, for a CAGR of 6.2 percent.

The terrestrial sensing and monitoring application segment, representing the second largest share, was worth $2.6 billion in 2008 and is expected to grow to $2.7 billion in 2009 and to $3.4 billion in 2014, for a CAGR of 4.7 percent. The third largest segment, atmospheric sensing and monitoring, was worth $800 million in

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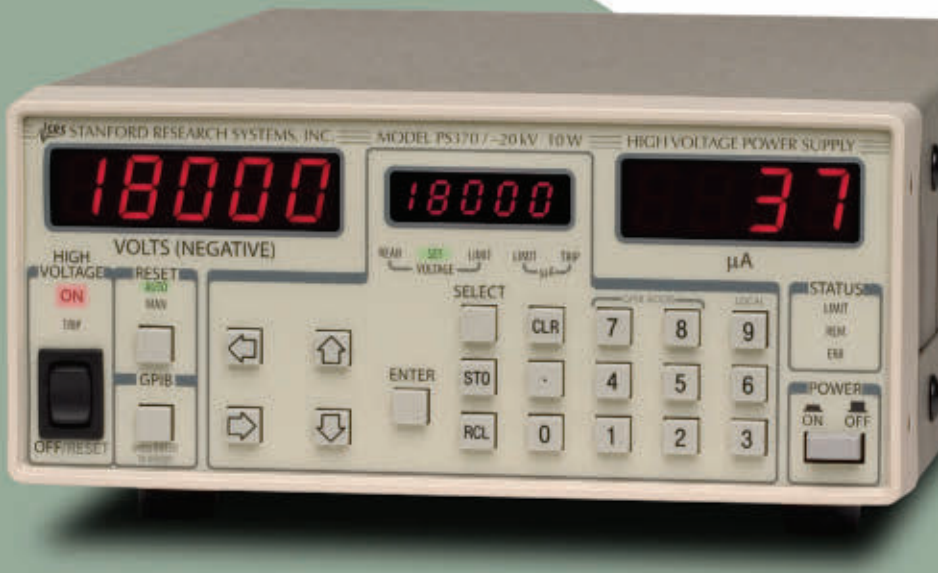

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2008 and is projected to increase to $1.5 billion in 2009 and to $1.8 billion in 2014, for a CAGR of 3.1 percent.

Real-time warning

Based on the rate of growth in revenues, the fastest-growing emerging areas include the application of photonics-based sensors for water processing and wastewater treatment as well as for photonic devices employed in biosensing, according to analyst Kevin Gainer, author of the report. For example, he said, in water processing, treatment and monitoring, many initiatives are being pursued to detect and classify pathogenic micro-organisms in liquids using multiangle light scattering and other photonics techniques.

These methods also can detect and classify biological agents such as bacteria and bacterial spores as well as those including chemical, biotoxin and radiation agents, he said. Real-time warning in water treatment is a key operative trend in terms of uses of photonics-based applications, Gainer said. The application of in situ photonics sensor-based technologies can greatly reduce the time lag seen in standard laboratory analyses, which can take up to 72 hours per test.

The remote sensing category encompasses many photonics-based techniques, while the "new technologies" category includes additional important photonics advances such as silicon photonic integrated circuits, he said. He noted that significant investment has been made in developing optical methods for the remote or stand-off detection of trace chemicals, environmental pollutants, chemical and biological agents – even high explosives. These techniques involve advanced laser remote sensing based on Raman scattering or laser-induced fluorescence from a target sample.

Among the specific photonics techniques, fluorescence-based ones offer some of the most powerful molecular detection methods available, Gainer said. For optical fluorescence-based sensors, there are classes of nanoparticles that exhibit extremely enhanced photostability in fluorescence emission, enabling new types of sensors to be devised with extremely long operational lifetimes, he noted. He emphasized that other important photonics techniques are suitable for many applications, depending upon the contaminant being detected, the medium it is in, the distance from the sample and other variables.

Use of environmental sensors in places like this water-treatment facility is growing.

Nanotechnology is a principal driving force in the development of every type of sensor, including the class that one would consider photonics-based, Gainer said. A significant amount of research money is being spent on nanotech-based sensing techniques, he noted, as reported in the chapter discussing recent nanotechnology R&D initiatives funded by the Environmental Protection Agency in Washington.

The drive to adopt nanobased methods stems from the fact that, assuming that all else is held constant, the detection limit of a sensor scale approximates the cube of its characteristic length. Real-time detection is a common feature of nanosensing technology and, relative to that, the nanosensors being developed by industry operate in the seconds-to-minutes range, he said.

Sensing air pollution

Photonics-based technologies will be key going forward in the area of air-sensing technologies and the networking of multiple units to measure air pollution at the street level, Gainer said. As an example of networked sensing already in place, he cited the UK-sponsored "Mobile Environmental Sensing System Across a Grid Environment." He also noted that researchers from Siemens Corporate Technology in Munich, Germany, have developed a laser-supported technique for measuring carbon monoxide concentrations, adding that the method is much more reliable than conventional sensors.

"Technological dynamism" was the term used by Gainer to describe developing technology, which ultimately drives what the sensors can do. Detection limits are falling, and sensitivity and specificity of the devices are improving, he said.

The need to acquire reliable scientific data is another driving force in the environmental sensors business, he said. Scientists now require more sophisticated monitoring programs to detect ecological changes that are occurring as a result of climate change. Related to this is the need for monitoring programs that yield data meeting specific scientific standards and quality control procedures.

The development of more large-scale monitoring systems such as remote sensing and satellite-based large-area sensors represents another trend in the sensors business, Gainer said. Mobile environmental systems are being increasingly tested and proposed for urban areas, he noted, adding that such systems can identify and monitor urban air pollution events. Correlations can be made between resulting data and levels of local transport or industrial activity. These "rapid sensor grids" can enable real-time decisions, so as to reduce the impact of poor air quality on people and the environment, he said.

Finally, government spending is propelling the business, Gainer reported. He said government sensor research activity worldwide is significant and was enhanced recently in the US by the 2009 Economic Recovery Act, which provides millions of dollars to government agencies and laboratories for research on environmental monitors and sensors.

Technologies and applications

Among photonics-related sensor technologies, laser-induced incandescence is useful for monitoring vehicular emissions and, for remote sensing of vehicle emissions, UV and IR techniques are commonly used, Gainer said. For monitoring the combustion of fossil fuels, one such technology, a multiparameter fiber optic sensing system, uses an aperiodic sapphire fiber grating as the sensing element.

In the field of agricultural runoff monitoring, optical sensors for use with a visible-light laser excitation beam and a Raman spectroscopy detector can be used to detect chemical groups in an analyte. For industrial and mine waste disposal, an example is the use of optical fiber-mounted porous silicon photonic crystals for remote sensing of environmental toxins and volatile organic compounds. For ocean spills and dumping, IR/UV, microwave radiometers and imaging laser fluorosensors are all workable techniques, Gainer said.

For monitoring climate change, optical spectroscopic methods that can measure trace amounts of a particular atom or molecule, such as oxygen, carbon dioxide or water vapor, are of relevance, he said. In other applications, changes in stress or pressure, such as in water pressure in upstream flash-flood monitors, can be detected by measuring the optical transmission through fiber Bragg gratings.

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Federal Fellowship Program The US Department of Energy's Pacific Northwest National Laboratory based in Richland, Wash., has established the Pacific Northwest Distinguished Postdoctoral Fellowship Program. Currently accepting applications for fall 2009 appointments, the program is open to recent doctoral graduates who desire to work in a range of scientific fields, including chemical and molecular science, biological systems science, and nuclear science and technology.

Represented in Japan Linos AG of Munich, Germany, has signed an agreement with Optical Coatings Japan of Tokyo, under which the latter will represent its partner's range of products and optical solutions throughout Japan. The German company believes that the partnership will increase its customer base in that region.

Un-Acquired The Visualization Sciences Group (VSG) of Mercury Computer Systems, headquartered in Chelmsford, Mass., has become an independent entity once again. VSG was a standalone company prior to the 2004 acquisition of Template Graphics Software by Mercury. The new company will retain its current moniker.

New Testing Standard ASTM International of West Conshohocken, Pa., has created an international standard, G199, to provide a means of electrochemical testing for corrosion. The Guide for Electrochemical Noise Measurement presents a procedure to test for localized and general forms of corrosion, as well as methods for analyzing the resulting data. It is geared toward laboratory-based users.

Sights and Simulators In Camarillo, Calif., Optimum Optical Systems Inc. (OOSI) has received two new contracts. DRS Technologies Inc. of Parsippany, N.J., has awarded the California-based company $3.1 million to deliver the infrared mast-mounted sight from 2010 to 2011, at a rate of five per month, with a possible follow-on order. OOSI has signed a contract with Lockheed Martin Corp. of Bethesda, Md., to supply 12 simulators for its M-1 tanks for $820,000; a follow-on order is also expected.

Sharing the Load A partnership between Labsphere Inc. of North Sutton, N.H., and Orb Optronix Inc. of Kirkland, Wash., will change the development, manufacturing and distribution of products at both light-measurement companies. Select LED test instrumentation from Orb will be manufactured at Labsphere's facility in New Hampshire. The companies will collaborate on the development of broad-range LEDs and will share sales channels.

UK Distribution An exclusive distribution agreement has been signed between Stemmer Imaging of Tongham, UK, and Xenics NV of Leuven, Belgium. Cameras for industrial and systems integration applications, produced by the latter company, will be distributed by Stemmer throughout the UK.

Joining Forces In Birkerød, Denmark, Crystal Fibre A/S and Koheras A/S have merged to form NKT Photonics A/S. The new company will design and manufacture commercial- and industrial-class specialty microstructured fibers and high-power fiber amplifiers as well as fiber-based industrial systems. NKT will continue to produce and support the portfolios of both companies.

CMOS Contract Granted DARPA has awarded an 18-month Phase II contract to HRL Laboratories LLC of Malibu, Calif., for continued work on the COSMOS program. COSMOS, or Compound Semiconductor Materials on Silicon, will focus on improving the yield and density of the heterogeneous interconnect process using the HRL 400-GHz, 250-nm indium phosphide heterojunction bipolar transistor process combined with commercial 130-nm CMOS technology.

European Distribution AMS Technologies AG of Martinsried, Germany, and OEM Tech System Engineering of Minsk, Belarus, a manufacturer of high-voltage power supplies, have signed a distribution agreement. Under the terms of the contract, AMS will sell its partner's products throughout Europe.

Broader Offerings Fibre Photonics Ltd. of Livingston, UK, has signed a commercial agreement that will increase its range of products. The company now will be offering UV/VIS/NIR fiber optic spectrometers and fiber probe technologies from J&M Analytik AG of Munich, Germany. The devices have applications in chemical development and process analysis.

Micromaterials Site Opens Fianium, based in Southampton, UK, has opened a micromaterials processing applications facility in Portland, Ore., in collaboration with Summit Photonics of Lake Oswego, also in Oregon. The site will enable Fianium to work with OEMs to test material samples and to show the processing results possible with its picosecond fiber lasers.

Swapping Resources Oclaro Inc. of San Jose and Newport Corp. of Irvine, both in California, have agreed to a strategic asset swap. Newport will receive Oclaro's New Focus product line in exchange for Newport Spectra-Physics' high-power laser diode business and $3 million cash.

Cameras in Israel In a follow-up to its acquisition of Prosilica Corp., Allied Vision Technologies of Ahrensburg, Germany, has appointed OpteamX of Azor, Israel, as its exclusive distributor in Israel. The latter company has represented Prosilica in that region since 2006.

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The laser-solar connection

BY ANNE L. FISCHER
SENIOR EDITOR

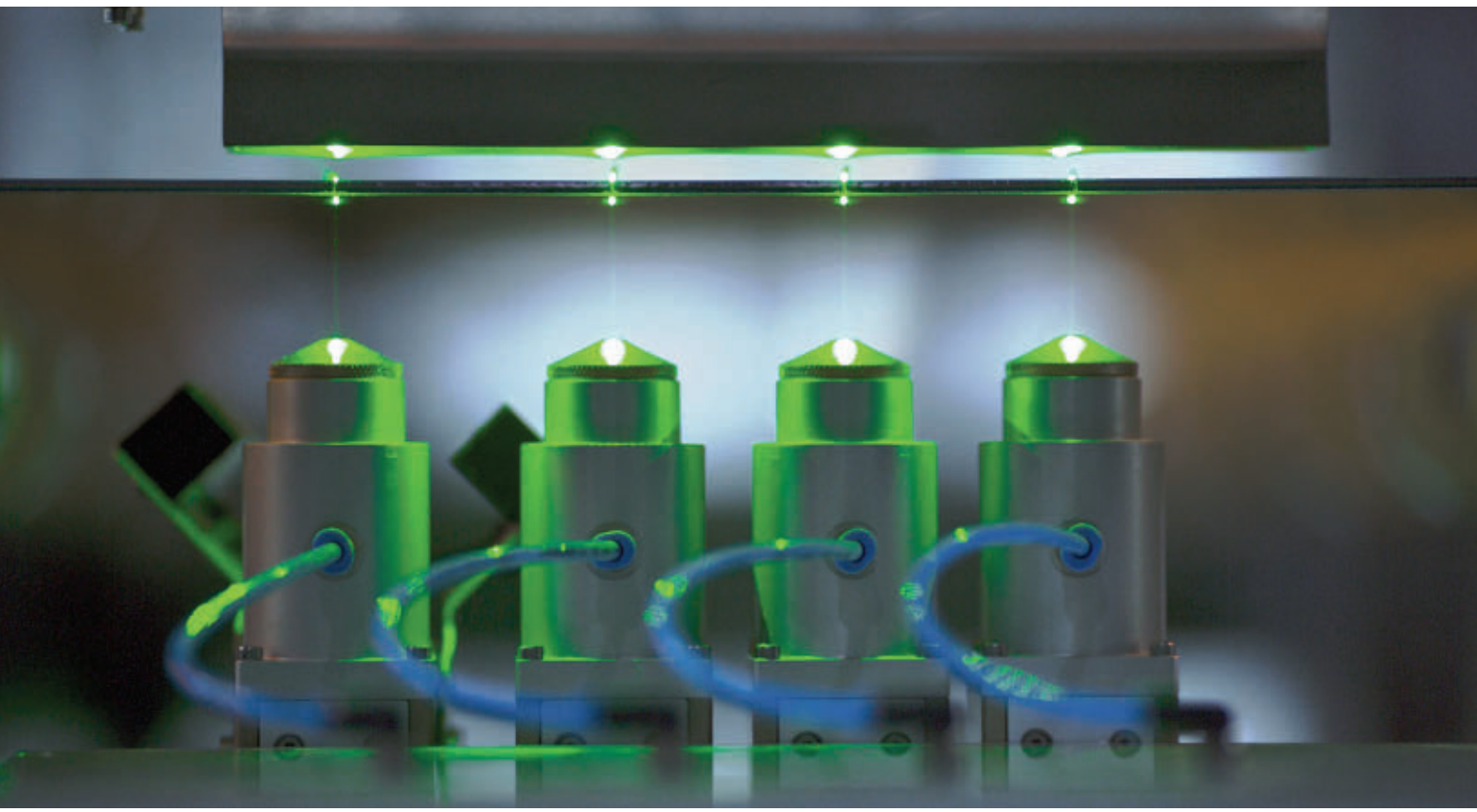
Competition among solar cell manufacturers is rising to new levels as grid parity looms on the horizon. New players are setting up shop for the first time and are implementing state-of-the art production equipment for mass production of high-quality solar cells. Veteran players are expanding and, in some cases, retrofitting existing production lines with newer systems. Not surprisingly, the laser plays a significant role in today's most advanced solar production systems.

Lasers are used by companies that produce crystalline silicon (c-Si)-based as well as thin-film solar cells. However, lasers are more heavily entrenched in the thin-film technology sector, which is newer, whereas the veteran c-Si manufacturers need proof that retrofitting is worth the investment in time and resources. While thin-film technology currently makes up only about 10 percent of solar manufacturing, traditional c-Si panel makers can benefit from lessons learned in adopting lasers for scribing, patterning, etching and more, from not only the thin-film solar industry but also the display industry. For example, Rofin-Sinar Technologies of Plymouth, Mich., and Manz Automation of Reutlingen, Germany, recently announced manufacturing equipment for the thin-film module industry that includes laser edge ablation and laser cutting. The process stems from Manz Automation's experience with handling glass substrates for the LCD industry and now combines laser edge ablation and laser cutting for the thin-film solar industry.

> "The devices meet the cost-of-ownership road map and allow for very precise processing."

Lessons from the thin guys

The thought behind thin film was to develop a method of generating solar power without using expensive silicon wafers. Instead, thin semiconductor layers are deposited on glass, stainless steel or even plastic. The active thin-film layer consists



The Oerlikon LSS 1200 is an automated laser processing system that uses multiple beams for high-speed scribing on a thin-film production line
Photo courtesy of Oerlikon Solar.

of an absorbing semiconductor. This is sandwiched between two thin-film electrode layers, typically a transparent conductive oxide layer on one side of the absorbing semiconductor, which lets the light enter, and on the other side a second transparent conductive oxide layer and back reflector or a reflective metal contact. Semiconductor junctions are formed either as a *p-i-n* device or as a heterojunction. To optimize the module voltage and efficiency, the large panels are segmented into a number of narrow cells across the surface. Lasers are used to scribe isolation lines in the front and back contacts of adjacent cells and to scribe the interconnects through the absorber layer between the cells. The laser patterning processes are performed in between the various coating steps so that the cells are connected in series across the module.

For thin-film photovoltaic manufacturing, Oerlikon Solar of Truebbach, Switzerland, supplies production equipment and end-to-end production lines that incorporate solid-state lasers for module patterning. According to Heather Booth, head of the laser product group at Oerlikon Solar, "Laser tools are the proven industrial standard, and laser patterning is the de facto method for fine-scribing in thin-film silicon." The primary reasons that Oerlikon uses lasers in its production lines, Booth explained, are that the devices meet the cost-of-ownership road map and allow for very precise processing. A huge advantage in thin-film processing is "the high throughput that's achieved whilst maintaining a very narrow scribe region. This minimizes the area that scribes take on the panel, optimizing the module efficiency," she added.

The lasing advantage

One way that lasers are advantageous in the thin-film process is that coatings can be annealed onto glass without having to be baked in an oven. Instead the coating is applied to the glass, and a laser beam sweeps over it. The glass doesn't have to go through a cooling process and can be handled soon after the annealing process is complete. Advanced Solar Photonics of Lake Mary, Fla., a solar manufacturer that uses lasers in several areas of its production process, has found that its laser annealing process improves both the efficiency of light transmission and the conductivity of the transparent conductive oxide layers by up to 35 percent.

With many laser-based processes being evaluated within R&D or pilot production lines, manual wafer handling is often performed during tool qualification prior to automated production integration. Photo courtesy of Coherent.

Short-wavelength green and UV laser solutions commonly have been used for edge isolation in c-Si manufacturing. Now they are starting to be used for scribing trenches, ablating dielectric layers and for drilling through silicon for wrap-through cells. According to Finlay Colville, director of marketing at Santa Clara, Calif.-based Coherent, just as nanosecond UV and green lasers typically were used in the semiconductor and flat panel display industries, now short-wavelength, short-picosecond diode-pumped solid-state lasers are finding a home in both silicon and thin-film solar manufacturing.

Lasers in solar manufacturing are competing with established processes such as plasma etching, screen printing, mechanical cutting and more. In the thin-film industry, Colville said that laser scribing is already a standard because "it's the only method that can do fine-scribing in a non-contact manner." Colville acknowledged that the big challenge for laser manufacturers is to show improved return on investment by demonstrating high throughput, better tool uptime, low operating cost, fast wafer processing and more. As the solar road map leads the way to increased efficiency, laser techniques will play an increasingly significant role in both silicon and thin-film solar cell manufacturing.

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Hot Spots for Solar

Germany, Germany, Germany. It seems as if all anyone talks about in terms of the hottest place for solar is Germany. But others are turning up the heat, creating hot spots in Asia and the US as well.

According to the "Europe's Solar Market: Is the Outlook Still Sunny?" report released in May by London-based Frost & Sullivan, it takes research, manufacturing and government support to make a well-rounded industry. And, according to Alina Bakhareva, program manager of renewable energies at Frost & Sullivan and author of the report, much is happening around the world in each of these areas.

Research

Lowering the cost and increasing the performance of solar cells are keeping researchers everywhere busy as they look for new sources of energy (See "Solar research marches on," *Photonics Spectra*, May 2009, p. 40.). There is an increasing focus on reducing cost and improving efficiency for cells and modules as well as on making manufacturing methods more efficient. Although the report focuses primarily on the European solar industry and lists Germany, the Netherlands, France, Italy and Switzerland as leaders in solar research, Bakhareva said she would add China and the US to a list of global research leaders.

Manufacturing

It used to be that solar cells and modules came from European and Japanese manufacturers, but now, Chinese and Taiwanese cell producers have achieved a market share of more than 40 percent, moving them into the top 10 spot. What sets many European manufacturers apart is that they have been at it long enough to be virtually fully integrated. They own – or have – long-term supplier/buyer agreements for everything from raw materials through finished solar systems (For more on integra-

Solar in India

The government of India recently announced its National Solar Mission, which calls for 20 GW installed by 2020, 100 GW by 2030 and 200 GW by 2050. This in a country that currently has only 3 MW of solar capacity in place.

Ramping up will require government funding – $18 million to $22 million has been set aside for the project – and a carefully executed plan that calls for implementation in three phases.

The first phase, deployment, will take place through 2012, with the goal of installing 100 MW by promoting utility-scale projects and mandated rooftop installations on government and public buildings.

The second phase, which will be completed by 2017, will promote solar thermal power plants, and the third will culminate in 2020, by which time the government hopes to have achieved grid parity and to have solar systems installed on 1 million rooftops.

Ramping up solar in India is one way to bring dependable electricity and lighting to areas that have gone without or that have suffered with intermittent power (See "Lighting up lives," *Photonics Spectra*, July 2009, p. 39.).

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Top 10 Solar Cell Producers

Company	Home Country	Production, 2008 MWp	Production Capacity, 2008 MWp	Planned Production Capacity, 2010 MWp
Q-Cells	Germany	574	840	1270
First Solar	USA	504	716	1186
Suntech Power	China	498	1000	1350
Sharp	Japan	473	870	1710
JA Solar	China	277	500	775
Kyocera	Japan	290	300	Double capacity by 2012
Yingli Green Energy	China	282	400	600
Motech Solar	Taiwan	272	450	600
SunPower	USA	237	414	1054
Sanyo	Japan	215	340	600

Notes:
1. For Q-Cells sales, €/US$ exchange rate of 1.47 was used as an average for 2008.
2. For Sharp sales, yen/US$ exchange rate of 0.0097 was used as an average for 2008.
3. For Motech Solar sales, NTD/US$ exchange rate of 0.0317 was used as an average for 2008.
4. Kyocera and Sanyo do not report sales for their solar business units separately.
5. MWp=megawatt peak.

Only one German solar manufacturer is listed in the top 10 globally, while Asian solar manufacturers are proliferating. All plan to expand production rapidly in the next year. Source: Frost & Sullivan.

tion, see "Don't give up on solar," *Photonics Spectra*, May 2009, p. 35.).

Another trend is that well-established European and US players, such as Q-Cells SE of Bitterfeld-Wolfen, Germany, and REC Solar of San Luis Obispo, Calif., are setting up shop in Asia, and with good reason: Governments are offering incentives such as tax holidays and low-interest loans.

Government support

Government support dating back to the early 1990s got Germany to the top of the solar charts, and recent US support for renewables is pushing the US solar industry up the list as well. Government support absolutely correlates to installed projects, according to Bakhareva, who noted that, "Whenever we see new support programs introduced, we see a surge in the market. In 2008, we saw the market in Spain surge as it installed more systems than any other country, and we are seeing the same trend in Italy and Greece, despite administrative hurdles."

One Asian government luring manufacturers with tax holidays and loans is Malaysia. Bakhareva said she is amazed at the number of plants being erected there. Q-Cells, for instance, is constructing a solar cell manufacturing facility and plans to have an overall capacity of 300 MW by the end of this year. India also is granting tax holidays and low-interest loans.

Government support also extends to the end user, which could be the business or homeowner who invests in solar. Programs of this type include feed tariffs, grants and accelerated depreciation.

Changes ahead

Because the global economy remains shaky, solar likely will see a dip in residential and retail installations. Large-scale projects, however, will move ahead, the report contends, with institutional investors showing interest in the solar photovoltaics market.

The greatest change that has taken place is the globalization of the market. Economies of scale now are coming into play, and low-cost manufacturing in Asian countries is closer to becoming a reality. The potential for both consolidation and production outsourcing seems likely for the future; however, about 50 percent of the market currently is controlled by just 10 cell manufacturers.

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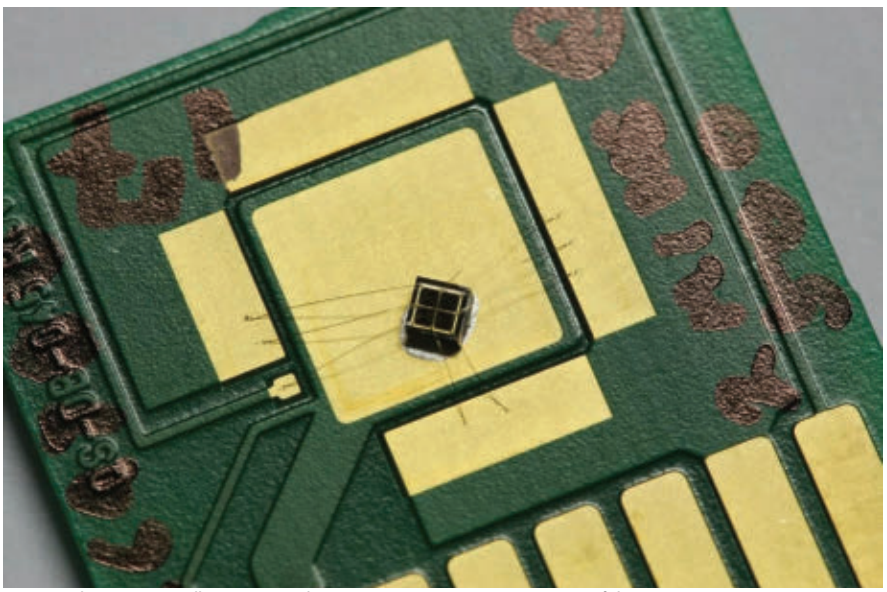
Quantum wells boost solar efficiency



Quantasol's 1.2-mm^2 cell was exposed to 2000-sun concentration as part of the test.

Another solar record has been set, and, once again, a unique design is involved.

QuantaSol Ltd. of Surrey, UK, recently announced a record efficiency of 28.3 percent for a single-junction solar cell aimed at use in concentrating photovoltaic systems. What sets this design apart is the use of quantum well structures within the solar cell.

The design uses gallium arsenide phosphide (GaAsP) for the barriers, which, according to its developer Keith Barnham, has a smaller lattice constant; the wells are indium gallium arsenide (InGaAs). Barnham, also the founder of QuantaSol, explained that the combination "balances the strain between the well and the barrier," adding that putting enough wells in a cell increases absorption.

"The great thing is that, while this trick works with single junctions, it works even better in tandem and triple-junction cells," Barnham reported. What is most important is the tunability, he said. When electricity is generated from a series of cells, the current usually is derived from the worst-performing cell. By adding quantum wells, the absorption can be tuned to optimize the tandem cell to produce at the highest efficiency, a capability that can be extended to location or time of day, deriving "not just high efficiency, but the best energy yield."

"The great thing is that, while this trick works with single junctions, it works even better in tandem and triple-junction cells."

The ability to adjust each subcell for the optimum bandgap for a given spectrum is extremely important for concentrating photovoltaics because, as Barnham pointed out, a concentrating system is mostly lenses or mirrors. "You have to move the whole module to keep the sun on the cell." By tuning the bandgap, the system can be optimized for the best energy harvest in a specific location over an entire year.

The team is working on developing a multijunction cell and expects to have samples in the first quarter of 2010 and volume production by the end of that year. Prices are expected to be very competitive, according to Kevin Arthur, chief executive officer.

"The business model we have with foundries has convinced us," he said.

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Scanning the clouds

Computed tomography (CT) commonly is used to take x-ray images of the human body, but researchers recently employed the technique to scan clouds, creating three-dimensional maps from the data for use in climate change studies and weather forecasting.

The research is being conducted by scientists from the US Department of Energy (DoE) 's Brookhaven and Argonne national laboratories in Upton, N.Y., and Illinois, respectively, and from the University of Colorado at Boulder.

Researchers traditionally use microwave radiometers to observe clouds, but because clouds form, take shape and dissipate at varying spatial scales – from submicrons to thousands of kilometers – in situ cloud probes cannot provide the necessary information at the required spatial scale or resolution.

Atmospheric scientist Dong Huang of Brookhaven, the lead investigator, explained that there are mainly two categories of cloud measurement techniques: in situ, where probes, either radiometric or hot-wire, are placed in clouds, and remote sensing. Although in situ observations are expensive and can sample only a small volume, they provide more direct measurements; remote sensing techniques are less direct and usually involve complicated mathematical problems.

For the CT project, five sensors placed one mile apart along a north-south line at the DoE's Atmospheric Radiation Measurement Climate Research Facility (ACRF) in Ponca City, Okla., continuously scanned a flat vertical plane. The instruments included three commercial WVR 1100 radiometers from Radiometrics Corp. of Boulder and two polarimetric scanning radiometers developed by the University of Colorado. One sensor at each of the five locations scanned without human intervention, Huang said.

The scientists gathered data on the cloud's thermal emission – tracked as the cloud changed – enabling them to piece together a map of the cloud's structure. This is important, Huang said, because clouds previously were assumed to be homogeneous. "Now, with 3-D cloud maps, we can calculate the radiation reaching the Earth's surface much more accurately." He said the information will be useful in understanding precipitation processes, which will help improve climate and weather forecasting models.

The data gathering is simple and straightforward. The real challenge lies in constructing the cloud structure from radiometric measurements, Huang said. Very complex mathematical problems must be resolved to turn the data taken from a "limited view cloud tomography problem" into a 3-D map

The scientists plan to validate the quality of the cloud and moisture reconstruction by comparing it with data currently being collected from another study, this one by Brookhaven scientists. In the latter, investigators are collecting long-term data on low-optical-depth clouds using an in situ instrument suite designed for routine observations of cloud properties. The suite includes cloud microphysics, radiation, aerosol and meteorology instruments. The probes related to the cloud tomography study are cloud liquid water and water vapor instruments from Gerber Scientific Inc. of South Windsor, Conn.

The CT scan project was conducted from May to July 2009, after which the data will be available to the public through the Atmospheric Radiation Measurement Program.

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Three microwave radiometers at the US Department of Energy's ACRF Southern Great Plains site and another two from the University of Colorado at Boulder were arranged in series to continuously scan clouds passing overhead. The data collected will be used to reconstruct 3-D cloud maps. Courtesy of the US Department of Energy's Atmospheric Radiation Measurement Program.

All the Energy You Need . . . from Tiny Leaves

Power generation from artificial photosynthesis is a green dream beginning to grow tall.

BY LYNN SAVAGE
FEATURES EDITOR

On a warm summer afternoon, you may find yourself on a leisurely walk through bucolic meadows or toiling under the glare of the sun because the lawn just won't mow itself, but why not let the grass do some work and earn its keep?

Grass, as does all green plant life, gets the energy it needs to thrive and reproduce by using sunlight to convert chlorophyll, carbon dioxide and water into sugar (giving off oxygen as a by-product). Ever since this light-driven mechanism was first elucidated, scientists and engineers have wondered about the possibility of replicating it to power homes, cars or gadgets.

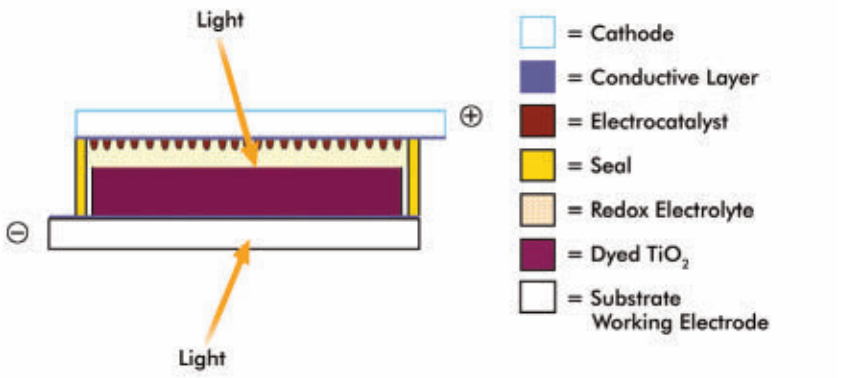
Finding out what makes plants tick was one thing, but redesigning the process using man-made materials has not been easy. Furthermore, the hoped-for result isn't food at all but rather hydrogen fuel or electrons that can be either channeled into a storage battery or used to power a device directly. No matter which approach is taken, the name of the game is "artificial photosynthesis."

According to Hans Desilvestro, chief scientist at Dyesol in Queanbeyan, Australia, the Earth receives nearly 100,000 times more energy from the sun than is required worldwide every year. In the US, energy consumption is currently 15 to 25 TW annually, but even as that figure rises to 45 to 50 TW by century's end, it pales next to the 2200 TW available from solar.

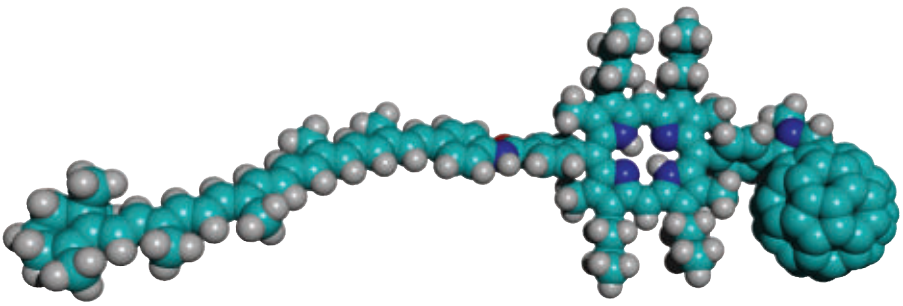
The most common approach to achieve artificial photosynthesis – and the one taken by Dyesol – is to develop a photoreactive dye that takes the place of chlorophyll. As with the natural material it tries to mimic, the dye must include molecules that capture photons, then transfer the electrons kicked loose by the light's energy. It is not enough to duplicate the solar conversion ability of chlorophyll, however; plants convert only a fraction of the energy provided by the sun that people would need.

Dyesol's efforts are toward the development of a solar cell whose main constituents are titanium dioxide, a photoactive chlorophyll analogue and an iodide-based reduction-oxidation (redox) compound.

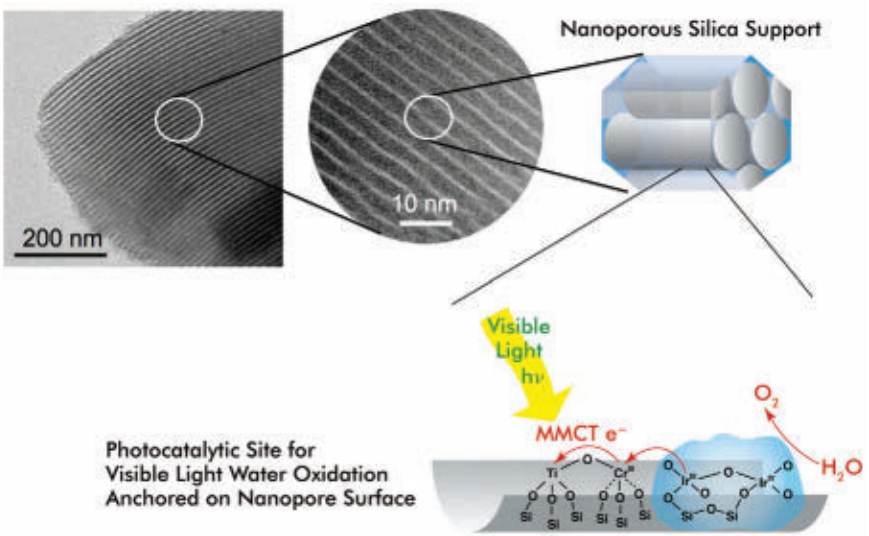
The basic Dyesol cell structure starts with a working electrode made of a substrate coated with a <20-µm film of nanoparticulate TiO_2. Atop this base lies a single-molecule layer of a photoactive dye such as a ruthenium-based compound, followed by a sealant gasket and a redox electrolyte layer containing iodide and triiodide. The cell is completed with a counterelectrode made of a conductive substrate coated with a thin layer of catalyst material. Desilvestro said that the substrates may be made of conductive glass, plastic or metal foil, although at least one must be transparent. Light entering



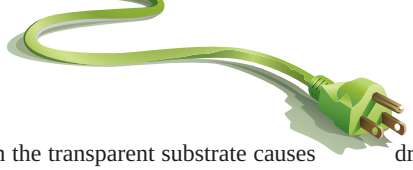
A schematic diagram of a dye-sensitized solar cell highlights the key components. Courtesy of Dyesol.



One of the most challenging hurdles in artificial photosynthesis is the formation of molecular reaction centers – constructs that replicate the plant enzymes that capture sunlight and use its energy to create fuel for the plant. Courtesy of Devens Gust, Arizona State University.



Artificial photosynthesis depends on efficient charge separation and transport to get the most value from solar photons. Besides effective chlorophyll substitutes, a photosynthetic system must employ a substrate material that helps capture and shuttle light. At Lawrence Berkeley National Laboratory, specialized light absorbers act as visible-light electron pumps for driving water oxidation or CO_2 reduction. Three-dimensional nanoporous supports arrange the photocatalytic units. Courtesy of Heinz Frei.



through the transparent substrate causes charge separation in the electrolyte, and that charge is then collected, stored and applied to power a device.

Dyesol uses a nanoporous form of TiO_2 for two reasons: First, the scale and porosity of the material improve its light-gathering ability; second, the material can be painted onto the substrate or even screen-printed to create decorative designs.

Ultimately, the company sees so-called dye-sensitized panels as overtaking even photovoltaic solar technology.

"It takes three to four years in sunny climates – eight years or longer in areas such as Germany or northern Europe – for a traditional photovoltaic panel to produce the amount of energy which went into its production," Desilvestro said. "The corresponding energy payback period for dye-sensitized panels is only two to six months under the same conditions."

Splitting water

Energetically beating electrons out of a chlorophyll substitute is not the only way to think of artificial photosynthesis. The other major research approach is to use the sun's energy to separate water into its hydrogen and oxygen components. The hydrogen, kept in its ionic form, would then be collected for use in fuel cells or similar power-generating technology.

Scientists at the Tempe campus of Arizona State University's newly minted Energy Frontier Research Center for Bio-Inspired Solar Fuel Production are working on the hydrogen fuel approach.

"[Artificial photosynthesis] incorporates the basic science of photosynthesis into technological systems that will be optimized to produce energy in forms useful to humans," said Devens Gust, a chemistry professor and director of the solar fuel research center.

A key concept being addressed by Gust and his colleagues is the re-creation of the reaction centers in photosynthesizing plants – the molecules that convert light energy into chemical energy. And, again, replication is not enough; man-made reaction centers must improve on the original.

Gust said that most of the sunlight used in natural photosynthesis is not absorbed by a plant's reaction centers; rather, the light is gathered by simpler molecular "antennas" that then send the excitation energy to the reaction centers. Furthermore, the antennas help regulate the photosynthetic process and prevent damage from too much light.

Plant life requires fuel, but far less than people and their electrical appliances. Natural photosynthesis converts light into energy at a fraction of a percent efficiency. Researchers are aiming at 10 percent efficiency as a start. To achieve a higher rate, Gust and his associates Thomas A. and Ana L. Moore are testing a number of potential biomimetic candidates, including carotenoids, which are readily available organic pigments.

Out of the blue

Another potential candidate for helping the artificial photosynthesis process is cobalt. At Lawrence Berkeley National Laboratory in California, Heinz Frei and his colleague Feng Jiao found that nanometer-scale crystals of cobalt oxide (Co_3O_4) efficiently separate oxygen from water molecules.

Plants use manganese-infused enzymes to catalyze the water-splitting process, but Frei's group wanted a material that also was water-soluble. Iridium was a strong option, but it is very rare and thus too ex-

pensive for large-scale use. Cobalt also was a candidate, but the researchers first tried micron-scale, which turned out to be too inefficient and slow to react to light. However, when they used nanoscale Co_3O_4 crystals, efficiency spiked by 1600 percent. The best performers were 8 × 50-nm cobalt clusters.

An ANSER to the question

Increasing the efficiency of solar conversion is the overwhelming theme to artificial photosynthesis projects across the globe. The drive for more power per photon is driving collaborative efforts as well, such as ANSER, the Argonne-Northwestern Solar Energy Research Center.

ANSER combines the efforts of scientists at Northwestern University and at Argonne National Laboratory, both in Illinois, as well as at Yale University, at the University of Illinois at Urbana-Champaign and at the University of Chicago. Its impetus is to explore solar power as a means to provide clean sources of energy to fulfill a growing demand.

"We hope that the fundamental science and technology that we are currently developing will result in widespread use of cheap solar-driven energy technologies based on artificial photosynthesis," said Michael R. Wasielewski, chemistry professor at Northwestern and director of ANSER. "The turning point will occur when these technologies are 10 percent efficient at price points that are below today's energy supply costs from competitive technologies."

Investigators affiliated with ANSER are looking into both direct generation of electricity and production of hydrogen or other fuels using artificial photosynthetic methods. As with similar programs from Europe to Australia, the main mission is to find the right sustainable, easy-to-build structures that at first mimic, then improve upon, the way greensward has fueled itself for millennia.

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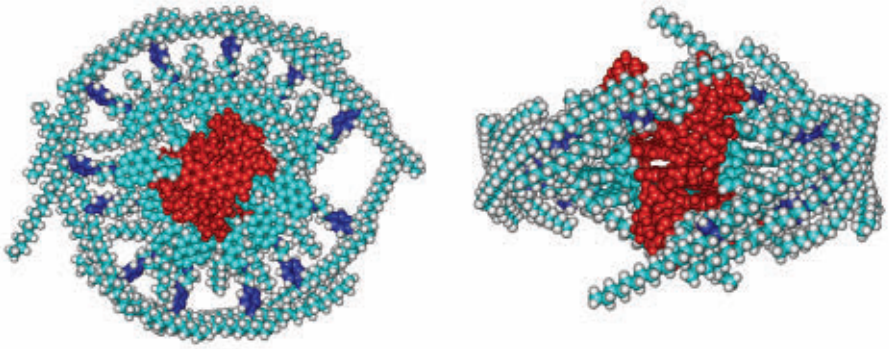
Self-Assembled Structure for Photodriven Charge Transport



Self-assembling electron donor-acceptor building blocks form protein-size charge-transport systems that could be used to create artificial photosynthesis systems for fuel or flexible organic solar cells. Courtesy of Michael Wasielewski, Northwestern University.

Precision Laser Diode Current Source and Temperature Controller

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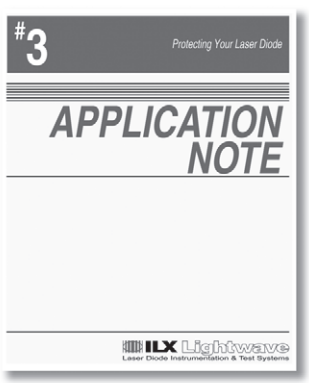

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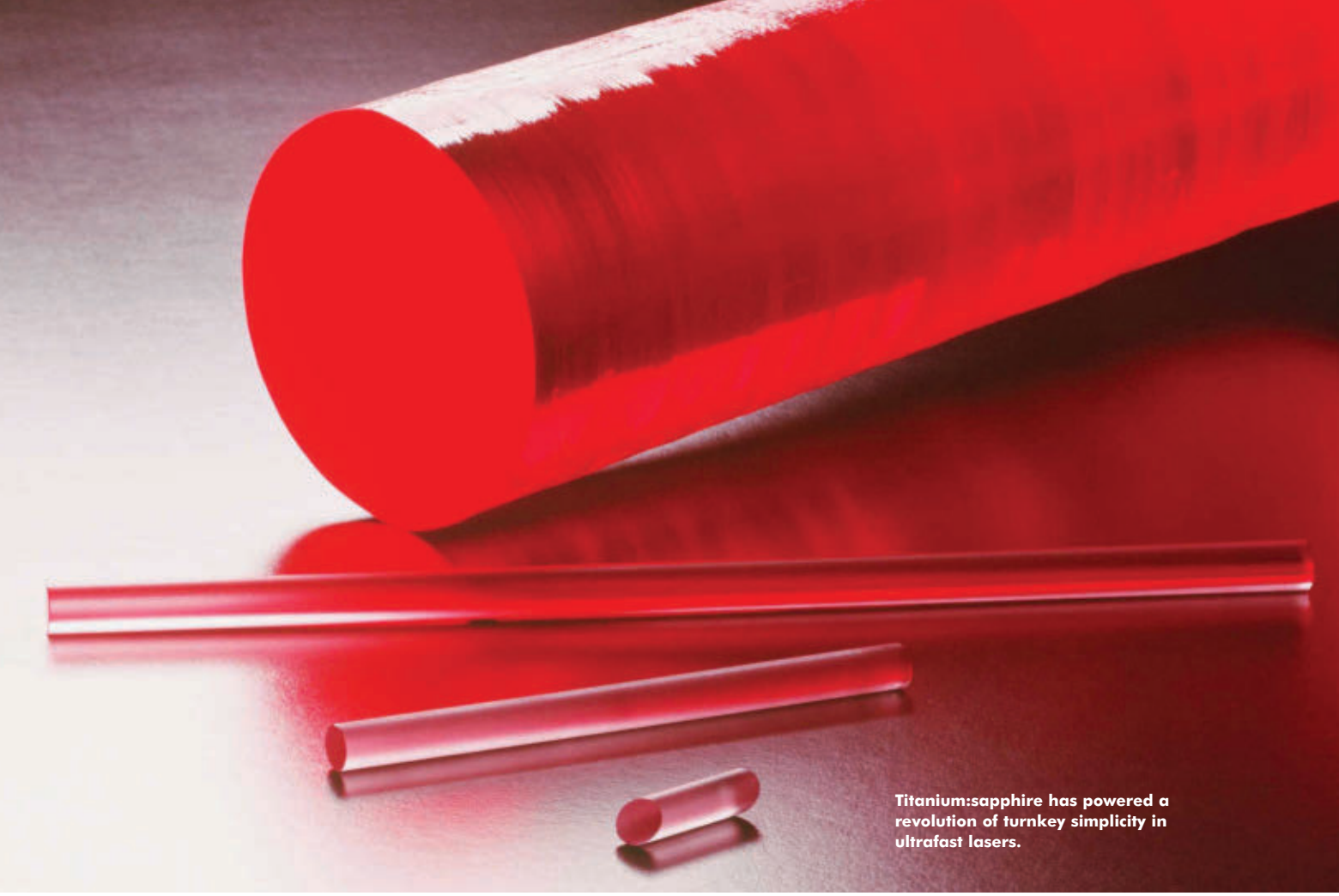


Titanium:sapphire has powered a revolution of turnkey simplicity in ultrafast lasers.

The *Devil* Is in the Details

Careful control of fabrication steps is key to superior performance from the ubiquitous ultrafast laser material, titanium:sapphire.

BY KEITH HEIKKINEN AND MARK ANDERSON,
SAINT-GOBAIN CRYSTALS

Ultrafast lasers – with femtosecond or picosecond pulse widths – support a growing range of applications, from precision micromachining to multiphoton imaging to attosecond physics. Titanium:sapphire is the most widely used gain material in ultrafast lasers, but optimizing its crystals presents significant technical obstacles.

Although Ti:sapphire's wide gain bandwidth of approximately 650 to 1100 nm makes it ideal for both tunable laser output and mode-locked laser operation in the femtosecond pulse width regime, its potential drawbacks must be overcome.

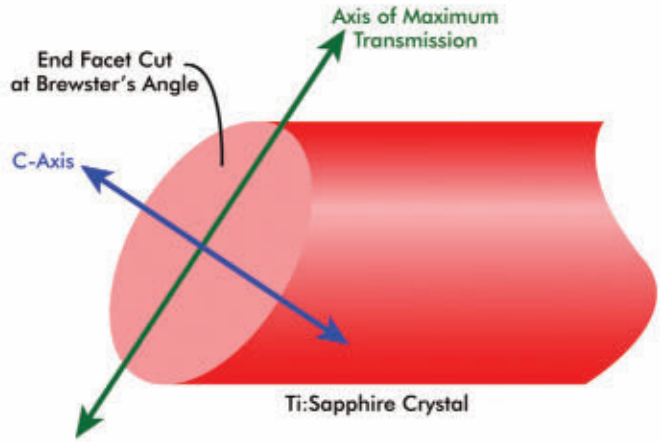
First, it is a vibronic emission system with a 3.2-ms upper-state lifetime, leading to low gain. From a laser designer's viewpoint, this low gain necessitates pumping with a high-intensity green laser source and using cavity optics with minimum loss, such as double-chirped broadband cavity mirrors.

For crystal manufacturers, the inherently low gain must be maximized in every way possible. The three most important aspects are the figure of merit equation, the titanium-ion concentration and the orientation of the crystal and lasing axes.

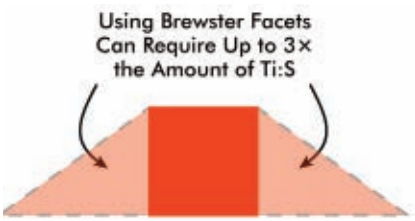
From an OEM vendor's viewpoint, product uniformity is key.

The figure of merit is defined as the ratio of the absorbance at the pump wavelength – 532 nm – to the reabsorption at the peak emission wavelength of 800 nm. Laser emission is due to Ti^{3+} ions, but the presence of oxygen in the sapphire matrix causes a small amount of the Ti^{3+} to be oxidized to Ti^{4+}. This higher valence state is responsible for parasitic reabsorption, so a low Ti^{4+} concentration is important to a high figure of merit and to higher gain.

Ti:sapphire is grown by slowly drawing a cylindrical boule vertically from a hot liquid melt of titanium and aluminum oxides. Although some manufacturers attempt to use very tight control of the boule drawing conditions to minimize the amount of Ti^{4+}, Saint-Gobain Crystals of Hiram, Ohio, has found it more effective to use a patented annealing process incorporating a hydrogen-rich atmosphere to reduce virtually all of the rogue Ti^{4+} to Ti^{3+}.



Because of the low gain of Ti:sapphire, it is vital to create Brewster facets with their transmission plane – e-vector – perpendicular to the C-axis of the Ti:sapphire crystal.



To spread the power in Ti:sapphire amplifiers, the Ti:sapphire must have a large aperture-to-length ratio. Facets are cut at just off normal incidence. Brewster's angle facets would require wasting a huge amount of material.

The advantages of this approach are that it allows the boule growth conditions and figure of merit to be independently optimized, provides active control over the figure of merit and leads to uniformity throughout the boule, enabling a large number of highly consistent rods from a single boule for OEMs. Most important, however, is that the method consistently delivers high figure of merit values, typically anywhere in the 300- to 500-nm range.

Increasing total titanium-ion concentration raises gain but also increases lattice defects and makes the lattice physically weaker. At ion concentrations above 0.3 percent, these problems cause yields to drop precipitously, specifically because of cracking caused by thermal gradients and stresses during the boule growing process. Also, pushing to higher ion concentrations results in a vertical concentration gradient, which can significantly lower the useful yield, thus raising the cost while lowering the product quality for longer crystals cut from such a boule.

Early Ti:sapphire lasers used ion concentrations in the 0.1 to 0.15 percent range. Today the demands of smaller oscillators and ultrashort amplifiers have driven Ti:sapphire fabricators to push the concentration to 0.2 and even 0.25 percent.

Optical axis alignment

Losses are minimized in ultrafast oscillators by cutting the Ti:sapphire crystal with end facets at Brewster's angle. However, sapphire is a hexagonal crystal favoring lasing action with the electric field vector perpendicular to the C-axis. So it is very important to cut the Brewster windows at the correct orientation. In a worst-case scenario, if the C-axis is aligned parallel to the Brewster window transmission plane, the crystal acts as a self cross-polarizer, preventing lasing.

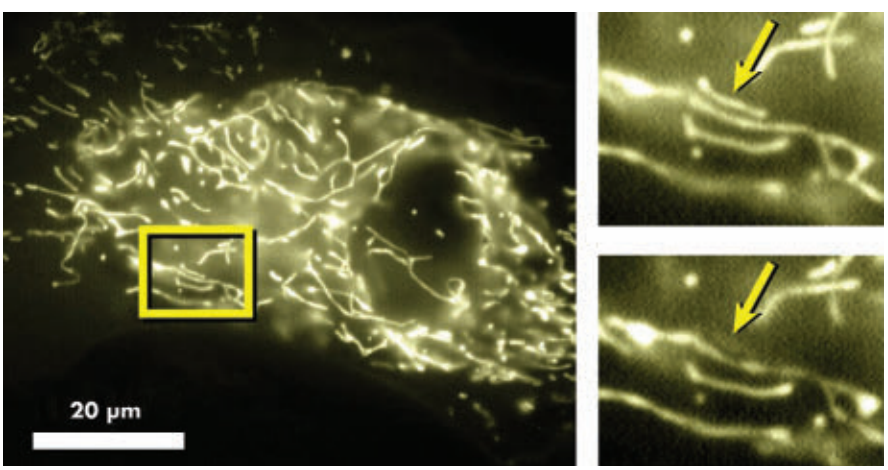
Fortunately, as the boule is drawn from the hot melt, the C-axis is naturally oriented perpendicular to the drawing axis. And because the cylindrical laser rods are cut parallel to this axis to maximize yield, the C-axis is automatically in the correct plane. But this still leaves the issue of rotation of that plane. Saint-Gobain uses x-ray crystallography for this purpose. Specifically, each rod is rigidly mounted in a special jig and placed in an x-ray machine. The diffraction pattern then registers the precise orientation of the C-axis relative to the mounting jig, which is rotated to the correct angle in the Brewster grinding/polishing station. As a result, the tolerance for this relative alignment in the finished laser rod is within 30 min.

Meeting laser trends

Commercial Ti:sapphire lasers fall into two categories: oscillators and amplifiers. Oscillators operate at repetition rates up to 100 MHz, with pulse energies at the nanojoule level. The pulses often are amplified in either a regenerative or multipass amplifier, with repetition rates at the kilohertz level and pulse energies up to the millijoule level. Not surprisingly, oscillators and amplifiers need Ti:sapphire crystals prepared in two distinct ways.

To support the low gain operation in an oscillator and provide superior mode performance, Ti:sapphire rods are supplied as thin cylinders or rhomboids. Losses are minimized by cutting the cylinder ends at Brewster's angle.

For amplifiers, a larger beam cross section is necessary to physically spread the power and avoid damage to the amplifier components. Commercial amplifiers with crystals as wide as 30 mm are not unusual and typically are supplied with facets cut just off normal incidence, rather than at Brewster's angle. The reason is that, with a large clear aperture relative to the crystal length, cutting the ends at Brewster's angle would dramatically increase overall crystal volume and, hence, price. Instead,



Femtosecond pulses from a Ti:sapphire laser can be used to remove a single mitochondrion with no damage to nearby structures such as other mitochondria. Courtesy of Mazur Group, Harvard University.

the facets are coated with an antireflection coating. Manufacturers usually offer a broadband coating to support standard pulse lengths – e.g., up to 200 fs – with wide wavelength tunability, and a coating usually optimized at 800 nm, which supports compressed pulse durations as short as 10 fs.

An exciting new market trend is smaller oscillators with crystals as short as 3 mm and with a clear aperture as small as 1 mm. The oscillators' lower power makes maximizing gain and minimizing lasing threshold particularly critical. The crystals usually are supplied with a square cross section, simplifying mounting and providing a better surface contact for cooling through the mount.

Enabling diverse applications

Applications for ultrafast lasers have expanded in recent years because of the advent of turnkey, highly integrated Ti:sapphire systems. For example, ultrafast oscillators are now widely used for multiphoton excitation methods in microscopy. They produce diffraction-limited, three-dimensional images, enabling biologists to use markers such as green fluorescent protein and long-wavelength recombinant DNA tools such as m-cherry to study expression of a wide variety of genes. These techniques allow the investigation of key processes such as morphogenesis, the study of how physical feedback controls the expression of regulatory genes, producing embryonic features of the correct spatial characteristics.

The ability to drive multiphoton processes also enables amplified ultrafast systems to perform cold-ablative micromachining with unprecedented precision and 3-D control, including *within* relatively transparent substrates, such as glass, to create microfluidic tools, and to pattern thin films for the electronics and display industries. Ultrafast lasers also are used to cut the cornea in the "all-laser" version of lasik surgery.

In a technique that combines 3-D imaging and machining, life scientists are using ultrafast lasers to perform microsurgery and visualize sequelae; e.g., the deliberate damaging of tiny blood vessels in rat brains to artificially create an ischemic stroke. And at even higher resolution, scientists are using the same technique to destroy individual genes or subcellular organelles in developing cells.

Other applications include generating short-wavelength, or x-ray, pulses, producing and detecting terahertz radiation for imaging applications such as security and screening, for experiments in attosecond physics and for generating highly accelerated subatomic particles. One goal of the latter process is to produce an affordable proton beam that oncologists could use to provide improved spatial selectivity in the radiation treatment of tumors.

Ultrafast applications have grown because laser manufacturers have packaged this sophisticated technology in a way that makes it readily accessible to end users, many of whom are not laser experts. In turn, laser crystal fabricators have supported the growth with products that deliver performance optimized for specific uses, greater reliability and reduced cost.

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new Shine on old Gems

Trivalent chromium-doped LIGO/LISO offers the widest lasing bandwidth in the telecommunications windows.

BY MIKHAIL SHARONOV, ALEXEY BYKOV AND ROBERT R. ALFANO
INSTITUTE FOR ULTRAFAST SPECTROSCOPY AND LASERS, CITY COLLEGE OF THE CITY UNIVERSITY OF NEW YORK

Newly developed Cr^{3+} laser crystals called LIGO and LISO, developed at the Institute for Ultrafast Spectroscopy and Lasers (IUSL) at City College of the City University of New York, extend the family of ruby and alexandrite lasers operating in the near-infrared from 1150 to 1620 nm for possible 6-fs-pulse-generation and telecommunications applications.

Combined with Ti:sapphire crystals, pulses as short as approximately 2 fs could be produced. In addition, the broad spectral operation of these materials is suitable for generating 6-fs-pulse optical coherence tomography, condensed matter physics, and biological and chemical time-resolved applications. Using supercontinuum generation and pulse compression could result even in the attosecond regime.

The 470-nm range of operation of LIGO and LISO slightly surpasses the "king" of broadband lasers – the Ti:sapphire (650 to 1100 nm) – and perfectly complements its range in the near-infrared.

Trivalent chromium laser operation was first demonstrated with the ruby (Cr^{3+}:Al_2O_3) laser by T.H. Maiman in 1960. The ruby operates at a fixed and narrow wavelength of 694.3 nm. In 1963, a broadband tunable laser was demonstrated in Ni^{2+}:CaF_2 at cryogenic temperatures by Johnson et al. Several other transition metal-doped crystal lasers operating at low temperatures followed in the mid-1960s but did not attract much interest because of the necessity for cryogenic cooling. The development of broadband lasers eventually shifted from doped crystals to dyes and color-center laser media in the 1970s and 1980s.

Research on transition metal-doped tunable lasers exploded in 1980 after Walling et al demonstrated tunable lasers operating in the 700- to 820-nm range at room temperature in trivalent chromium-doped Cr^{3+}:$BeAl_2O_4$ (alexandrite) crystals (Figure 1). Since then, hundreds of Cr^{3+}-doped crystals have been studied and tens of Cr^{3+}-doped laser crystals have been developed operating in the deep red.

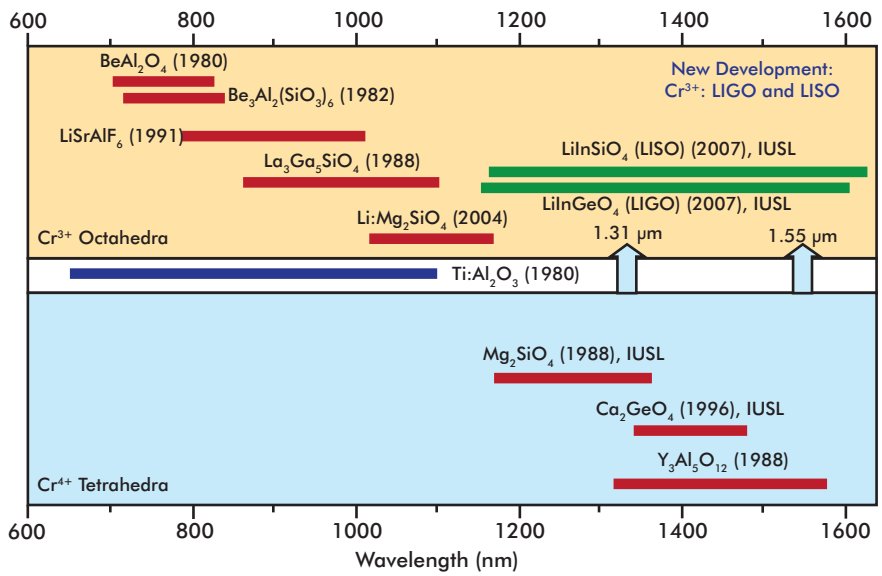

Figure 1. Shown is the range of tunability of some chromium-doped lasers. Trivalent chromium centers in octahedral sites are shown at the top, and tetravalent chromium centers in tetrahedral sites at the bottom. Distortion of octahedral sites moves lasing in novel Cr^{3+}:LIGO and Cr^{3+}:LISO crystals into the indispensable range for numerous applications, the near-infrared range of the spectrum being at the same time the widest of both trivalent and tetravalent chromium lasers. The range of the Ti:sapphire laser is shown in dark blue. Major telecommunication windows at 1.31 and 1.55 μm are depicted by gray arrows.

Cr^{3+} occupies octahedral sites – oxygen ions – in the crystal lattice. The range of tunability of trivalent chromium-doped crystals previously did not extend beyond 1.1 μm because of the relatively strong crystal field of octahedral sites.

Early advances

Near-infrared room-temperature tunable laser operation spanning 1150 to 1300 nm was obtained in chromium-doped Mg_2SiO_4 (forsterite) crystals in 1989 at IUSL. In forsterite crystals, chromium is in the tetravalent state, Cr^{4+}, and occupies tetrahedral sites of the lattice. Tetrahedral sites have almost twice the lower crystal field compared with octahedral sites, resulting in less energy-level splitting and in the spectrum of fluorescence shifted toward longer wavelengths.

Tetravalent-doped forsterite has an 1170- to 1370-nm range of tunability. Since 1989, several other Cr^{4+} laser materials have been developed around the world.

The salient feature of the first tunable tri- and tetravalent chromium-doped Cr^{3+}:$BeAl_2O_4$ and Cr^{4+}:Mg_2SiO_4 (forsterite) lasers is that they belong to the same olivine crystal structure. In this structure, there are octahedral and tetragonal sites. Their occupancy by tri- or tetravalent chromium, respectively, depends on chemical composition of the crystals and on growing conditions.

In forsterite, both trivalent and tetravalent chromium can be presented; the active centers are tetravalent chromium in tetrahedral sites, while trivalent chromium is harmful because it reduces efficiency of laser operation. Many efforts were made to suppress entering the trivalent chromium into forsterite lattice. In 1989, a new Cr^{4+}-doped crystal, Ca_2GeO_4 (cunyite), was developed by IUSL in which only tetravalent chromium centers are presented; the formation of trivalent octahedral centers is prohibited by Ca/Cr ionic radii mismatch.

In 2005, also at IUSL, the commonly accepted 25-year rule that trivalent chromium is for the range shorter than 1 μm and tetravalent chromium, for the 1-

to 1.6-µm range, was broken. Researchers found that, in novel chromium-doped $LiInGeO_4$ (LIGO) (Figure 2), $LiScGeO_4$ and $LiInSiO_4$ (LISO) crystals – with the same faithful olivine structure – the ion responsible for near-infrared fluorescence in the 900- to 1800-nm range – typical for tetravalent chromium in tetrahedral sites – is actually trivalent chromium in distorted octahedral sites.

This is possible because of the strong distortion of octahedral sites. The distortion leads to weaker Coulomb repulsion between d-electrons of dopant and oxygen ligands and, therefore, to significantly lower splitting of energy levels compared with undistorted octahedra. A unique combination of a low symmetry crystal field, a strong Stokes shift and relatively low nonradiative quenching made possible room-temperature laser operation in the 1.1- to 1.6-µm range with a width of 470 nm.

Small modifications

In the olivine structure, substitution of both octahedral and tetrahedral sites by tri- and tetravalent chromium is possible, respectively. Absorption of both is seen in the absorption spectra (Figure 3), but in contrast to similar Mg_2SiO_4 (forsterite) and Ca_2GeO_4 (cunyite) crystals, emission of tetravalent chromium is totally quenched. Small modification of the olivine structure caused by Li-In or Li-Sc pair the replacement of Mg or Ca in Mg_2SiO_4 (forsterite), and Ca_2GeO_4 (cunyite) crystals render optical behavior of these crystals drastically different; in some, opposite to forsterite and cunyite. Emission from trivalent chromium is strong and emission of tetravalent chromium is quenched, in contrast to forsterite tetravalent chromium centers, which should be suppressed because they reduce efficiency of lasing.

Many of the uncommon properties of these novel crystals – LIGO, LISO – are yet to be understood, but it is clear that novel trivalent chromium-doped crystals are very promising media for applications in the near-infrared range.

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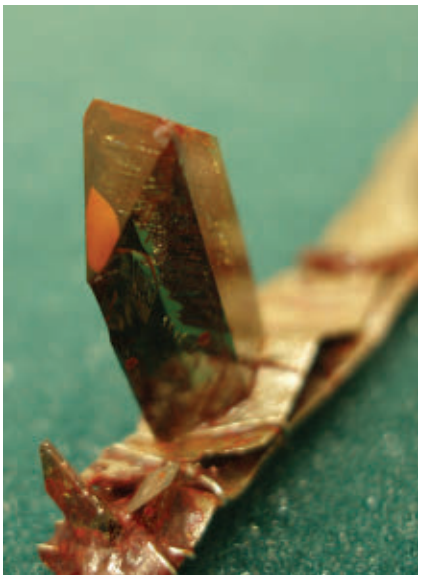


Figure 2. This Cr:$LiInGeO_4$ single crystal (20 × 7 × 4 mm) was grown spontaneously from flux.

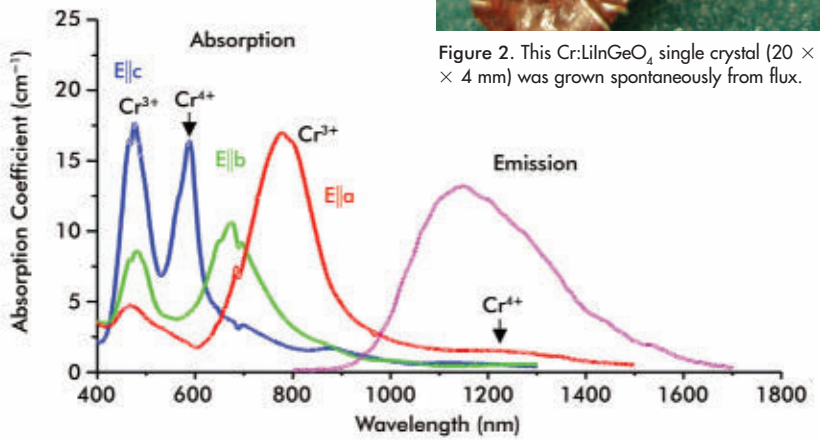


Figure 3. In this view of the polarized absorption and emission spectra of Cr:$LiInGeO_4$, both trivalent and tetravalent chromium absorption are visible. Bands assigned to absorption of tetravalent chromium in tetrahedral sites are marked with arrows. There is no emission on excitation into Cr^{4+} absorption bands; broadband emission from 900 to 1700 nm is attributed to Cr^{3+} centers. Absorption of tetravalent chromium in the range of emission results in lower efficiency of the laser operation.

Surface-Emitting Laser Array Scales Power for Industrial Applications

BY MANOJ KANSKAR AND FRANÇOIS BRUNET, ALFALIGHT INC.

High-power, multimode laser diodes are workhorses for many industrial applications. They are used as tools for cutting, welding, sintering and soldering various materials and as pump sources for fiber, disk and solid-state lasers. Many of these applications require fiber-coupled output or a uniformly focused beam.

The task of fiber-coupling and beam-formatting edge emitters is not simple because of large and asymmetric beam divergence. Expensive micro-optic arrays, interleavers and beam-transformation optics are needed to squeeze the power into a small fiber, and this drives the dollar-per-watt amount to more than an order of magnitude higher than the cost of manufacturing the laser diode.

Fiber-coupled or formatted beams are still too expensive or cost-prohibitive for many applications. Brighter diodes with a useful beam format that requires inexpensive and low-cost manufacturing techniques can further push down the dollar-per-watt figure. Alfalight Inc. in Madison, Wis., has developed an architecture that achieves just this – a two-dimensional array of curved-grating surface-emitting distributed feedback (SE-DFB) lasers.

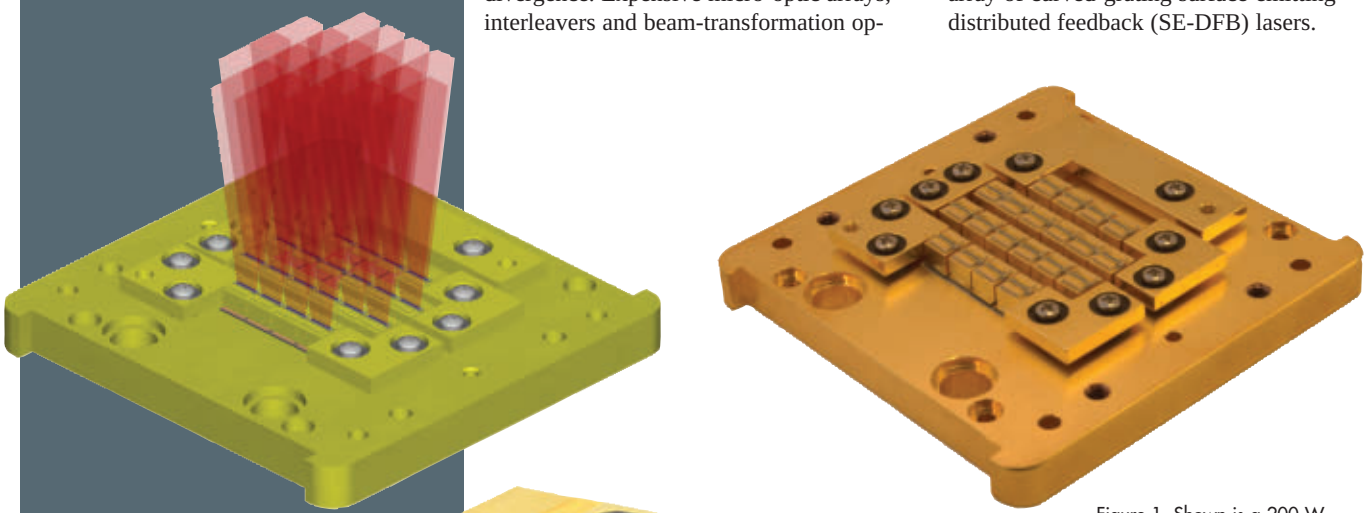


Figure 1. Shown is a 200-W surface-emitting distributed feedback (SE-DFB) laser array optimized for fiber coupling. Laser chips are arranged on a flat heat sink in a 4-6-6-4 configuration.

Figure 2. Alfalight builds fiber-coupled 200-W SE-DFB array lasers. The 976-nm beam is coupled into a 200-μm, 0.22-NA fiber connector.

Why brightness matters

Spatial brightness is defined as power generated per given area and solid angle. Therefore, using brighter sources, more power can be focused on smaller areas or coupled into smaller fibers. An ideal way to generate high power would be to combine single-mode diode lasers. Unfortunately, such sources produce, at most, 1 W of useful power and would require an unmanageable number of diodes for power-hungry industrial applications. Instead, multimode 100-µm-wide, broad-stripe laser diodes typically are used.

A single such device produces about 10 W of power out of a 100-µm, 0.15-NA fiber with a relatively simple coupling scheme, but further power scaling remains a challenge.

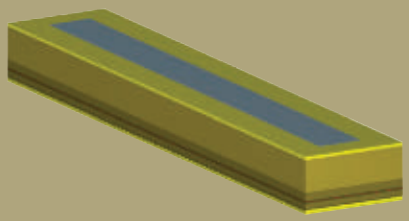
Combining more chips helps generate higher power but at the penalty of higher cost and complexity. An alternative method uses fiber coupling of bars and stacks. In this case, diffraction-limited collimators, expensive microlens arrays, interleavers and precision beam-formatting optics must be used in high-tolerance, complex configurations. These sophisticated elements between the source and the fiber are what drive the cost of high-power fiber-coupled systems.

A lower-cost solution

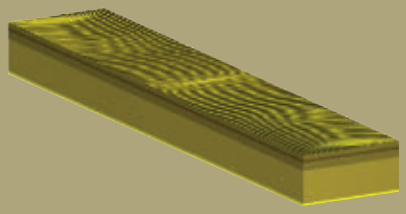
Arrays of SE-DFB lasers have several key attributes, lifting many limitations and cost drivers of current high-power laser diode systems. Those attributes are enabled by one crucial feature: a curved second-order grating etched on the *p*-side cladding of the laser chip (See sidebar).

Producing SE-DFB chips is more efficient than making standard edge-emitting lasers because key steps are performed early in the manufacturing process. Because fabrication of the laser output window and probe testing of individual lasers

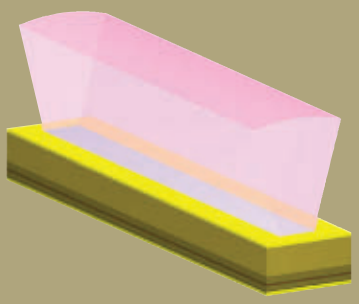
What Is a Surface-Emitting Distributed Feedback Laser?



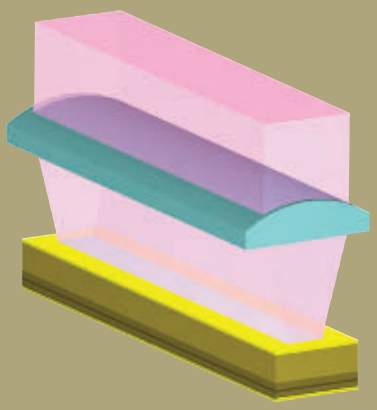
(a) A surface-emitting distributed feedback (SE-DFB) laser is based on a semiconductor quantum well and waveguide structure similar to more common edge-emitter laser diodes. Instead of being emitted through the edge of the chip, however, the output beam shines through a window on the top of the laser. Optical feedback from the edges of the chip is suppressed by an absorber region.



(b) The optical cavity-generating laser effect is formed by a curved second-order diffraction grating etched at the bottom of the laser.



(c) The first-order diffraction is steering the beam orthogonally from the waveguide, projecting it through the output window. The grating curvature shapes the wavefront to enhance brightness and collimate the beam in one axis.



(d) In the orthogonal direction, the beam slowly diverges with a full angle of 8°. A simple cylindrical lens collimates the beam.

are performed directly on the wafer, known good dies are selected before the laser chips are even cleaved, avoiding potential yield losses at expensive downstream packaging steps.

The SE-DFB array architecture provides a number of additional cost-saving advantages over the current technology. Whereas edge emitters must be placed on the knife edge of expensive, diamond-turned heat sinks, SE-DFB lasers are simply picked and placed on a low-cost, flat heat sink with an order of magnitude looser tolerance. Lasers in an SE-DFB array are wired in series, substantially reducing power loss in cables and power supplies. Furthermore, low-current power supplies are cheaper, reducing the overall system cost.

Another key advantage of the SE-DFB architecture is that the electrical connection is isolated from the coolant. This avoids galvanic corrosion that plagues microchannel-cooled bar stacks. Even at the kilowatt level, SE-DFB arrays are cooled with standard house water.

Customized beam with simple optics

The simple way that SE-DFB lasers are laid out on a heat sink makes it straightforward to customize the geometry of an array for a given application. For example, certain applications require an asymmetrical, thin rectangular beam. This is the case for laser-based surface treatment, hardening and cladding operations, where the beam is used as a broad optical brush to sweep large surfaces quickly. An SE-DFB laser array can be arranged into a few columns, each containing a number of laser chips. Because the beam is readily collimated straight out of the chip in one direction, no collimating optics are needed for individual chips.

In the orthogonal direction, the beam diverges slowly with a full angle of about 8°. Each column therefore can be collimated with a single standard cylindrical lens. This architecture yields important cost savings with respect to the collimation of edge-emitting bars, which requires expensive, diffraction-limited fast-axis collimation microlenses.

Fiber-coupled SE-DFB arrays

Figure 1 shows a 200-W quasicircular SE-DFB array that is coupled into a fiber cable with high efficiency without using beam transformation optics. In this configuration, four cylindrical lenses are used to collimate four columns in a 4-6-6-4 arrangement, and a single aspherical lens focuses the beam into a 200-µm, 0.22-NA fiber. The most stringent mechanical tolerance in this module with respect to fiber coupling is about 3 µm, two orders of magnitude looser than the 50-nm precision required for performing the same operation with a stack of laser bars. More rugged fiber-coupled SE-DFB products can be envisioned, handling shocks, vibrations and thermal gradients better than the current technology.

Alfalight's 200-W fiber-coupled module has been designed for pumping ytterbium-doped fiber lasers (Figure 2). The important challenge of wavelength yield for 976-nm modules is waived with SE-DFB

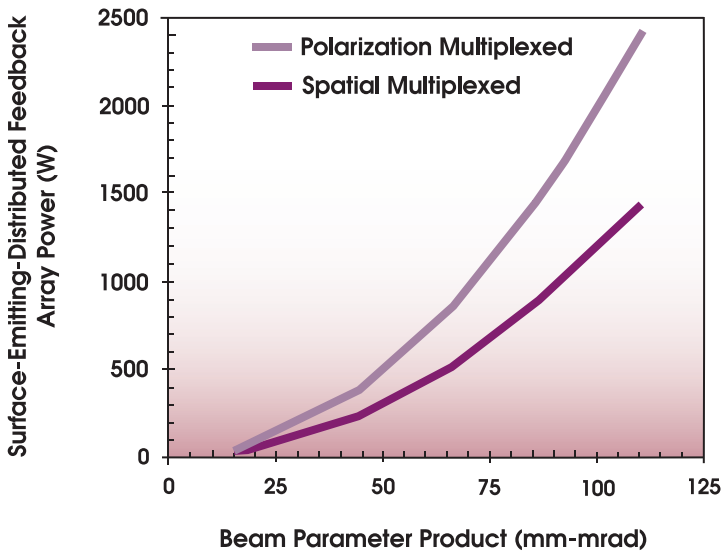


Figure 3. The achievable output power of an SE-DFB laser array scales quickly as the constraint on the beam quality is relaxed.

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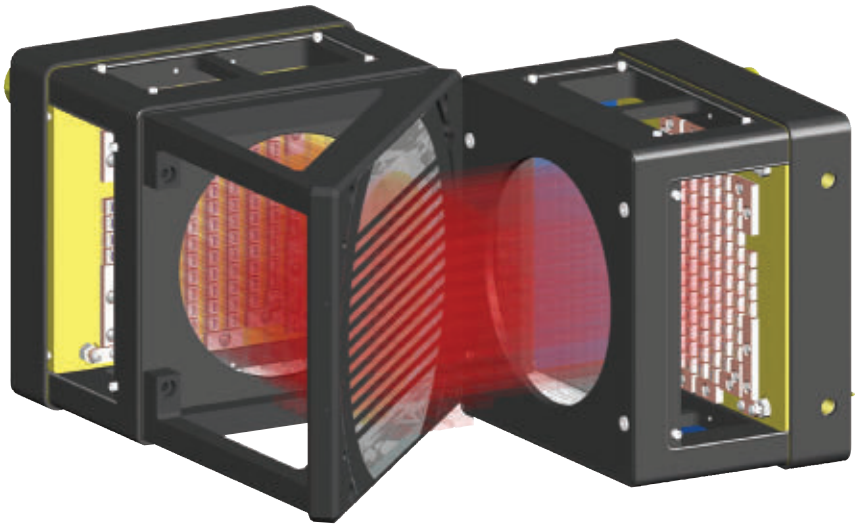

Figure 4. Using an interleaver, two arrays can be combined to create a 1-kW SE-DFB laser module.

technology because the grating precisely determines the output wavelength and guarantees a wavelength yield of virtually 100 percent across the wafer.

Besides delivering a narrow spectrum centered on the ytterbium absorption peak, the technology comes with other practical advantages; for example, the wavelength shift over temperature is only 0.07 nm/°C – five times slower than standard laser diodes. The pump absorption in the doped fiber consequently has only a weak dependence on the temperature of the cooling water. On a system perspective, this means that several pump modules can be cooled with a unique chiller with no temperature tuning required to optimize absorption.

Wavelength-locked high-power laser diodes bring benefits to industrial applications other than pumping solid-state media; for example, laser soldering of thermoplastics is generally realized by overlapping a transparent with a strongly absorbent polymer. The laser beam transmits through the top layer to melt the bottom, absorptive material, joining both pieces upon cooling. Materials must be carefully chosen to meet the respective requirements of high transmission and high absorption at the laser wavelength. SE-DFB arrays could provide low-cost solutions for this application, with an operating wavelength tuned on absorption and transmission bands of specific polymers.

Power scaling

Power scaling of SE-DFB arrays is possible using a larger number of emitters per array, as plotted in Figure 3. An additional level of power scaling is achievable by interleaving two arrays, as illustrated in Figure 4. Alfalight is developing a kilowatt SE-DFB array based on this latter approach and has demonstrated polarization combining of SE-DFB arrays with efficiency better than 98 percent, thanks to a polarization extinction ratio better than 1:1000 for single SE-DFB lasers. Moreover, the wavelength-locked, narrow spectral bandwidth of each array makes power scaling beyond 1 kW achievable through wavelength beam combining over a relatively narrow band.

Multikilowatt SE-DFB arrays would be a good fit for pumping high-power thin-disk lasers. A thin-disk laser can be pumped with a single beam, reflected several times by the pump cavity and absorbed by the thin solid-state gain medium over multiple passes. The benefits of simpler pump architecture and an emission wavelength locked on the absorption band of the disk would generate important cost savings, especially when scaled at the kilowatt level.

Limitations taken for granted on brightness, architecture and yield of high-power laser diode manufacturing are being lifted as the very first generations of SE-DFB lasers are being integrated into prototypes. Whether used as direct laser sources or for pumping fiber and solid-state lasers, SE-DFB laser arrays will quickly become a game changer for industrial applications.

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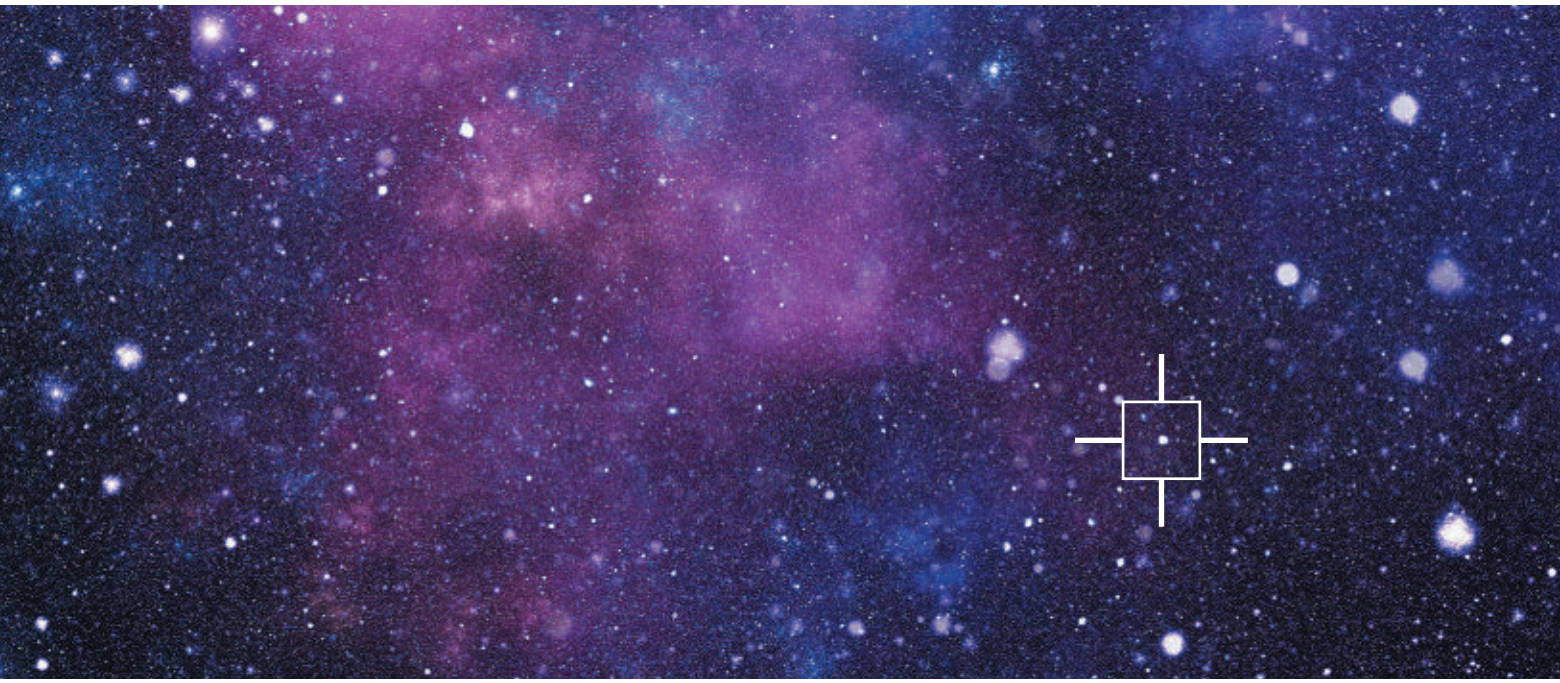

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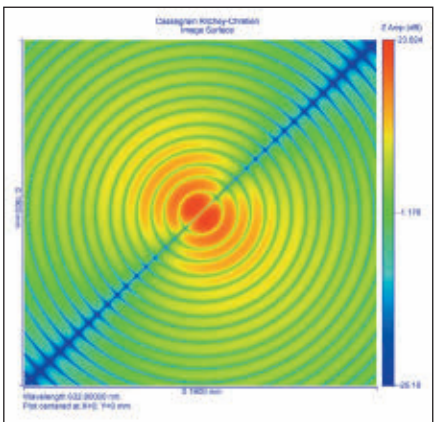

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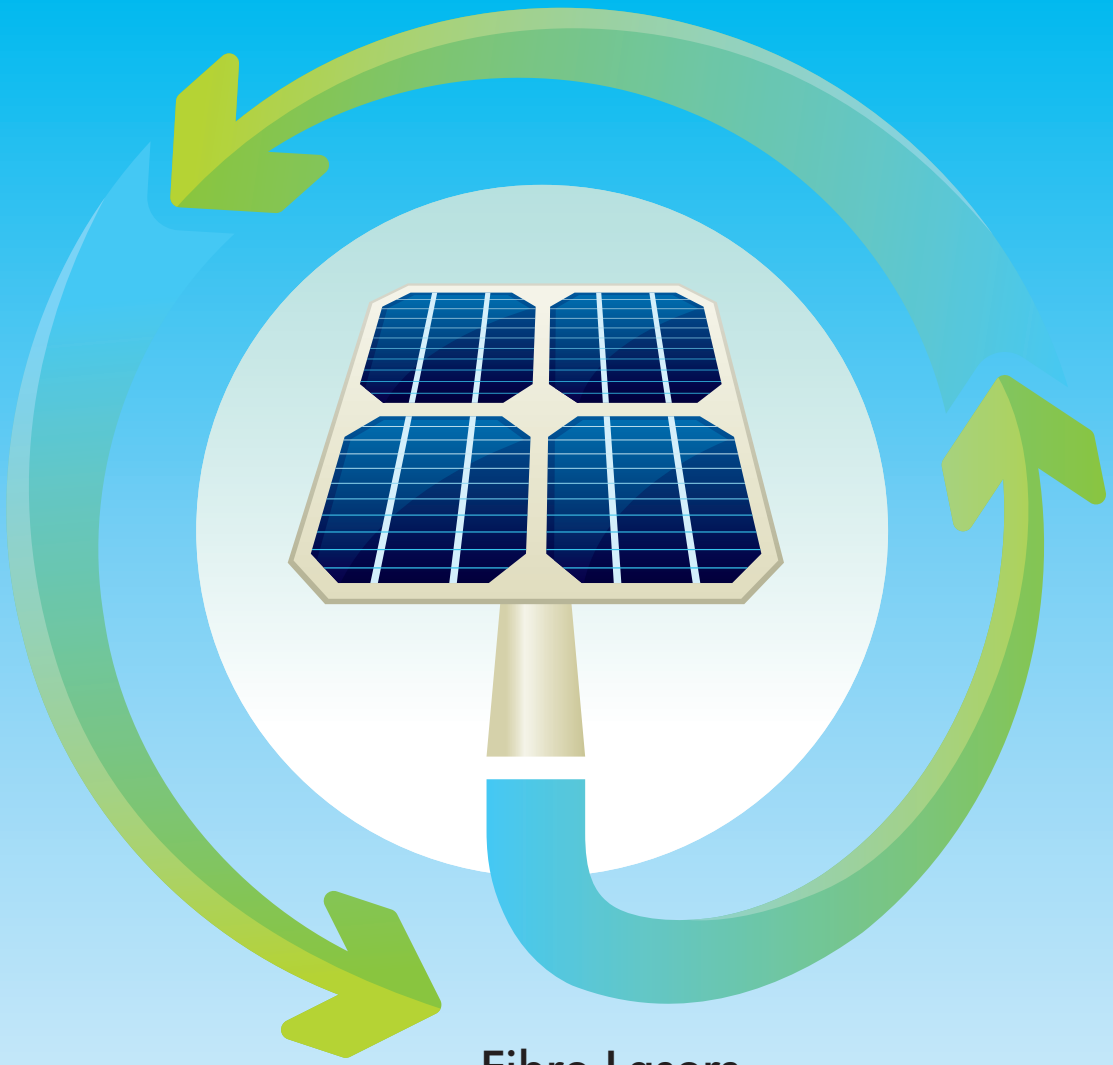

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Around the world in a solar airplane

ZÜRICH, Switzerland – The world's first totally solar-powered airplane is ready to circumnavigate the globe. Designed to fly day and night, the aircraft demonstrates how new technology can be harnessed to fight climate change.

"It was a dream. Today it's an airplane. Tomorrow it will be an ambassador of renewable energies and energy savings – flying day and night with no fuel and no pollution," Swiss adventurer Bertrand Piccard said at the unveiling of a prototype of the plane.

Piccard and his partner, André Borschberg, presented their aircraft – dubbed Solar Impulse HB-SIA – at Dübendorf Airport near Zurich on June 26. The plane will begin test flights by year's end.

Piccard first made history in 1999 when he circled the globe nonstop in the Breitling Orbiter 3 balloon.

"From the 3.7 tons of liquid propane [that Piccard and co-balloonist Brian Jones] had at the start [of their voyage], only 40 kilograms were left at landing," explained Borschberg, adding that the historic success could have turned into a failure because of the lack of fuel. "It was then that Piccard decided his next flight around the world would require no fuel – totally independent of any fossil energy."

After a six-year effort, sponsored in part by chemical and materials specialist Solvay SA of Brussels, Belgium, Swiss

The Solar Impulse HB-SIA (top) has a comparable wingspan to that of a Boeing 747-400 (bottom). Courtesy of Solar Impulse.

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watchmaker Omega and Deutsche Bank of Frankfurt, Germany, Piccard and Borschberg believe that their breakthrough design will prove the business viability and profitability of renewable energy.

Built around a carbon fibre-honeycomb composite to keep it extremely light, the craft uses super-efficient solar cells, batteries, electric motors and propellers to get it through the dark hours.

Despite a wingspan equal to that of a Boeing 747-400, the Solar Impulse weighs about the same as an average car – 1.7 tons. About 12,000 solar cells are mounted on the gliderlike wings, supplying renewable energy to the four 10-horsepower electric motors. The solar panels charge the plane's lithium polymer batteries during the day, allowing it to fly at night.

"If Solar Impulse really manages to fly around the world with no fuel – only on solar power – nobody will be able to pretend anymore that it is impossible to do the same for cars, for heating or cooling systems, for computers and so on," Piccard said.

After fine-tuning on the ground, the aircraft should make its first test flights between now and the end of this year. A first complete night flight is scheduled for 2010 and, as the pilots' confidence increases, they will move to a day-night circle, a feat never before accomplished in a piloted solar-powered plane.

Although the vehicle is expected to be able to fly nonstop around the globe, Piccard said he will make five long hops, sharing flying duties with Borschberg.

"The airplane could do it theoretically nonstop – but not the pilot," Piccard said. "In a balloon, you can sleep because it stays in the air even if you sleep. We believe the maximum for one pilot is five days."

The results from the Solar Impulse HB-SIA tests will serve in the design and manufacture of a second aircraft, the HB-SIB, which is expected to circumnavigate the globe in 2012 in five stages, each lasting several days.

"Our goal is to share how exciting, how positive it can be to invent another future, to invent alternative ways to behave and to act, thanks to the new technologies that can reduce the impact of human beings on the environment," Piccard said.

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Supporters can enroll at www.solarimpulse.com to receive news in real time, to adopt a solar cell on the wing, to reserve a VIP visit to the Solar Impulse base or to place their names on the aircraft's fuselage.

Controlling photons a step toward quantum computing

BRISTOL, UK – Controlling nonclassical light is key to the development of quantum technologies for such applications as quantum computers and ultraprecise metrology. And researchers from the University of Bristol Centre for Quantum Photonics have brought such technologies a step closer by demonstrating control of four single photons on a silicon chip.

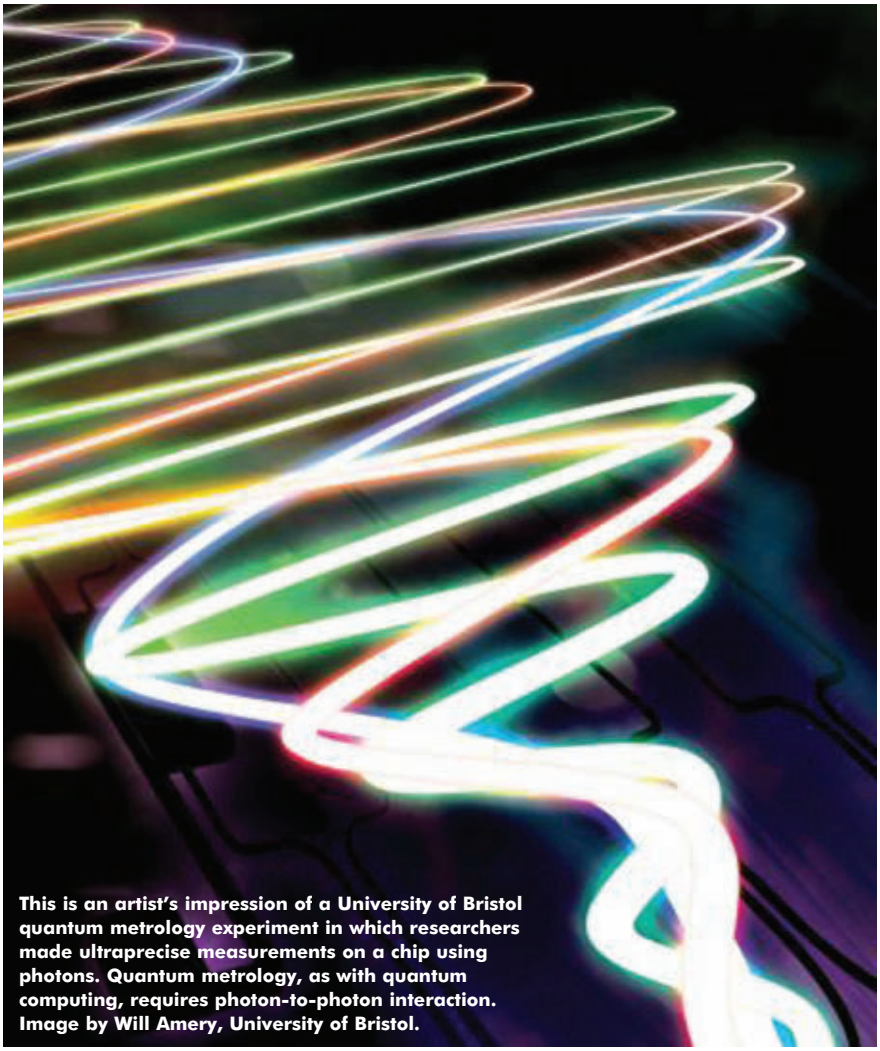
Quantum particles such as photons can exist in two states at once, unlike PC transistors, which can exist only in "0" or "1" states at a given time. Photons are not the only choice for quantum technologies, but they are an ideal one because of their relative lack of noise, their resilience to decoherence and their speed – light speed.

And manipulating single photons is easy; it's making them interact with each other that is difficult. Difficult, but important: Nonclassical interference of single photons is critical for generating the entanglement necessary for quantum technologies.

Jeremy L. O'Brien, director of the Centre for Quantum Photonics and a professor of physics and of electrical engineering, led the current research. In 2003, he demonstrated the interaction of two photons in a quantum logic gate; in 2008, the Bristol team demonstrated such interaction on a silicon chip.

"Despite these impressive advances, the ability to manipulate photons on a chip has been missing," said Alberto Politi, a doctoral student at the centre.

But now, O'Brien, Politi and colleagues have used a microscopic metal electrode lithographically patterned onto a silicon chip to demonstrate precise control of four photons. As in optical fibres, the photons propagate in silica waveguides patterned



This is an artist's impression of a University of Bristol quantum metrology experiment in which researchers made ultraprecise measurements on a chip using photons. Quantum metrology, as with quantum computing, requires photon-to-photon interaction. Image by Will Amery, University of Bristol.

on the silicon chip, and the electrode is used to manipulate them.

"This precise manipulation is a very exciting development for fundamental science as well as for future quantum technologies," O'Brien said.

Using optical fibres, the researchers coupled photons into the CIP Technologies chip and then back out. They changed the temperature of the silica waveguide by applying a voltage across the metal electrode above it; this changed the path along which the photons travelled. To confirm precise manipulation of the photons in the chip, they measured the output of the device.

They proved that up to four photons achieved quantum entanglement. "These entangled states are responsible for famously 'weird' behaviour arising in quantum mechanics, but are also at the heart of powerful quantum technologies," said Jonathan Matthews, also a doctoral student at the centre, who carried out the experiments with Politi.

Attaining quantum entanglement with four photons means that the state of each individual photon could not be determined; only the collective state of all four could be defined. By linking photons together in this nonclassical manner, Matthews said, dramatic advantages over classical physics can be realized.

Quantum computing is not the only application that could benefit from the Bristol group's research. The investigators have demonstrated its usefulness for quantum metrology, and there are more possibilities. "As well as quantum computing and quantum metrology, on-chip photonic quantum circuits could have important applications in quantum communication, since they can be easily integrated with optical fibres to send photons between remote locations," Politi said.

"The really exciting thing about this result," O'Brien said, "is that it will enable the development of reconfigurable and adaptive quantum circuits for photons. This opens up all kinds of possibilities."

The team has reported its results in the June issue of *Nature Photonics* as well as in a Postdeadline Paper at June's International Quantum Electronics Conference (IQEC) in Baltimore.

A *Nature Photonics* commentary on the research described this work as a key step on the road to quantum computation, concluding: "The most exciting thing about this work is its potential for scalability. The small size of the [device] means that far greater complexity is possible than with large-scale optics."

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Sensors help map out cleaner cities

LONDON – Most weather stations will give you a vague prediction of the daily air quality in your area, as a nod to those who are sensitive to changes in pollutants. How much more helpful for those concerned would it be, though, simply to log on to the Internet and see the current conditions for their location!

This is exactly what researchers from Imperial College London and from the universities of Cambridge, Leeds, Newcastle and Southampton, all in the UK, are working on. They have created MESSAGE (Mobile Environmental Sensing System Across Grid Environments), an initiative that brings together groups working in e-science, transport, sensors and communications to develop a system that can map the distribution of pollutants in cities.

At the beginning of July, the scientists deployed three types of sensors in South Kensington, Leicester, Gateshead and Cambridge to measure and model air pollution in these areas. The most sophisticated sensors in the study, which were attached to vehicles driving in South Kensington, simultaneously measure as many as five traffic pollutants, including nitrogen oxide and sulphur dioxide. These detectors are equipped with ultraviolet absorption spectroscopy technology that enables them to take measurements at 5-second intervals.

Other sensors will be attached to traffic lights and streetlamps to model pollution clouds in three dimensions, possibly enabling scientists to manage traffic congestion and improve air quality. The smallest versions will be carried by cyclists and pedestrians, who will transmit data through their mobile phones, recording everything from vehicle fumes to cigarette smoke.

The air quality measurements from each sensor, as well as each sensor's location, will be tracked on Google maps. The study initially is using 100 sensors, but the researchers imagine that thousands of these devices eventually will be used across the country, changing the way we monitor, measure and manage urban pollution.

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De-twinkle, de-twinkle little star

MARSEILLE, France, and GARCHING, Germany – Thanks to what is being billed as the world's fastest and most sensitive astronomical camera, the European Southern Observatory (ESO)'s Very Large Telescope might be able to spot planets orbiting another star within a few years. Nonastronomical applications for the camera might lie in ophthalmology, combustion analysis or the study of chemical reactions.

Jean-Luc Gach, an instrumentation engineer at Laboratoire d'Astrophysique de Marseille, was responsible for the development of the OCAM camera. He noted that the device could be used where there is a particular need for speed and sensitivity. "You almost don't need any light," he said.

Ground-based telescopes, such as ESO's multioptical instrument that sits on a mountain in Chile, must overcome a major obstacle: The atmosphere is turbulent, which gives rise to temporary optical distortions. One result is that stars twinkle, thereby preventing telescopes from realizing their full potential.

The solution is to employ adaptive optics, a technique that detects and cancels out these atmospheric distortions as they happen. If done properly, the view from the ground can rival that from air-free space.

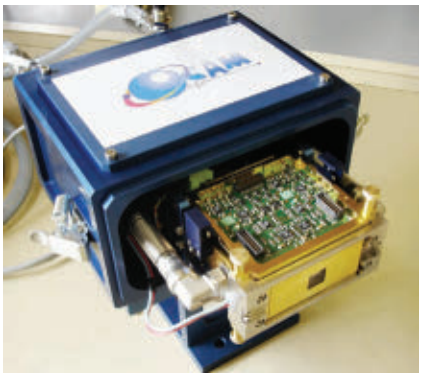
Currently, such corrections are done hundreds of times a second. But next-generation instruments – such as the exoplanet finder that ESO plans to deploy in 2011 – require corrections more than 1000 times a second. Consequently, the camera capturing the correction-determining data must be both faster and more sensitive.

The greater sensitivity is a result of the need for speed. A shorter exposure time means that there is less light with which to work. On top of that, faster electronics usually create more noise, further increasing the need for sensitivity.

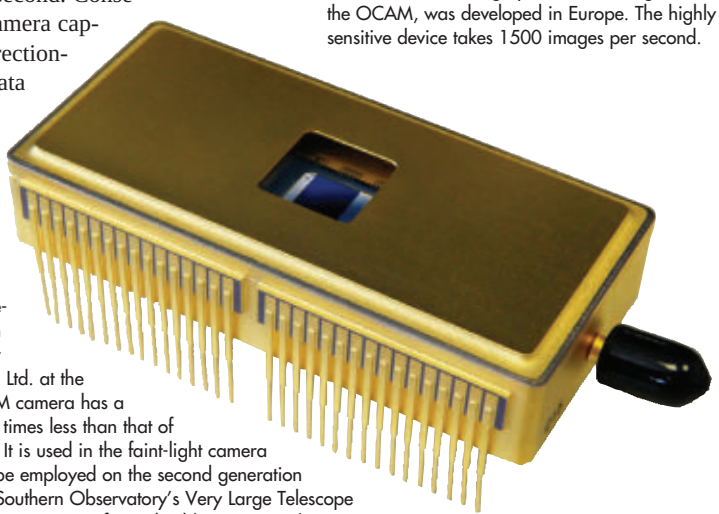
Gach was part of a team – including others from ESO and from Laboratoire d'Astrophysique de Grenoble – that came up with the solution. Working with image sensor manufacturer e2v technologies (UK) Ltd. of Chelmsford, it developed a suitable camera.

In fact, the team achieved a better-than-magnitude increase in performance. The OCAM offers a 1500 fps rate with a half-electron readout noise. That's three times as fast as the existing camera, with less than 10 per cent of the noise, Gach said. The camera development effort was funded by the European Commission and took five years.

Although the OCAM meets current needs, the technology must be improved



The world's fastest high-precision faint-light camera, the OCAM, was developed in Europe. The highly sensitive device takes 1500 images per second.



The 240 × 240-pixel CCD220 detector from British manufacturer e2v technologies (UK) Ltd. at the core of the OCAM camera has a readout noise 10 times less than that of current detectors. It is used in the faint-light camera systems that will be employed on the second generation of the European Southern Observatory's Very Large Telescope instruments. Images courtesy of P. Balard/INSU-CNRS/ESO.

to handle tomorrow's larger telescopes. On the drawing board is the European Extremely Large Telescope, which will cost €1 billion and have a light-gathering area that spans 42 m. Correcting atmospheric distortions for that giant will require further development of the technology, said Norbert Hubin, head of adaptive optics at ESO.

Key will be increasing the number of pixels, from the current camera's 240 × 240 to 1600 × 1600. The frame rate for the larger detector, however, might be only 700 Hz. The development of a camera for the new telescope, dubbed the E-ELT, is ongoing. But the recently unveiled OCAM might play a role in operation of the large telescope, Hubin said. "We might actually make use of this camera for the E-ELT at first light."

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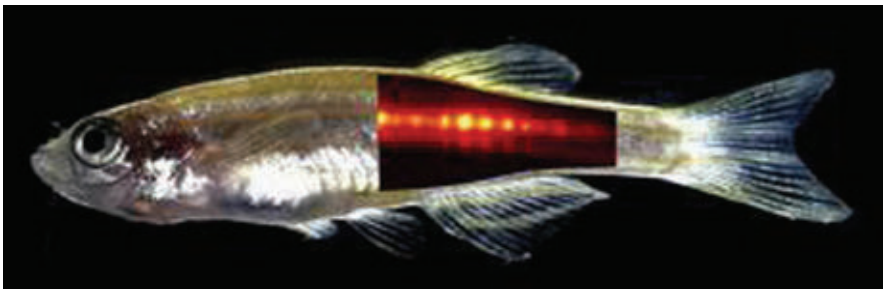
From light to sound to 3-D images



Light and ultrasound can be used to visualize the red fluorescent spinal column of a live fish: Multispectral optoacoustic tomography, or MSOT, allows the investigation of subcellular processes in live organisms. Image courtesy of Helmholtz Zentrum München/TU München, montage.

MUNICH – Scientists have long used light to scrutinize thin sections of tissue for ascertaining whether they are diseased, or for investigating cell function. However, the penetration limits of light range between one-half and 1 mm of tissue. In thicker layers, light is diffused so strongly that all useful details are obscured.

Now, professor Vasilis Ntziachristos, director of the Institute of Biological and Medical Imaging of the Helmholtz Zentrum München German Research Center for Environmental Health, has broken through this barrier and rendered three-dimensional images through at least 6 mm of tissue, allowing whole-body visualization of adult zebra fish.

To accomplish this, Ntziachristos and his team made light audible. They illuminated the fish from multiple angles using flashes of laser light that were absorbed by fluorescent pigments in the tissue of the genetically modified fish. When the pigments absorbed the light, local temperature increased slightly, which in turn resulted in tiny local volume expansions. This happens very quickly and creates small shock waves. In effect, the short laser pulse gives rise to an ultrasound wave that the researchers pick up with an ultrasound microphone.

The real power of the technique, however, lies in specially developed mathematical formulas used to analyze the resulting acoustic patterns. A computer evaluates and interprets the distortions caused by scales, muscles, bones and internal organs and generates a three-dimensional image.

The result of this "multispectral optoacoustic tomography" is an image with a spatial resolution of better than 40 µm.

Dr. Daniel Razansky, who played a pivotal role in developing the method, said, "This opens the door to a whole new universe of research. For the first time, biologists will be able to optically follow the development of organs, cellular function and genetic expression through several millimeters to centimeters of tissue."

Ntziachristos is convinced that "multispectral optoacoustic tomography can truly revolutionize biomedical research, drug discovery and health care. Since multispectral optoacoustic tomography allows optical and fluorescence imaging of tissue to a depth of several centimeters, it could become the method of choice for imaging cellular and subcellular processes throughout entire living tissues."

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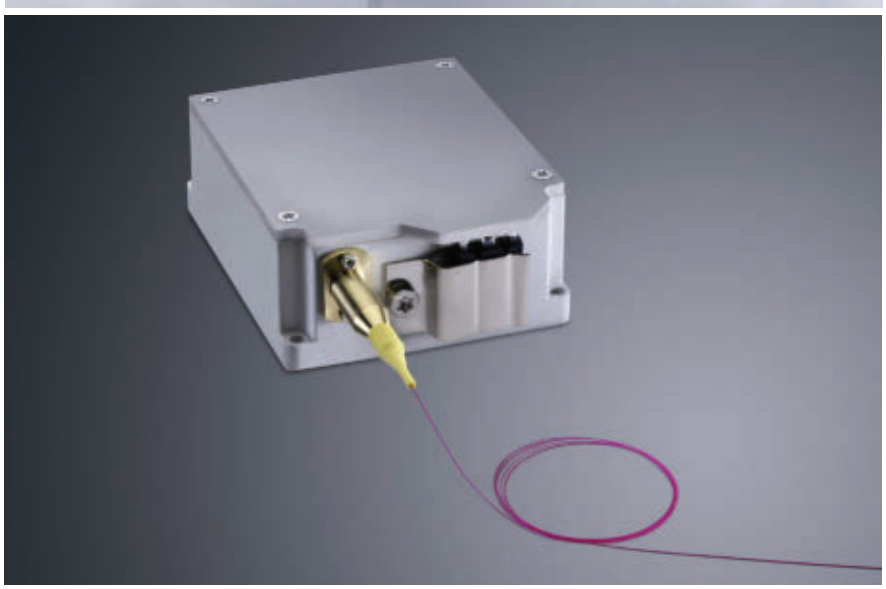
FIBRE LASERS STEAL THE SHOW

At Laser Munich this year, fibre lasers emerged as real contenders.



Fibre-coupled diode modules (bottom), producing output of up to 100 W and running through a 100-µm fibre, are the core of Trumpf Inc.'s TruDiode 3006 diode laser system (top) for direct manufacturing applications. Several of these modules are combined into a laser unit to achieve the output of 3 kW, with a socket efficiency of up to 40 per cent.

BY JÖRG SCHWARTZ
EUROPEAN CORRESPONDENT

Diode-pumped solid-state lasers have gained widespread use in industrial applications, a fact that might make you think that things have settled down with regard to new lasers entering the materials processing arena, or that vendors would be focusing on improving current lasers, or – often more importantly – that they would be improving how they meet new and current applications.

However, because lasers often displace other technologies when it comes to solving an application, there is always the question of which laser is best for a particular situation. Add to this the fact that new laser types enter the market and quickly replace others, which was in evidence at this year's Laser World of Photonics show in Munich.

Fibre-coupled high-power diode lasers are major contenders for direct materials processing applications and have now become part of Trumpf GmbH & Co. KG's lineup. The company says the beam quality enables it to replace current lamp-pumped solid-state lasers not only for soldering and conduction welding but also for keyhole welding and cutting.

Jens Bleher, managing director of Trumpf Laser- und Systemtechnik GmbH, said that, "If a customer uses our TruDisk diode laser instead of a slab laser with three-kilowatt output power, the electrical power consumption is reduced by a factor of ten." This is obviously not only good for the environment but also for the operating costs. "Under typical three-shift production conditions, like in automotive production, a sample calculation gives a cost

reduction from six euros to less than fifty cents per hour," a result of not only the high efficiency – up to 40 per cent – but also of the long lifetime of the laser components.

Power increases

The maximum output power from diode lasers has been increasing continuously over the past few years, and the new 10-kW LDF series from Laserline GmbH, delivered via a 1-mm fibre, allows a spot site in the same order with 100-mm focusing. The lasers, intended for heavy-duty industrial applications such as cladding or welding of thick sheets, use active cooling to enable a 770 × 950-mm footprint and reach efficiencies of up 45 per cent. Otherwise, the multikilowatt power range has been dominated by solid-state and CO_2 lasers for decades.

And if you thought CO_2 lasers were out of business, think again. They are far from it, according to their manufacturers. Vendors including Rofin-Sinar Laser GmbH note that their instruments are simple and clever. Even those from the "solid state" camp, such as Friedrich Kilian, executive vice president of Trumpf and a speaker at the World of Photonics' Lasers in Manufacturing Congress, predict a long period where the CO_2 will co-exist with its "young and aspiring" challengers.

And, indeed, progress has been made in CO_2 lasers. Coherent Inc. presented its new E-150/E-1000 models – 1500 × 500 × 400 mm, including the power supply – which provide output power of 150 W and 1 kW, respectively, for small machine applications in cutting and drilling of nonmetals. "And these lasers now come with a reliability comparable to fibre lasers – including their RF [radio frequency] power supply," said Stuart Woods, director of business development at Coherent.

Rofin-Sinar, a leader in the industrial CO_2 laser market, made a big splash about fibre lasers during the show. The company is pushing the power of its industrial fibre laser systems up to 2 kW, making them suitable for more classical cutting and welding as well as for new applications such as remote cutting. Worth noting is that it is pushing fibre lasers well into the kilowatt domain, whereas rival Trumpf currently offers 400 W and appears to be leaving the kilowatt range to its conventional, yet successful, disc lasers – at least for now.

Fibre lasers such as this water-cooled system from Lasag AG offer high power stability, beam delivery, customized processing optics and laser control. The CFS Cut was specifically designed for processing of thin-walled metallic parts such as medical stents, with a cut width of under 20 µm.

Another turnkey materials processing vendor not placing all bets on the new horse is Lasag AG, a Swiss manufacturer of laser precision processing with either lamp-pumped Nd:YAG or diode-pumped fibre lasers. The company's CFS series comes as a complete laser solution, incorporating 50- to 200-W water-cooled fibre lasers with high-power stability, beam delivery, customized processing optics and laser control as well as customized options for cutting and welding when making medical devices, electronics and watches.

Another area where "old" and "new" argue the merits of change is laser annealing in LCD screen production and similar semiconductor processes. In this case, the defender clearly is the excimer laser, for which improvements have been made by Coherent with regard to reliability, simple operation and cost of ownership. But frequency-doubled solid-state laser makers say they can do better.

Photovoltaics targeted

A related area that drew attention at the show was lasers in photovoltaics production. For this, many manufacturing jobs are done best by lasers – edge isolation, silicon cutting, marking, drilling and thin-film removal – and in particular for thin-film solar cells, which are sensitive to mechanical handling. A variety of lasers compete for these jobs and, as usual, many parameters beyond power and beam quality must be considered, including wavelength or repetition rate and pulse width. The jury is still out on quite a few applications for this growing market, in which, unlike most others, it is not about one laser replacing the other.

In manufacturing thin-film solar cells – and in some other areas where power is needed in precisely the right spot – short-pulse and ultrashort-pulse lasers are likely to gain commercial relevance in manufacturing. They will not compete with the big guys, where power and beam quality are at the top of the wish list, but they have their sweet spot wherever small impact on surrounding areas is required, which is key to ultraprecision processing in various areas of application. Whether in medicine, electronics, aerospace or solar technology, thin coatings can be removed, fibre-reinforced plastics drilled and ceramic components' surfaces structured.

Femtoseconds are the shortest that lasers pulse these days (see Photonics.com story on Congress opening), and most commercial short pulse lasers use picoseconds. A wider use of femtosecond lasers is limited by the costs connected with the complex optical modules required and by the average output, which is currently limited to below 100 W on commercial systems. This could change with the Fraunhofer Institute for Laser Technology ILT's development of a 400-W femtosecond laser based on its InnoSlab technology.

Exciting progress is coming our way in lasers in manufacturing, in particular fibre-coupled, directly applied diode and fibre lasers. However, as usual in this field, even somewhat aged technologies will continue to be optimized and demanded, and various generations of lasers will co-exist for the same application.

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Thermophotovoltaics: A hot topic in the UK

Both efficiency and bandgap engineering provide electricity via heat waste recovery.

BY JÖRG SCHWARTZ
EUROPEAN CORRESPONDENT

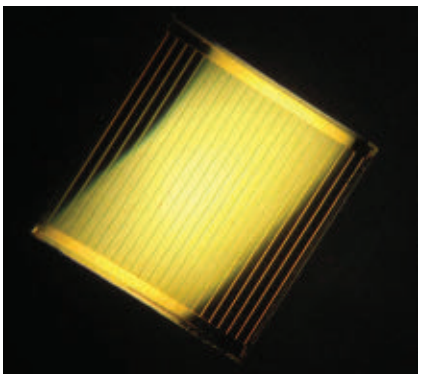
SWINDON/IPSWICH/MILTON KEYNES, UK – Two British consortia have received funding from the country's Technology Strategy Board for the development of thermophotovoltaic (TPV) technology. One project, now finished, set a record for energy conversion efficiency; the other, focusing on a different material platform, has just begun.

Thermophotovoltaic systems consist of solar cells that bring their own sun – where the "sun," or emitter, usually is radiating in the infrared spectral range, and the actual cells converting the photons into electrons are different from standard solar cells, which are tailored for high efficiency in the visible.

In their classical configuration, TPV systems comprise an emitter – such as a burner – a semiconductor-based converter cell, and filters and reflectors to direct and select the radiation to be converted. This makes them quiet and self-contained – yet nonrenewable – electricity sources with few or no moving parts. Consequently, applications such as remote site and portable electricity generation have been among the most obvious targets for TPVs, not only for off-grid power generators but also to feed battlefield electronics.

Recently, however, their potential use for the recovery of waste heat from industrial plants such as blast furnaces has come into play. Here the emitter and its temperature radiation profile are a given and can no longer be tailored to match the converter cell; thus, engineering the cell's bandgap is even more important, so that the absorption properties of the cell match the emitter's IR radiation spectrum.

"TPV technology has a lot of potential but is still in its early stages, and one of the main areas for improvement is the conversion efficiency," said Dr. David Rogers, TPV project manager at the Centre for Integrated Photonics (CIP) Ltd. In his project, which was funded by the Engineering and Physical Sciences Research Council, CIP and its partners, Oxford University and Wafer Technology Ltd., demonstrated a record conversion efficiency of up to 12 per cent from devices with a single *p-n* junction, based on indium phosphide (InP) materials. This compares with 9 per cent from existing commercially available cells.



Cells converting infrared radiation into electricity are key parts of thermophotovoltaic systems. This cell was made using InP, which is well-known because of its widespread use in photonic applications such as integrated optics.

Fabrication and growth of InP, including compound InGaAs crystals, is a known technology, making for efficient production and the opportunity to apply some tricks to optimize the bandgap.

In the second consortium, research continues in another more traditional material platform, gallium antimonide (GaSb), which has a bandgap of 0.72 eV – similar to InGaAs – and which has been widely used in TPV research and engineering. This project aims to use alloys such as InAsSb or InGaSbN and to lattice-match them to GaSb substrates, further reducing the bandgap and improving the absorption characteristics at long wavelengths.

"In contrast to InP, the materials are less well understood," said Dr. Mark Furlong, director of Wafer Technology. "But if this is changed, the benefit can be substantial." The expectation is that the new cells will more effectively generate electricity from waste heat sources, such as glass melting furnaces, for which temperatures below 1000 °C are particularly relevant.

Partners in the second project include defence company QinetiQ Ltd., Lancaster University and, again, Wafer Technology, which, obviously, has more than one iron in the fire.

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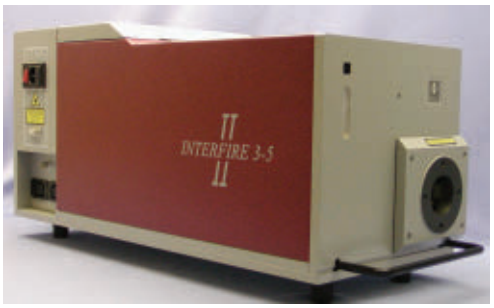


Infrared Interferometer

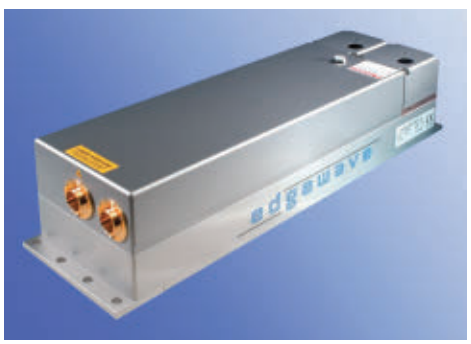
The Interfire II 3-5 infrared interferometer from Precision Solutions operates in the 3- to 5-µm region of the spectrum and can be used for performance testing of infrared materials and optical systems. Suitable for measuring wavefront distortion through IR systems and components, the device can evaluate high-specification lens assemblies to produce interference fringes that indicate the degree of aberrated performance. It features an accuracy of λ/20 and repeatability of λ/50.

Precision Solutions
robin.addison@mbda-systems.com

Interferometer

Arden Photonics Ltd. has introduced an interferometer that inspects optical fibre ends with diameters between 100 and 1000 µm for quality and flatness. The VF-20 Trio has three user-selectable settings providing fields of view of 150, 500 and 1000 µm, and it operates in inspect and fringe modes, eliminating the need for separate inspection equipment. Analog and digital outputs enable the device's use with a video monitor or computer. Applications include cleaver manufacture and maintenance, components manufacture, fibre research and development, and inspection of polished fibres. It is suitable for use with Vytran and other splicer holders.

Arden Photonics
sales@ardenphotonics.com



Ultrashort-Pulse Amplifier

EdgeWave GmbH has released the Innoslab ultrashort-pulse IS10I-A amplifier with an average power of 100 W. The device features a circular Gaussian beam with M^2 <1.5, a line-shaped one-dimensional Top-Hat with M^2 <2 and square two-dimensional Top-Hat with M^2 <2. It delivers pulse energy up to 1 mJ, an input power of 2 W, a 100-W output power and an optical efficiency of 50 per cent. Applications include precision micromaterials processing, cutting, drilling and rapid tooling; ablation of thin metallic and dielectric layers; scribing of thin-film solar cells; and structuring of silicon wafer solar cells.

EdgeWave
info@edge-wave.com

Smart Camera System

The Caminax image-processing system, based on a smart camera by Vision Components, has been used by FiberVision to design a positioning system for the manufacture of spinnerets. The positioning system adjusts nozzle openings with diameters between 60 and 500 µm, while the camera, mounted sideways at a distance, uses a telecentric measuring lens to achieve a resolution of 2 µm at a working distance of 110 mm. The compact system, operating without a separate PC, control cabinet or fan, displays its results on a VGA monitor.

Vision Components
sales@vision-components.com

Diode Lasers

LIMO Lissotschenko Mikrooptik GmbH has expanded its product portfolio to include the compact LIMO15-F200-DL808 and LIMO20-F200-DL980 diode laser modules. Suitable for dentistry applications, the 15- and 20-W models also can be used in surgical applications for faster healing because of their high absorption in water. Featuring a typical threshold current of 3 to 4 A, typical efficiency of 42% and a slope efficiency of 0.8 W/A, they produce 20 A for the 15-W model and 27 A for the 20-W model. Available accessories include fibre detection sensors, monitor diodes and a pilot laser.

LIMO
a.gruetz@limo.de

Seed Laser Module

3S Photonics has unveiled a 500-mW continuous-wave version of its 1064-nm seed laser module for fibre lasers. Providing a peak operating current of up to 1.7 A with 1-µs/500-kHz pulses, it operates from 1050 to 1070 nm, delivers short-pulse operation of 5 to 500 ns and offers a heat sink temperature up to 50 °C. Housed in a low-profile hermetically sealed 14-pin butterfly package, the system includes an internal thermoelectric cooler, a thermistor and a back-facet monitor photodiode. It also features a polarization-maintaining single-mode fibre pigtail and is RoHS-compliant.

3S Photonics
jphirtz@3sphotonics.com

Reflectometer

Luciol Instruments SA has introduced the LOR-220, a high-resolution optical time-domain reflectometer. The fully portable device can measure optical attenuation and bend-loss along a fibre, and it can characterize optical harnesses and fibre assemblies from beginning to end. It can see through bad connectors and strong reflections, and it measures both insertion and return losses with dead zones of 10 cm for event and 40 cm for attenuation. It is suitable for characterization, monitoring and troubleshooting of fibre assemblies in harsh environments, as fibre optic sensors, and for aviation and defence applications

Luciol Instruments
info@luciol.com

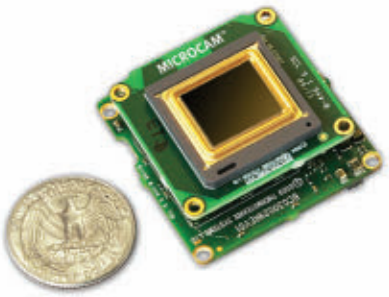
Nanopositioning Stages

PI (Physik Instrumente) LP has extended its line of piezo stages for superresolution microscopy to include the nano series nanoposi-

tioning stages. Featuring a low profile of 20 mm and a large aperture, they deliver highly accurate motion with subnanometre resolution in two and three axes. The instruments are suitable for scanning and single-molecule microscopy, for three-dimensional imaging, for auto-focussing, and for scanning and alignment tasks in bionanotechnology. A piezo controller is included and comes with a 24-bit USB port, and Ethernet, RS-232 and analog interfaces, and software support for all major image acquisition packages. The stages can be supplemented with the company's M-545 manual X-Y microscope stage.

PI
photonics@pi-usa.us

Thermal Imager

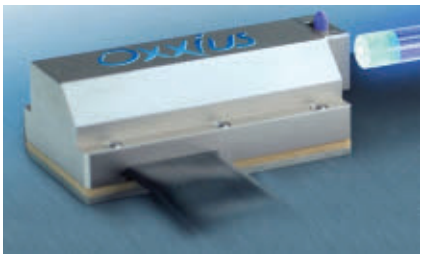


The Thermoteknix Microcam thermal imager from Thermoteknix Systems Ltd. draws <0.6 W of power while delivering a full 384 × 288 60-Hz composite video signal. Suitable for portable, power-critical and battery-powered applications, it offers night vision capability. Its unstabilized Tec-Less technology enables images to be delivered over the entire operating range without affecting power consumption. The instrument features 25-µm pixel pitch, operates at 60 fps, and delivers a spectral response from 8 to 12 µm and sensitivity <80 mK. It operates from −20 to 60 °C and offers users the ability to perform image rotation, flips and polarity inverts.

Thermoteknix
sales@thermoteknix.com

PRODUCT PREVIEW

DPSS Laser



The SLIM-473 blue continuous-wave diode-pumped solid-state (DPSS) laser from Oxxius SA emits up to 50 mW at 473 nm. Featuring a monolithic resonator, it offers a transverse mode beam with M^2 <1.2, ultralow noise of <0.2% rms and a pointing stability of <10 µrad over 3 °C. It is available in either an OEM version designed for systems integration or in a plug-and-play model for laboratory use. The single-frequency version is suitable for Raman spectroscopy, holography and interferometry.
Oxxius
sales@oxxius.com

Ultrafast Laser

Fianium has introduced its FP1060-HE high-energy ultrafast fibre laser. Based on a mode-locked model, it can deliver pulse energies >10 µJ with pulse durations to below 20 ps in challenging environments. The platform is based on a modular design with a compact remote optical head that offers users custom configurations within an industry-standard 19-in. rack-mount laser chassis. Its external modulator permits pulse repetition rates from single-shot to 20-MHz, and it enables flexible pulse shaping and burst-mode operation. The device is suitable for processing materials such as polymers, glasses, organic tissue and reflective metals.
Fianium
info@fianium.com

Fibre-Coupled Laser

Frankfurt Laser Co. has released the FBLD-976-8.0W-FC62.5-2Pin 976-nm fibre-coupled laser. The laser diode delivers 8 W from a 62.5-µm core fiber and features a high-brightness pump laser. Designed to power all-solid-state and direct diode laser systems, it comes in a hermetically sealed uncooled two-pin

package measuring 38 × 19 × 13 mm. It also is available in HHL housing featuring an integrated thermoelectric cooler, a thermistor and a monitor diode. An integrated pilot beam is also an option. The laser is suitable for medical, analytical, printing and pumping applications.
Frankfurt Laser
sales@frlaserco.com

Spectroradiometers

BFi Optilas has collaborated with Photoresearch to launch the next generation of Spectrascan spectroradiometers. The PR-730/735 offers twice as many detectors as the PR-705/715, the industry standard, and it offers higher resolution while being more sensitive and producing no polarization error or stray light. It comes with USB, Bluetooth wireless and RS-232 interfaces and a high-resolution colour touch-screen display. The PR-730 version has a 380- to 780-nm spectral range, while the PR-735 has a 380- to 1100-nm range. Applications include lamp standards metrology, phosphor research, tooth analysis and military displays.
BFi Optilas
info@bfioptilas.com

Parametric Oscillator

The compact Chameleon OPO (optical parametric oscillator) from Coherent Inc. is an alignment-free, fully automated and computer-controlled device that is suitable for use in multiphoton excitation microscopy. Featuring a wavelength range from 680 to 1200 nm, it offers an optimal penetration depth and minimal sample damage for excitation wavelengths >1 µm. The system's multimodality enables it to function using alternative imaging methods, including coherent anti-Stokes Raman and stimulated Raman scattering, as well as second- and third-harmonic generation. It can simultaneously excite different fluorophores, including green and red fluorescent proteins.
Coherent
tech.sales@coherent.com

Controller Board

The VAC2000 PC/104-Plus multichannel video annotation and overlay controller board from Advanced Micro Peripherals features two real-time analog NTSC/PAL input channels. The boards can mix with one another or with computer-generated graphics and text for TV and VGA output. The device's hardware relieves host processor loading and enables video systems to be created with low-power fanless processor boards. The VAC2000 accepts either two S-video inputs or up to four composite video inputs from video cameras, DVRs, TV broadcasts or other NTSC/PAL sources. Each

input can be alpha-blended with another video channel or with graphics by using one of 256 translucency levels from opaque to transparent.

Advanced Micro Peripherals
gmiddleton@ampltd.com

Telecentric Lenses

Edmund Optics Inc. has introduced its new line of TechSpec compact telecentric lenses for integration into gauging systems. The fixed iris and focus render the lenses suitable for factory floors and assembly lines as well as for robotics applications. The lenses are available in a primary working distance of 65 mm with magnifications of 1×, 2×, 3× and 4×, and with a working distance of 110 mm with magnifications of 0.5×, 0.75×, 1× and 2×. All sizes provide a maximum sensor format of in., distortion of <0.2% and telecentricity of <0.2°. All lenses accommodate a C- camera mount.

Edmund Optics
sales@edmundoptics.com

Spectral Sensors

Mazet GmbH's multirange spectral sensors can be adapted to applications with regard to the number of spectral channels and the spectral transmission characteristics of each channel. The first sensor released in the line offers six spectral channels whose filters, which range from 400 to 700 nm, overlap one another and are uniformly distributed over the range. The compact modules feature parallel signal processing of all spectral channels, a high operating temperature range, long-term stability and high resistance to environmental effects. They are suitable for use in areas where spectrometers cannot fit, and they can be used as microfluidic or basic process sensors, or as hand-held devices for qualitative analysis.

Mazet
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a ADVERTISER INDEX

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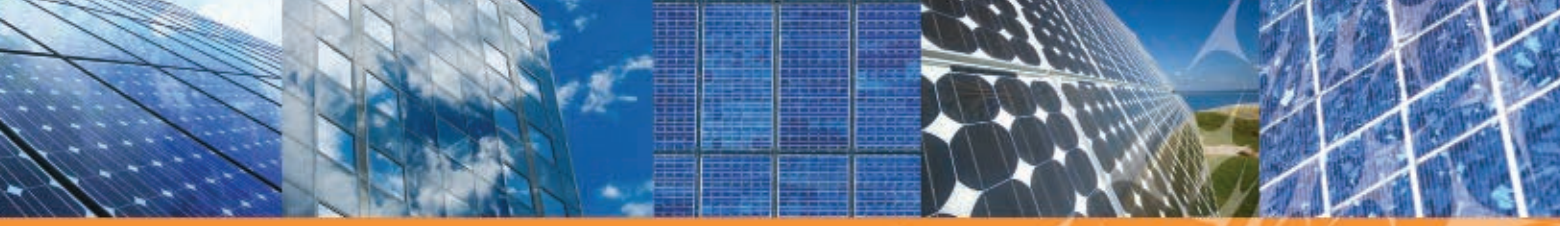

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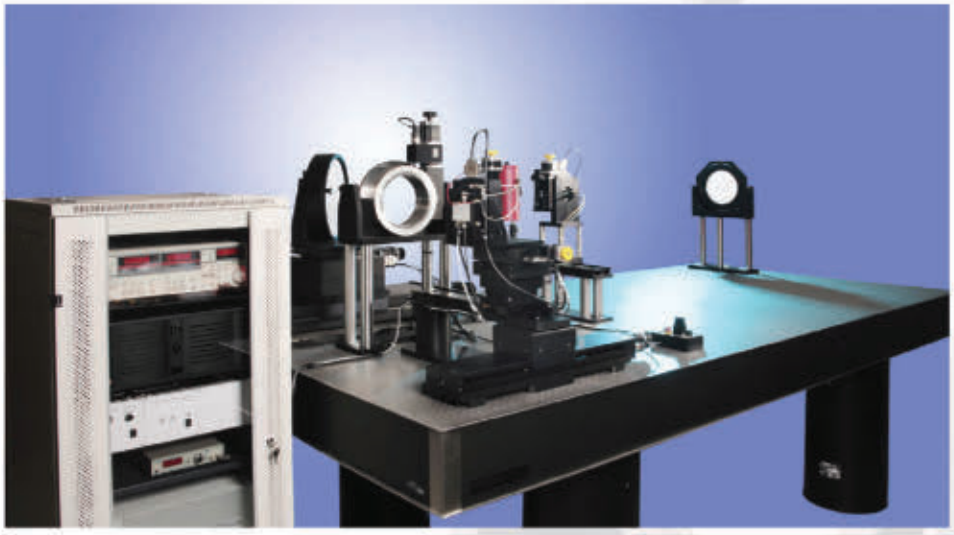

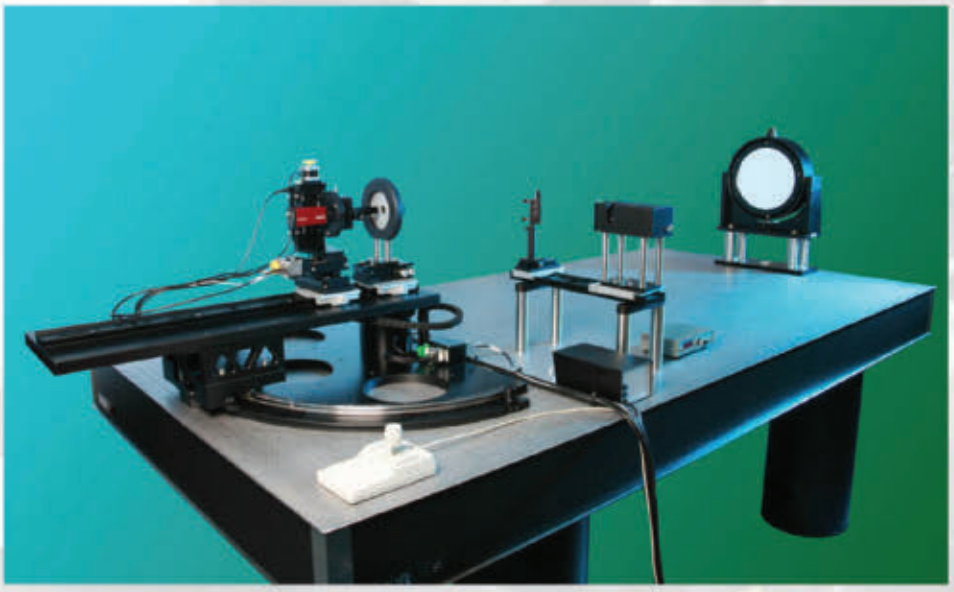

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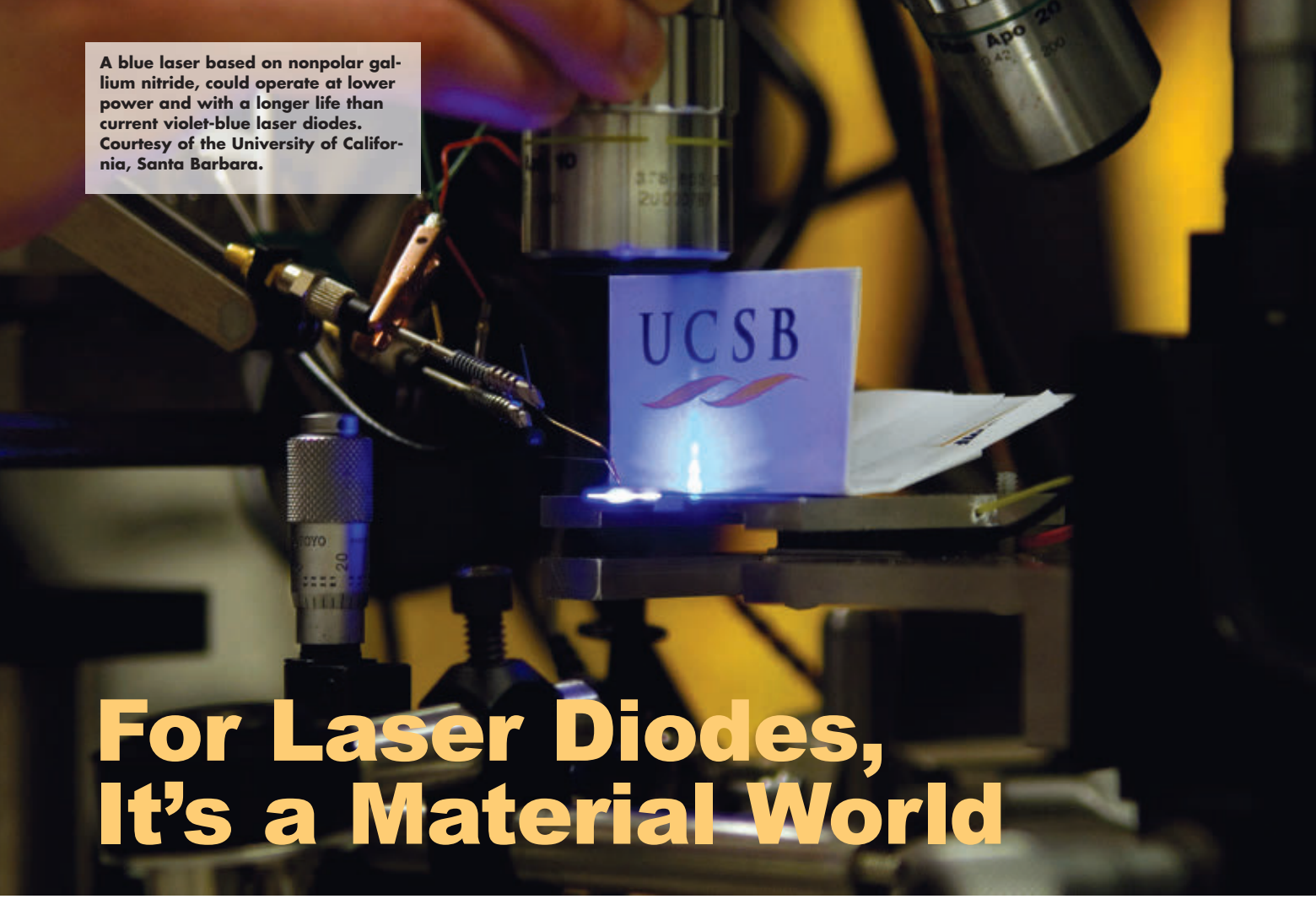


A blue laser based on nonpolar gallium nitride, could operate at lower power and with a longer life than current violet-blue laser diodes. Courtesy of the University of California, Santa Barbara.

For Laser Diodes, It's a Material World

BY HANK HOGAN, CONTRIBUTING EDITOR

Despite the economic downturn, laser diodes keep on pumping – sometimes literally. They often provide the pump for fiber lasers, a market segment that is still relatively strong. However, laser diodes are more than just sidekicks. They also are very useful on their own and in other settings.

No matter the application, there has been some encouraging news lately for laser diodes. For one thing, costs look to be declining. For another, advances involving semiconductor materials promise new types of laser diodes. Other innovations look as if they might lead to a plastic version of the devices. A look at these and other developments reveals some of the trends in laser diodes.

Putting out power

As with light-emitting diodes, laser diodes consist of complementary semiconductor materials that convert electricity into light. Injecting the appropriate current into the device at the right voltage results in lasing, with a material-dependent emission wavelength.

Given that, the choice of the right material can prove an advantage. For example, consider a line of diode laser arrays operating at 1940 nm from Dilas of Mainz, Germany. Designed for medical and industrial markets, these are the first commercially available devices with wall-plug efficiencies that are greater than 10 percent. Jörg Neukum, director of sales and marketing for the diode laser maker, said that, because the efficiency is for a fiber-coupled device, it already accounts for coupling losses.

In building these diode lasers, Dilas had a choice of two material families, gallium antimonide (GaSb) and indium phosphide (InP). Both emit near 2 µm. The company chose to fabricate its devices with the first set of materials for performance reasons, Neukum said. "Our experience is that the gallium antimonide devices are of higher efficiency than the indium phosphide devices in the overlapping wavelength region. The gallium antimonide allows us to select wavelengths between roughly 1850 to about 2300 nm."

He noted that there is a general trend toward higher efficiency and higher power in the industry. There are, however, limits to both. For instance, the energy of a photon at 1940 nm is about half that of one at the commonly used 980 nm. So a longer-wavelength laser diode that puts out as much power as one operating at the shorter wavelength is already generating about twice as many photons, implying that the efficiency of the device structures is already pretty high.

In the future, vendors who seek to increase device power may have to resort to other methods, Neukum said. One possibility would be to do so by increasing media gain, which might involve a longer resonator or other means.

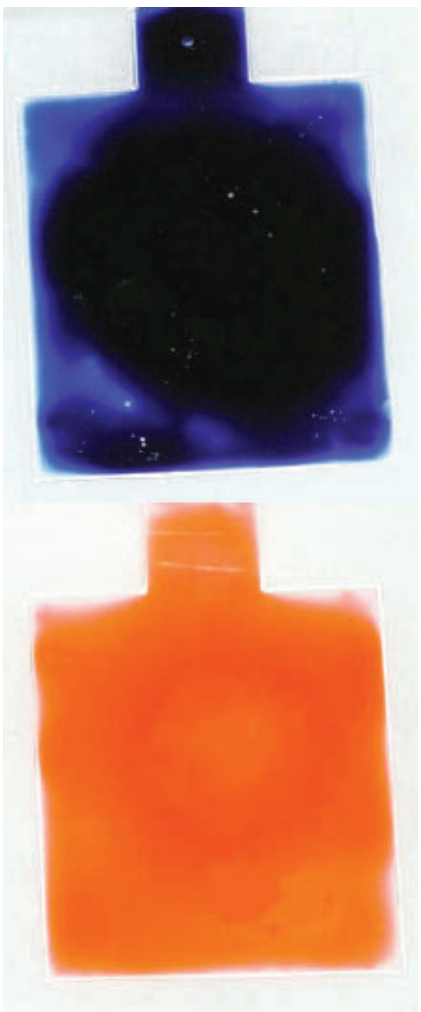
At Coherent Inc. in Santa Clara, Calif., key directions involve improvements both internal and external to the laser diode itself. Stuart Woods, director of direct-diode and fiber laser systems for the company, noted that one reason behind these changes is the need to maximize delivered brightness through such attributes as efficient fiber coupling. Having that capability enables the device to be located some distance away from the point of application while still delivering as bright a beam as needed.

The power demands of industrial users, he added, can be quite high; for example, mainstream welding applications require

3 to 4 kW from a direct diode. Getting to those power levels in the company's products is done through the use of laser diode bars, where many individual emitters sit on a single substrate. According to the company, this approach allows for the greatest optical-to-electrical efficiency to be achieved.

For industrial applications, Woods said there were two challenges. One was getting the most light into the fiber, which in turn would help deliver the highest brightness to the point of use. The second was the serviceability of the system, a key point for the company's target group of industrial users, he said. "Today's customers want the manufacturers to address serviceability openly and in the field – as much as possible."

When asked for examples of an architecture that offers this serviceability and efficient fiber coupling, he pointed to Coherent's recently introduced HighLight 1000F, which can be placed up to 50 m from the application and which offers proprietary microchannel cooled diode laser bar technology as well as a modular design that helps field support.



These polymer films, which are transparent in the visible, can be welded together using 1940-nm diode lasers. Changes in wavelength often can help in materials processing. Courtesy of Dilas.

A fifth a year

As with integrated circuits, which also are made from semiconductors, diode lasers have their own metric for ongoing improvements: higher power at lower cost. It often is expressed as dollars per watt, said Andre Wong, industrial diode laser product line manager at JDS Uniphase Corp. (JDSU) in Milpitas, Calif.

The increase is not a steady march, however. Research and development projects will result in advances, which show up as a step function improvement in performance when products exploiting the new technology appear. "On the average, what we've seen is a 20 percent increase year to year," Wong said.

He added that most industrial applications involve near-infrared wavelengths, although there are some emerging medical uses around 1400 nm. For its part, JDSU is focused on single-emitters, such as its L4 family of products that operate around 950 nm. Company plans call for a continued decrease in cost per watt over the next few years.

Besides lower cost, Wong said that other trends involve longer wavelengths, with medical and consumer products demanding eye-safe emission at 1400 or 1500 nm. Another push is toward greater emission stability, particularly with regard to the center emission wavelength versus temperature. One way to achieve that is to use an on-chip grating that would act to suppress off-center wavelength emission. Such winnowing out of unwanted wavelengths, however, must be done in a way that does not affect output power too adversely.

Avoiding polarization problems

Of course, one way to enhance laser diode performance is to use entirely different materials. Researchers worldwide are doing just that, including a group at the University of California, Santa Barbara (UCSB), which is working on a new version of a familiar laser material, gallium nitride (GaN). Producing blue-violet light, GaN-based laser diodes have found a home in leading-edge optical recording technology, such as high-density DVDs and Blu-ray discs. The violet wavelength of these lasers is necessary to achieve the higher optical recording density of such products.

However, today's conventional GaN devices face an inherent limitation. They are grown with an orientation that results in internal polarization-induced electric fields that, in turn, limit the optical efficiency of the devices.

So the California group has been working to eliminate the problem by creating nonpolar laser diodes. They succeeded a few years ago with the first demonstration devices operating at 405 nm, the same wavelength used for high-density optical storage. Because of their lack of polarization, they should operate at lower power and provide a longer lifetime, potential advantages that are causing a number of companies to look at them for commercial applications, said Steven P. DenBaars, a professor of materials at UCSB.

Since that initial demonstration, the researchers have continued to make progress, he reported: "We've been able to push up the wavelength to 478 nm, which is now in the blue-green spectrum."

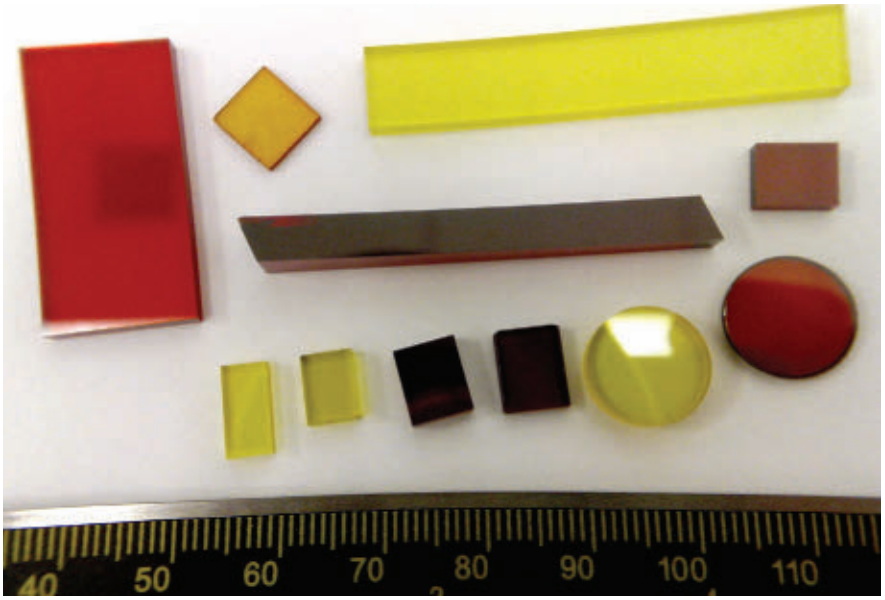
That opens up new applications in projection and other markets. If the devices can get to 488 nm, they could replace argon-ion lasers. Right now the efficiency is about 20 percent, but DenBaars believes a figure of >50 percent can be achieved. That would be higher than what is available from gas lasers, such as argon-ion, or from frequency-doubled lasers.

Currently, the power output of nonpolar diodes is in the few tens of milliwatts range and, hence, still low. However, the researchers are working to improve this. They also are working to implement a vertical-cavity structure for the devices. Doing so could cut the cost to a tenth or less of today's laser diodes of comparable wavelengths.

Asked why such nonpolar gallium nitride devices can now be built, DenBaars pointed to the recent availability of bulk gallium nitride. Previously, devices had to be grown on silicon carbide or sapphire, substrates that made it difficult to produce nonpolar laser diodes.

A longer story

At the University of Alabama at Birmingham, physics professor Sergey Mirov is working on semiconductor laser materials for the other end of the spectrum. He is investigating chromium-doped zinc-selenide laser crystals, which emit in the mid-infrared and are broadly tunable from 2 to 3 µm. The optical conversion efficiency of such lasers can be as much as 70 percent. In the future, the material might lead to



Semiconductor materials, chromium-doped zinc-selenide (red) and chromium-doped zinc-sulfide (green) crystals, could be used for mid-infrared lasers and, perhaps, eventually in laser diodes. These crystals were fabricated at Photonics Innovations Inc.

mid-IR diode lasers that are broadly tunable.

Mirov noted that a tuning capability could be very useful. Water absorbs strongly at 2.7 μm and much less so at other wavelengths in the tunable range. This absorption enables a more than thousandfold dynamic range of penetration of this laser light in soft tissue, leading to a potential application.

"As a laser scalpel, it can be a beautiful commercial system," he said.

Cutting and welding plastics are other potential uses of chromium-doped zinc-selenide lasers. Again, the key is the ability to tune the emission so that it hits an absorption peak of the material being processed.

Mirov is doing his part to make such possibilities a reality. Besides conducting research into lasing materials such as zinc selenide and zinc sulfide, he is president of the Birmingham-based Photonics Innovations Inc., a company he helped found to commercialize the technology.

He noted that chromium-doped zinc-selenide crystals are a mid-IR analog of Ti:sapphire, the workhorse laser material in the near-IR. One problem that has held zinc selenide back has been the difficulty in growing high-quality crystals from it. But, he said, his group has overcome that issue.

The word is plastics

Finally, there is the possibility of a whole new class of laser diodes as researchers work to create lasers using conducting plastics. One benefit could be emission wavelengths virtually anywhere in the visible spectrum, thanks to the ability to tune the electrical and optical properties of polymers across a wide range.

Dr. Paul N. Stavrinou, a physicist from Imperial College London, noted that some recent advances are bringing the creation of such a device closer to reality. For example, the group he is working with reported on the achievement of high conductivity and high gain from the same polymer in a *Nature Materials* paper last year. In the past, he noted, it was either one or the other. Importantly, both seem desirable for a good laser structure.

Other researchers have demonstrated a degree of integration of injection layers and optical gratings into an overall structure. The development of these device architectures is important because a successful polymer laser will have to combine conductive layers, a grating and a gain material in a manner compatible with organic and polymer chemistry.

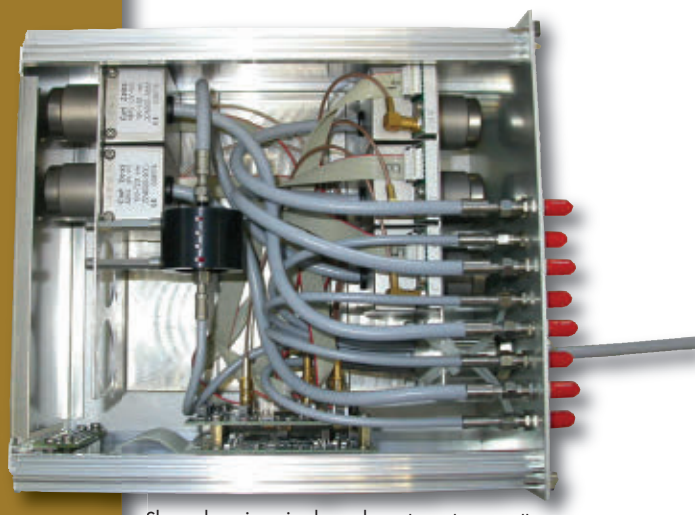
Stavrinou said another hurdle will be in understanding how to achieve continuous- or quasi-continuous-wave operation. He hopes that these problems will be solved, helping to make plastic laser diodes feasible.

Such a reality could be closer than it looks because key developments are at hand, Stavrinou said. "I do think it very likely an electrical injected polymer laser will be demonstrated soon. The elements required are all actively being realized."

hank@hankhogan.com

Multiplexing UV-NIR Spectroscopy Measurements

BY DR. GERT NOLL, TEC5USA



Shown here is a six-channel spectrometer cassette with electronic multiplexer. Photos courtesy of Tec5USA.

Optical coating of large areas has become an increasingly important step in materials processing. Achieving the highest possible performance and respective yield from large panes of architectural glass, solar cells and thin-film layers requires permanent control of the optical performance during production. Several measurement spots across a web are needed to determine optical performance.

For high-throughput process control, only fast-readout spectrometer systems based on detector arrays are appropriate because only they can acquire a full spectrum in milliseconds or less (if a sufficient amount of light is detectable in that short period of time). Such detector array spectrometers have the further advantage of no moving parts, rendering them highly stable devices if assembled by someone with experience in mounting and cementing techniques. This is the key to generating data report after data report in no time with high reproducibility. Since there is no scanning grating or other wavelength-selective element that would have to be moved, all detector pixels see light at all times; no photons are filtered out and, therefore, wasted. This makes a detector array-based spectrometer a very efficient device, ideal for achieving short measurement times.

To measure multiple spots for transmission, reflectivity, color or thickness, a traverse typically is used, transporting the measurement head – or the full spectrometer system – from spot to spot, one after the other. However, the drawbacks of such a setup are the problem of moving larger masses in a reliable way, the time required to move the measurement head to the individual spots and the high cost of traverse setup, including installation.

The perfect solution is to install a complete spectrometer system for each measurement spot. With a modern computer and software, it is no big problem to control more than 10 USB or Ethernet interfaces at a time. But the drawback of the high cost remains, especially if high-performing spectrometers are required.

Multiplexing

To save money, various multiplexing solutions can be applied:

1. Electronic multiplexing

Electronic multiplexing is based on a special electronic device that acts as a kind of operating electronics input expander. One set of electronics consisting of an analog-to-digital converter and a computer interface can handle various spectrometers (Solutions for up to eight N-type metal oxide semiconductor-based spectrometers are available). While using a multitude of spectrometer modules, the saving is on the electronics. Another advantage of this solution is that all spectrometers can be read out nearly simultaneously with a fixed time relationship between all channels.

This spectrometer system has a four-channel fiber optic multiplexer. The prices for optical multiplexers vary with the number of channels required.

No optical parts are moved, and the amount of light detected is not compromised. All spectrometers are sensitive at all times and are constantly collecting incoming photons. The overall measurement time can be as short as it takes to read out all spectrometers, which can be in the range of 10 ms at eight channels of spectrometers, based on 256-element detectors.

2. Optical multiplexing with a blocking device

If a multitude of spectrometer modules is too expensive, optical multiplexing can offer a cost-effective alternative. The most reliable way to do this is to use a setup that does not require any moving optical part. Such a design can be based, for example, on optical fibers that diversify the illumination light into various paths. Mechanical shutters or a chopper wheel are used to block and open the individual paths. Lightguides transport the light to the individual measurement spots and pick up the light to be analyzed; the light eventually is forwarded to one spectrometer. One after another, the individual paths are unblocked, and the measured spectra are allocated to the related channels, thus allowing differentiation among the various measurement spots.

The reproducibility of such a setup is as good as that of one with individual spectrometers, since no optical part is moved. Drawbacks are slower data acquisition, because the mechanical blocking mechanism has to move, and loss in light, because each measurement spot is observed during only a fraction of the overall time required to take the data. The more channels have to be used, the more light is lost.

While it is a feasible technology for two or three channels, losses may be too large for four or more. In this conjunction, it is important to recognize that losses in throughput must be covered by a longer measurement time or by sacrificing signal quality. While still sufficient to perform a transmission measurement, it might not be good enough for a reflectance measurement. The applicability depends strongly upon the task.

With a mechanical shutter approach, up to five measurements per second can be achieved. Switching times can be significantly lower if a chopper rotor is used to block the light, but a good synchronization between the chopper wheel and the data acquisition has to be guaranteed. This requires direct access to the control electronics. The limiting factor might be the amount of light available.

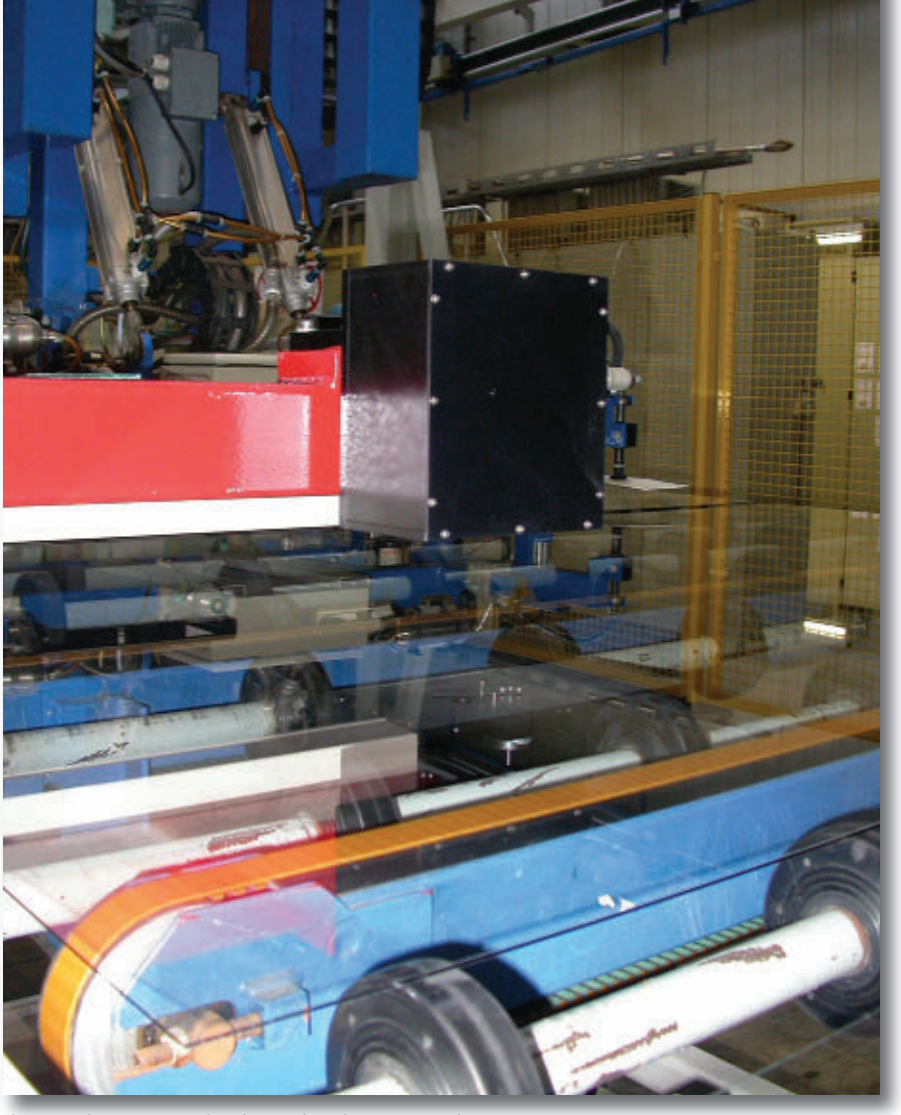
3. Optical multiplexing with a switching device

To overcome the introduction of high losses by a shuttered device, devices that redirect optical light can be used. One convenient solution is a fiber optic switch (or multiplexer). These switches move fibers – mostly driven by piezoelectric elements – so that, for example, the light from various input fibers coming from the sample heads is directed, one fiber at a time, to one output fiber leading to the single spectrometer.

Such switches are available with basic configurations of 1×3 or 1×4. If more channels are required, these basic elements can be daisy-chained to create, for example, an eight- or nine-channel switch. The losses of each step add up, which causes a decrease in throughput. However, the losses are much less compared to those with the shutter solution. Even an eight-channel switch has an efficiency of more than 50 percent, while an eight-channel shutter solution may have, at best, 10 percent.

The drawback is imperfect reproducibility: Short-term reproducibility values are in the range of 0.1 percent; long-term values are in the 1 to 2 percent range. And switching takes time. In this solution, as opposed to the shutter solution, the optical part not only has to be moved, but it also has to relax (stabilize again). Data rates higher than 20 spectra per second are tricky to achieve, and reproducibility may suffer at switching rates too fast, since the moved fiber might not relax enough.

The prices for optical multiplexers vary with the number of channels required, but the price per channel is lower than the cost of a good-quality spectrometer module.



This optical measurement head is used in glass pane production.

Referencing

Measuring several channels more or less simultaneously offers the benefit of having a permanent reference channel available. Instead of using one channel to observe another measurement spot, it can be directed to, for example, a mirror (for reflectivity measurements) or a flat uncoated piece of glass (for transmission). Such referencing helps to eliminate drifts present in all light sources or originating from contamination of optics, depending on how the actual setup is executed. If only one spectrometer is used, time-dependent errors of the spectrometer module itself, such as sensitivity change due to a temperature increase, can be automatically corrected.

A flashlamp has the advantage of low maintenance because the lifetime of a xenon bulb is quite high (billions of flashes), but a drawback is the high pulse-to-pulse variation in the percent regime. In combination with electronic multiplexing, one spectrometer can be permanently dedicated to observing the source and thus improving the stability of the measurement results by an order of magnitude. Sequentially operating an optical multiplexer cannot accomplish this; only simultaneous operation of multiple spectrometers will work. Such referencing can improve the signal quality by an order of magnitude.

Multiplexing can improve the amount and the accuracy of measurement data taken. However, there is no general overall solution. The various possibilities must be checked against individual needs to find the best approach. Features such as speed of measurement data acquisition, intensity level of the signal to be detected, accuracy demand, measurement principle, environmental conditions and, of course, cost have to be considered.

Meet the author

Gert Noll is the general manager at tec5USA in Plainview, N.Y. Tec5USA is the US subsidiary of tec5 AG in Germany.

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LEDs Shine at Work

BY ANNE L. FISCHER, SENIOR EDITOR

Technology is the great catalyzer, catapulting the LED industry forward by enhancing existing applications and enabling new ones. Many technological advances are pushing LEDs away from the old single-color realm where they were used for specific applications such as emergency exit signs or brake lights, and closer to a domain where they play more versatile roles as replacements for the everyday white lightbulb, street lighting, surgical lighting and more.

Getting the light right

Producing LEDs that illuminate our homes and streets – or even our skin, as in surgical applications – would be impossible without advances in phosphors, materials and packaging. Natural white light is measured by the color rendering index (CRI), which is based on the light's ability to produce the truest color of the object being illuminated. Skin, for example, looks best when illuminated by a light source with a CRI of 70 or more.

Phosphors are chemicals that glow in various colors when excited and combine to form white light. Phosphor technology is one of the most active areas in chip development, according to Dr. Ralph Wirth, head of conceptual engineering for components at Osram Opto Semiconductors in Regensburg, Germany. Wirth sees phosphor combinations as "door openers that enable new applications." Osram recently released several new chip designs, all of which use phosphor conversion. "The main applications all use white light," Wirth noted. He said that Osram develops chips that allow customers to capitalize on the unique benefits of the LED. The main task with the new chips, he noted, was to improve the extraction efficiency and reflectivity to make the most of the light.

Sharp Corp. makes use of an advanced phosphor process with its new white-light LEDs with a CRI of 80, which is achieved through a combination of a blue LED die covered with a mixture of green and red phosphors. These LEDs are intended for applications including photography, store windows and decorations, where it's important to see the true colors of products, and surgical lighting, where seeing the exact skin color is necessary.

Another approach to using LEDs in medicine is to squeeze the light through a fiber optic illuminator. PerkinElmer of Waltham, Mass., recently introduced a lighting solution that uses an optical light engine that squeezes high-intensity white light into 3- to 10-mm fiber optic bundles. By means of proprietary drivers and software, the light can be dimmed without losing its color temperature, pattern or uniformity, according to Joel Falcone, vice president and general manager of PerkinElmer's global illumination business.

This fiber optic illuminator can be used in endoscopy, microscopy and machine vision. In endoscopy, for example, it replaces conventional light sources such as halogen and xenon, which Falcone noted have a limited lifetime and consume significantly more energy. LEDs, by comparison, have a lifetime 10 times that of conventional light sources. Falcone added that, "Eliminating the need to replace the source lamp every 12 months provides the hospitals and practitioners a significant

LEDs illuminate a parking lot at the University of Alaska in Anchorage. (AP Photo/Matt Hage)

Before and after images show the effect of LED lighting fixtures that were installed in the downtown Chapel Hill, N.C., as part of Cree Inc.'s LED City initiative. Photos courtesy of Cree.

cost savings opportunity, and it is environmentally friendly."

Energy smarts

One of the greatest drivers for many industries right now is energy savings, and the big push in the lighting industry is to increase the output of lumens per watt. The US Department of Energy (DoE) has set a long-term research goal of 160 lumens per watt in "cost-effective, market-ready" LEDs by 2025. The industry is not far from that goal. In April, Cree Inc. of Durham, N.C., announced white LEDs with 139 and 132 lumens per watt at 350 mA.

Adding to the DoE push is a performance threshold for lightbulbs as mandated by the Energy Independence and Security Act (EISA) of 2007. New research is going into incandescents and compact fluorescents to try to meet or exceed the thresholds, but high-brightness, high-efficiency LEDs already have a leg up in terms of efficiency. Advances inside the LED die and package that reduce refraction losses, as well as advances in thermal management contribute to efficiency gains. Paul Scheidt, product marketing manager for Cree's LED components group, noted that other optimizations – such as increased light output, reduced forward voltage and improved phosphor system efficiency – further increase performance and efficiency. He added, "We know how to create LEDs that purely optimize for efficiency, but the real question is this: Does that super-efficient LED produce light that people would actually use?"

According to Scheidt, other sources of light, such as low-pressure sodium, are also efficient, and they're relatively inexpensive as well. But the problem, he said, is that the light is a "yucky yellow brown that makes it impossible to tell the differences in color under the lights." Creating light that is pleasing will help drive LED adoption.

LEDs are used in grocery store refrigeration cases and other applications and seem to be passing the consumer eyeball test. In a survey conducted by Rensselaer Polytechnic Institute's Lighting Research Center in Troy, N.Y., shoppers chose LED over fluorescent lighting because LED lighting is brighter, more even and makes food labels easier to read. Refrigerator and freezer applications are great uses for LEDs because they like the cold. Couple that with all the other benefits of LEDs, and not only are the shoppers happy, but the store owners also benefit from reduced overall costs. A report by General Electric, which produces LEDs for grocery store refrigeration units, estimates that if a retailer were to replace fluorescent lamps for 100 refrigerated case doors in each of its 100 stores, it could save more than a half-million dollars a year and reduce carbon emissions by more than 5.2 million lb – the equivalent of planting more than 650 acres of trees a year (based on 24/7 operation at 10 cents per kWh).

While lighting in the grocery store affects many people, the ultimate consumer use for LEDs is replacement lightbulbs. We still can't buy them at our neighborhood hardware store, but LED bulbs are now popping onto the market. And although prices are high compared with other types of lighting, costs are expected to go down as production goes up. Lighting Science Group Corp. of Westampton, N.J., the company behind some of the most visible LED applications in the world, including the 2009 Times Square New Year's Eve Ball and 7 World Trade Center, recently announced an LED lightbulb. Fred Maxik, the company's director and chief technology officer, said that efficiency has at least doubled in the past 24 months, to the point where we're approaching "a true replacement on a lumen-for-lumen basis." The new lightbulb screws into a traditional socket and replaces a 60-W incandescent or 13-W fluorescent bulb. It uses 7.4 W and is expected to last six times longer than the average compact fluorescent. The bulb is expected to cost $25.

Setting the standard

Standards are important in the bulb replacement market. The consumer information that the LED lightbulb industry will provide on its packaging – and that consumers have become accustomed to read-

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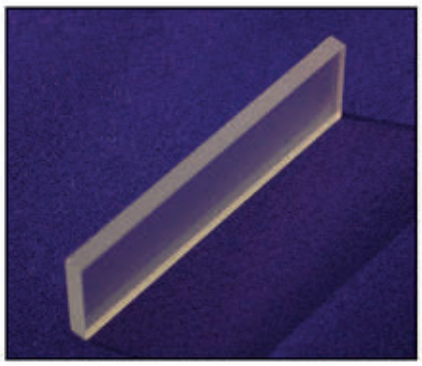

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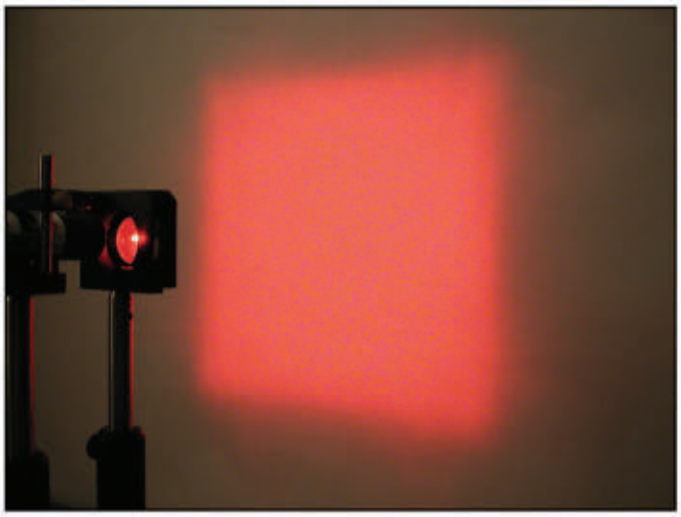

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ing when buying incandescent bulbs – will benefit the industry. About a year ago, the Illuminating Engineering Society of North America published the LM-79 standard for testing solid-state lighting products, giving the lighting industry benchmarks that have enabled lighting designers to concentrate on innovations such as LED lightbulbs, optical control and more.

The standard gives photometric information on lumen output and intensity, chromaticity coordinates, correlated color temperature and the color rendering index for solid-state lighting products. Electrical information includes current, voltage and power. What the standard means, according to Scheidt, is that LED luminaires are all measured consistently. He equated the standard to the US Environmental Protection Agency gas mileage for cars. "Without that standard, car makers could each decide how to measure mileage, and you probably couldn't compare the numbers from one maker to the numbers from another. LM-79 serves a very similar purpose for the LED lighting industry."

By using LEDs to light up a parking garage at Tufts University in Boston, Lighting Science Group estimates an energy savings of 56 percent over what was consumed by the metal halide fixtures previously used. In addition to savings on the electric bill, there are the longevity and maintenance factors. With advances in thermal designs, LEDs are expected to last 50,000 hours, which is 50 times the life of a typical incandescent bulb and five times the average for a compact fluorescent. Bulbs that last 50 times as long as other lighting sources are changed 50 times less often, thus dramatically reducing maintenance costs. In the Tufts garage, for example, savings on energy and maintenance is expected to be more than $27,000 with a three-year payback.

Signage and street lights are additional applications where reductions in maintenance costs are driving increased use of LEDs.

No stopping now

The science of solid-state lighting is still relatively new and rapidly advancing. Yet we've crossed a threshold, according to Nadarajah Narendran, director of research at the Lighting Research Center, "where performance is comparable [to] or better than traditional lighting." Companies are taking different approaches to creating solutions to meet the requirements for specific lighting applications and, as Narendran pointed out, quality can vary. But as quality goes up and price comes down, LEDs will become predominant in street lighting, parking garages, store lighting, freezer cases, building interiors and exteriors, and more.

LED technology also has capabilities that will extend beyond general illumination. The tunability of LEDs is one area of research that may have an impact on how light affects biology. As Lighting Science Group's Maxik explained, by enhancing or removing certain areas in the spectral waveform, we may be able to change the pattern of disease or to enhance vision. The science of light is also advancing from a materials angle, giving designers more control over the shape, quality and intensity of light coming out of the fixture, which can reduce or eliminate light pollution. The bottom line is that LEDs are no longer the lighting technology of tomorrow – they are here today in use in myriad general illumination applications.

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Getting it right with high-performance ISR windows

In intelligence and surveillance applications, superior performance is a must.

BY DR. M. ROMAN HACHKOWSKI, ZYGO CORP.

High-precision windows used for intelligence, surveillance and reconnaissance (ISR) applications can be as large as 0.9 m and must be transmissive at various visible and infrared wavelengths, with a significant focus in the IR. End-user applications range from high-altitude identification and surveillance of enemy threats, to naval sensing systems used onboard ships and submarines, to civilian systems used in law enforcement and on commercial aircraft.

Given the expanding capabilities of sensor technology and the increasingly stringent requirements of missions, ISR windows must exhibit superior performance with respect to transmitted wavefront error so as not to negatively affect overall system operation. Furthermore, performance must be maintained while the window withstands harsh environments such as blowing desert sand, high-speed aerial impacts and ocean conditions. The fabrication processes used to manufacture ISR windows will greatly influence the lifetime of the windows and the success of their missions. To maximize window strength and performance while providing extended mission lifetime, critical trade-offs must be considered when selecting the window material, shape and manufacturing process.

Six requirements

In manufacturing an ISR window, six critical requirements that directly influence application performance must be considered:

- Provide a large clear aperture relative to overall part size
- Maintain defect-free edges and optical surfaces
- Manage subsurface damage and window perimeter conditions
- Monitor overall wavefront performance
- Assess material properties: strength, birefringence, transmission
- Determine coating performance and durability

Other important factors include delivery time of specialized materials such as Cleartran, sapphire, high-quality silicon and fused silica. One also may want to include extended fabrication time required for window sizes larger than 0.3 m.

As with any manufacturing process, the first step is inspection of incoming material. Critical delivery risk can be mitigated by using large-aperture Fizeau interferometers ranging from 102 mm to 0.8 m in diameter to qualify the bulk optical material or identify issues that could be problematic during fabrication.

The next step in fabricating ISR windows is the control of edge surfaces during the computer numerical control (CNC) process. During this step, it is necessary to machine-edge surfaces that are free of fractures and chips while producing a fine-ground surface that is close to being specular, which is a measure of being fracture-free. Because windows are fabricated from either glasses or ceramics that have high bulk material strength, the absence of edge fractures enables the window strength to be near the innate bulk material strength. Because many of the IR/VIS materials also have significant birefringence effects, it is necessary that these operations do not introduce additional material stress that will affect wavefront performance.

After CNC operations, both surfaces of the window undergo grinding and polishing. An efficient grinding process must exhibit significant material removal and must not introduce additional subsurface damage or local surface defects. To achieve this, one can employ a multistage process that uses various grinding techniques or a highly refined grinding process that offers significant material removal

Shown is an 8 × 3-in. sapphire window with polished bevels and edges.

rates while meeting the subsurface damage criteria.

Because polishing processes have the lowest material removal rates, high-speed polishing can be used to remove any remaining subsurface damage layers quickly. High-speed polishing has limited figure control, so one must include either single- or double-sided polishing and/or computer-controlled polishing as part of the final process to correct the remaining figure errors. It is at this time that the effects of stress from coating or grinding must be compensated for to maintain surface figure. Again, full-aperture high-resolution interferometry is desirable to guarantee overall quality.

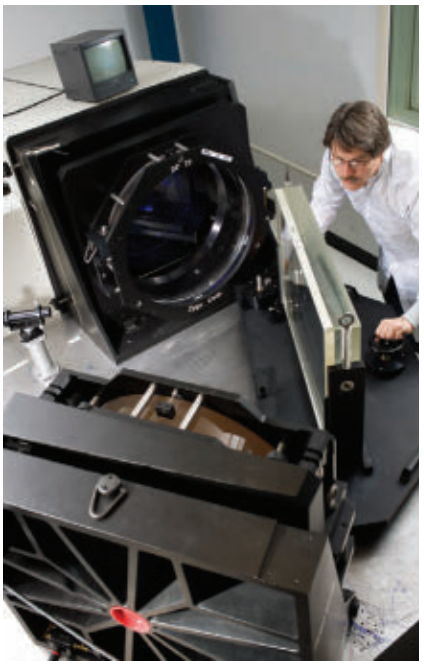
Because optical material costs are often greater than fabrication costs, there is an emphasis throughout the manufacturing process on proper equipment and handling procedures. Any minor damage to the optics affects both the performance requirements and delivery schedule, which will have a detrimental impact on the overall program schedule. Extensive processes and material handling capability are a must to mitigate damage or scrapping of production optics. Throughout all of the fabrication work areas, overhead cranes and lifts as well as specialty tooling are installed to ensure that all optic moves and lifts are operator- and glass-safe.

The final polishing process (preferably deterministic) requires simultaneous solving of three nonlinear equations to satisfy the customer's physical requirements for thickness, subsurface damage layer and wedge, while ensuring that the surface/transmission wavefront errors are minimized across a range of spatial frequencies. This also ensures that final surface roughness and defect requirements are met. If any of these nonlinear relationships do not converge at the same time, the final polishing process time can be greatly affected.

Gaining control

By implementing deterministic polishing processes, one gains added control of the subsurface damage layer as well as of the subsurface deformation layer within the optics. All of these procedures increase performance in many of today's most demanding ISR applications.

Another requirement growing in demand is the need to apply complex coatings and/or electromagnetic grids to the optical surface(s). These additional treatments greatly influence the surface/transmissive qualities of the window by introducing shear stresses to the entire surface. These stresses "pull" the optical surface and change the shape and wavefront performance of the window. Analytical tools and fabrication techniques remove these effects by imparting or imprinting the conjugate (or negative) shape into the surface so that it is flat after the coating application.



This 2-in.-aperture Fizeau interferometer measures optic wavefront error.

ISR Windows

The last critical element in the fabrication of ISR windows is extensive surface inspection. The results from this inspection process support optical specifications as well as the bulk strength necessary to meet the mission dynamic requirements.

By focusing on the various fabrication and metrology issues, manufacturers can deliver optics that not only meet the system's performance requirements but also expand the mission capability of the payload while providing the benefits of an extended life cycle. If manufactured properly, ISR windows can be exposed to high dynamic loads and extreme environmental conditions whether on the ground, at sea or in the air. These windows will continue to exhibit superior performance with respect to transmitted wavefront error so as not to limit the sensing qualities of the internal payload behind the windows. The windows that are the final result will greatly influence the success and lifetimes of their missions.

Meet the author

M. Roman Hachkowski is optical products and technology director at Zygo Corp. in Middlefield, Conn.; e-mail: rhachkowski@zygo.com.

Technicians man a 168-in.-diameter single-sided continuous-polishing work center.

East Asia Photonics Industry: Rising to Opportunity

BY CAREN B. LES, NEWS EDITOR

Views from China

Affected by the global economic downturn, the output of some optical manufacturing enterprises in China hit bottom between the fourth quarter of 2008 and the first quarter of 2009, but production has been going up from the second quarter of 2009, according to Xin Qi Ming, associate lead professor of the Optics Manufacturing Subcommittee of the Chinese Optical Society and deputy general manager of Chengdu Crystal Technology Co. Ltd. in Sichuan, China. He added that a great number of businesses making traditional optical glass lens elements based on foreign orders have undergone the most difficulties. He said he feels positive about China's photonics technology market not only because of the eventual recovery of the international economy but also because of a great demand in China for photonics products, among them consumer-related items, medical instruments and energy-saving LED sources, because China, with a population of 1.3 billion, is getting richer and is home to a trendy younger generation.

For a very long time, many of China's optical enterprises have been producing optical products for relatively low-technology items such as binoculars and civilian gun sights, said Xin Qi Ming, who added that these products, at their highest production level, achieved a 70 to 80 percent share of the global market. He said that some of the companies mainly make glass spherical elements and prisms for digital cameras, camcorders and projectors for some famous foreign enterprises. A recent development has been the mass production of the lenses for camera modules in cell phones – lenses that consist largely of optical plastic aspheric elements, he said.

Medical instruments

When asked his opinion about photonic technologies that are predicted to show significant growth in China in the next few years, Xin Qi Ming said that he expected to see a rise in such technical fields as lasers, optics, bio-optoelectronics, optical engine devices and laser medical instruments. He gave as an example that almost all of the limited number of laser medical instruments in China's major hospitals have foreign brands. With the reform of the medical system in China, community hospitals will increase rapidly, so it will be necessary to add a great number of medical instruments.

Optical components and devices still will be the major products of the Chinese photonics industry in upcoming years, but some new photonics-based products are likely to rapidly find a place in future markets, said Xin Qi Ming. Ascending technology may include medical equipment, pico- and pocket projectors for mobile displays, power LEDs for the optical engines of microdisplays and energy-saving illumination, new efficient photocells for sustainable energy sources, detectors for environmental protection, and new manufacturing and testing equipment, he said.

The latest innovations and emerging photonics technologies in China, he said, may be mobile displays and LED illumination, and the related design and manufacturing technologies, such as injection molding and coating of optical plastic steep aspheric elements, optical plastic free-form fabrication, optical glass aspheric precision molding and refractive-diffractive hybrid lens making.

Challenges for China

Because of the lack of globally popular famous-brand photonics products in China and a shortage of personnel for the research and development of products and technology there, R&D personnel and manufacturers in the photonic industrial chain face the challenges of designing and making new products that will be welcomed by consumers at home and abroad.

Xin Qi Ming suggests that an effective way to meet these challenges and to bolster China's photonic businesses would be to attract science and technology personnel from colleges and universities, research institutes and foreign technical teams to join in the development of products and technology for these enterprises. In his opinion, the main goals of China's photonics industry in the near future would be to upgrade the photonics industry in eastern China, to phase out or transfer to western China some traditional spherical element fabrication capacity, and to speed up the development of products and technology by taking advantage of the economic downturn.

The best bridge

New photonics products and technologies in China generally originate in some colleges and universities, or research institutes, mainly because China's optical businesses lack sufficient capital and R&D strength, according to Xin Qi Ming. He said that only a small number of research achievements become commercially available, while many others are shelved after

the related experiments and papers are completed. This well-known business problem, an old story, arises from the inadequate integration of production, education and research, he said.

Acknowledging that such a systemic problem cannot be overcome quickly, he said that it is gratifying that a group of ambitious medium- and small-scale entrepreneurs in China as well as some science and technology personnel returned from foreign countries have come to the forefront, delighted to absorb the world's advanced technologies and to transform them into new products. They may be building the best possible bridge between research and commercialization, he said.

New strategies

During this very critical and difficult global economic time, some areas of our business have been negatively affected, such as classical optics and those related to the information technology and semiconductor sectors, according to professor Song Fei Jun, executive vice president and chief technology officer of China Daheng Group Inc. based in Beijing, a specialist in photonics components, laser processing and medical equipment, including optical components, modules and optomechanical-electronic subsystems.

Song Fei Jun added that other areas of the business, notably medical devices and life science instruments, have been largely unaffected and even very active. He said that increased revenue in those areas has greatly compensated for the amount lost in classical optics sales. On average, the revenue and profit for Daheng Optics (a subsidiary of China Daheng Group) from January through May 2009 have been similar to corresponding figures reported in the past two years. His strategic consideration has been to turn the development into areas of emerging business while maintaining the classical optics business and the relationships with longtime customers. The company's recent innovations include some precision measurements, such as highly accurate optical phase retardation testing up to λ/500.

Fali Xie, president of Castech Inc. In Fuzhou, Fujian, China, a manufacturer of crystals and optics for laser applications, said that the company's sales have been influenced by the economic recession because more than 80 percent of the company's products are exported to the US, Europe and the Asian region. On the other hand, he added, the company is benefiting from the rapid development of laser applications in China, and its big challenge and opportunity is to win more market share there.

Singapore

Castech's recent new products include a 60-mm-long Nd:YVO_4 crystal with high inner quality and low bulk absorption as well as segmented grown YVO_4/Nd:YVO_4 crystals for high-power diode-pumped solid-state laser systems. It has recently expanded its product line in magneto-optical terbium gallium garnet crystals, an optimal material for Faraday devices for YAG, Ti:sapphire, tunable, ring and injection-seeded lasers. Currently in development at Castech are dual beta-barium borate crystals for Pockels cells for lower operating voltage.

As for the future, Fali Xie said that the company plans not only to pay close attention to quality and production cost control of its leading nonlinear optics and laser crystals, but also to develop a series of laser and telecommunications optics and components – including lenses, prisms, wave plates and polarizers – to encourage customer purchasing and to cut costs.

Product development

John Ling, chief executive officer of Photop Technologies Inc. of Fuzhou, Fujian, China, said that the company has more than 150 approved or pending patents on optics, lasers and optical communications and employs more than 200 engineers dedicated to R&D and new product development, from a total of 3100 staff members. The company is a photonics designer and integrated products supplier for optical communications, commercial and consumer optics, and laser applications.

Bejing

Recent company developments, he said, include the smallest green laser for commercial and industrial applications, advanced optical components and high-end modules for 40-G/100-G optical networks, fiber-coupled lasers and optical assembly for biomedical instrumentation, a series of new crystal materials, and new product development for LED and laser-based projection displays.

Generally speaking, Ling said, the company is facing challenges relating to its ability to develop products for new customers in a highly concentrated market and to commercialize these products. Other hurdles include managing growth and responding to competitive pressures. Some of the company's legacy products and volume production lines are affected by the global economic downturn, especially in the business sector of consumer products, he added.

As for goals, Ling said that the company aims to maintain continuous two-digit growth for the next two years and to strengthen its position in the market as a leading supplier and integrated manufacturer of crystal materials, optics, microchip lasers and optoelectronic modules with a main base in China. Among its strategies for achieving these goals are to grow revenues and increase margins within the existing customer base by cutting costs, to continue investing in technologies, to focus on high-growth products and market opportunities, and to improve its manufacturing process.

Collaboration welcome

Photop also is looking forward to establishing partnerships with industry leaders in the optical communications, biomedical systems, and laser and optical instrumentation sectors, Ling said.

Nanjing Sapphire Electro-Optics Co. Ltd. of Nanjing, China, has advanced equipment, an experienced technical force and a strict quality assurance system,

Nanjing

according to Pauline Liang, CEO of MPA Crystal Corp. of San Jose, Calif., which is the US branch of Nanjing Sapphire.

The Chinese company's products have earned a very good reputation in the world's optical components market – 90 percent of its products are sold to the North American and European markets, Liang said. The company specializes in producing high-precision crystal optics using its cold optical processing technology on crystal materials such as sapphire, fused silica, single silicon and optical glass. Its sapphire optics have applications in laser technologies, optical instruments, medical devices, and in space technology and equipment.

Among the company's goals for the next few years are expanding its capabilities, improving its current product series, developing new products and becoming more competitive, Liang said, adding that the business recently upgraded to a new 108,000-sq-ft facility. It welcomes other companies to join it to develop new products and invest in them.

At Changchun Boxin Photoelectric Co. Ltd., based in Changchun City, China, the number of employees has increased from 50 to 120 since 2008, according to Jenny Zhang, a company representative. The company's major products are optical components, coatings, crystals and lenses. Zhang said that many experienced engineers are on staff and that a classical polishing method is used to make the products, which are supplied to customers worldwide.

Quality control and delivery time are the major challenges facing Changchun Boxin Photoelectric right now, Zhang said, adding that the global economic downturn is not affecting the company so much at this time. Its major goal is to increase profit at least 10 percent each year.

Voices from Japan and Singapore

Tadahiko Shimazu, director and general manager of the accounting division of Hamamatsu Photonics KK, based in Hamamatsu, Japan, said that the global economic downturn has had a great impact on the company, and it is going to suffer a sales loss to the extent that it has not experienced in the past 34 years. The company produces photoelectric transducers such as photomultiplier tubes, light sources, opto-semiconductors, image sensors, laser diodes, and light-related modules and instruments for applications in areas such as spectroscopy, automotive, medical instrumentation and semiconductor failure analysis. It has produced innovative products for detecting low-light-level and ultrafast phenomena, and emerging technologies include fabricating miniature-size products and microelectromechanical systems technology.

The company's major goal at this time, according to Shimazu, is to recover from the downturn as quickly as possible and to build growth prospects in preparation for a paradigm shift.

In Singapore, the photonics market still has room for growth because the country is equipped with the infrastructure necessary for more multinational companies to set up manufacturing sites, according to Chee Kim Wui, senior business manager (civil optics) at Qioptiq Singapore Pte Ltd. He added that, in his opinion, the growth of photonics manufacturing in Singapore is limited by the number of photonics experts available in Southeast Asia. The lack of optics-trained engineers has hindered growth, he said, and the company is working with a local government agency to improve this situation. China is the nearest country from which experts in photonics could be imported, he said.

Qioptiq Singapore works in the area of components and assemblies for high-end optical parts, both in the civil and defense sectors. The company's civil optics division goes into various product segments, such as medical imaging devices (coupler and ophthalmic products), medical and semiconductor inspection equipment, large-venue and high-end rear projectors, filters for life sciences research and scanning equipment.

Chee Kim Wui said that there are pockets of growth within the civil sector that have shown encouraging signs for Qioptiq. Among them are the mid-tier equipment and nonselective medical care sectors, the demand for high-definition imaging, and the migration of analog to digital media, along with projection of these media.

He said that, to keep pace with the demanding consumer market, the company will continue to work on innovation and to upgrade its capabilities.

Notice that clear optical vision comes before action, he said, and welcome to the decade of optics!

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Improving Human Interactions in the Science Lab

BY DAVID L. SHENKENBERG, FEATURES EDITOR

Although scientists need to interact with one another in a laboratory environment, they typically receive no training in resolving interpersonal conflicts. According to Carl M. Cohen, a management consultant who specializes in training scientists, "There is a tendency in science to focus on objective issues and to believe that the correct argument will always win based on science, but, in reality, there are all kinds of factors that play a role."

Cohen should know. He was a science professor at Tufts University, and he held various management roles at St. Elizabeth Medical Center in Boston before going on to executive roles, including vice president and chief operating officer, at several Boston-area biotechnology companies.

Cohen's experience has shown him that the personnel issues in academic labs, small companies and corporations tend to differ. "In academia, it's all about getting credit for your work; students are frequently in conflict with their advisers and peers [because they are all] jockeying for advancement and recognition," he said. This individual-achiever mindset can create huge problems in a teamwork-oriented company environment. In large corporations, conflicts often are more subtle than in small companies. "I once consulted to a [large] company that actively discouraged the use of the words 'problem,' 'conflict' [and] 'disagreement,'" Cohen said. "In fact, there was a lot of conflict beneath the surface that wasn't getting dealt with."

Other common disagreements that can arise in the lab include arguments over shared equipment and space, as well as over cleanup. The lack of personal hygiene or professional attire also can cause friction.

Conflict resolution is best achieved by addressing problems in a way that is reasonable and fair. "If your leaders solve problems through intimidation, are demeaning of others, ignore conflict and hope it will go away, then others in the organization will learn this is the culture and will do the same," Cohen noted. His book, *Lab Dynamics: Management Skills for Scientists*, goes into more detail about these issues.

Question of allegiance

"Scientists don't like to be managed, so you have to be careful with how you manage them," said L. Wayne Collins, who has a 20-year history of lab management, primarily at Solvay. He suggests managing "more through persuasion than authority."

Collins said that allegiance to science often is at odds with allegiance to the company. For example, scientists want to have solid evidence before making a claim, whereas sales and marketing people often want to use "good enough" answers.

Although scientists with the best technical skills usually are promoted to lab management positions, technical wizards are not always the best managers. Effective lab management requires excellent "people" and business skills. Scientific credibility is important but not foremost on the list.

In many cases, it is often unknown whether the outcome of a science experiment will lead to a marketable result. Lab managers must decide where to focus the company resources. They also need to convey enthusiasm to their teams in the face of uncertainty. According to Collins, one way that scientists can learn people skills is through Dale Carnegie training.

Various models have been developed to increase employee performance, including two called Six Sigma and SMART. In the down economy, there has been a trend toward the lean laboratory, which is about eliminating waste. The Six Sigma model is similar to the lean laboratory model in that it looks for defects. The SMART model – an acronym for Specific Measurable Actionable Relevant Timely – is about evidence-based performance.

The pay-for-performance, or agency, model is another one to consider. Harvard Business School professor Robert D. Austin argues that this model applies poorly to knowledge workers because they often go into a field because they enjoy it, not because of bonus pay. He suggests playing up their love for the job and encouraging collaboration and professionalism.

Sometimes terminating the employment of a lab member becomes necessary. The reasons for termination can include forging data and credentials. "There is zero tolerance for that sort of thing," Collins said.

"One strike and you're out." Or a scientist simply might fail to perform the required functions of the job, even after extensive counseling.

Secrets of success

One helpful way to learn lab management is to take a course. That is why several institutions organized the San Diego Lab Management Symposium.

The course is geared toward postdoctoral researchers considering faculty positions at academic laboratories. The kinds of topics discussed include startup projects and budgets, time management, hiring staff, leadership styles, finding an academic job and navigating the tenure process. Past sponsors of the course include The Scripps Research Institute, Burnham Institute for Medical Research, the Salk Institute for Biological Studies and the University of California, San Diego.

Career fears often arise when searching for that perfect faculty position. "Career concerns can be closely tied to unclear professional goals or conflicting values," said Ryan Wheeler, who counsels postdocs and graduate students at Scripps. "I help [postdocs and grad students] examine their own interests, skills and values in order to clarify options," Wheeler added. "I also provide tools and approaches for constructive communication and goal-setting with their advisers."

The Burroughs Wellcome Fund and the Howard Hughes Medical Institute have produced a comprehensive guide to managing science labs called *Making the Right Moves*. All 13 chapters of this e-book are freely downloadable to anyone with Internet access to www.hhmi.org.

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As consultants, Carl M. Cohen and his wife, Suzanne L. Cohen, a psychologist, run workshops on- and off-site throughout the country via their company, Science Management Associates (www.sciencema.com). They also do individual training and coaching.

L. Wayne Collins is a past president of the Association of Laboratory Managers (ALMA) and the current editor of *Managing the Modern Laboratory*. He is the chemical and petroleum industry manager for Agilent Technologies.

Ryan Wheeler is manager of the office of postdoctoral services at Scripps Research Institute. He meets regularly with postdocs and grad students for career counseling, serves as facilitator for job search workshops and organizes professional development events.

Business methods put to the technological test

Business methods are a company's particular processes for conducting business. These practices include handling business transactions, managing an organization, piloting an Internet commerce deal, investing in products and processing financial data.

Since 1998, when the Federal Circuit Court of Appeals allowed the patenting of a business method involving tracking mutual fund investments, numerous others have been patented by the US Patent and Trademark Office on the premise that they impart a useful and evident result.

In October, however, the US Court of Appeals for the Federal Circuit in Washington proposed that, for business methods to gain patent protection, the processes must be "tied to a particular machine or apparatus" or must convert an article into a separate state or entity.

By law, intellectual property represents a novel approach, incorporates a plausible application and signifies nonobviousness.

Regarding the thousands of business method patents that have been issued, many believe that they are mainly abstract ideas and do not promote innovation as physical inventions do. On the other hand, proponents of business method patents believe that, in an information-based economy, the patents heighten innovation.

Accenture, a global consulting and outsourcing company, says it supports patenting business methods because the techniques use science and engineering principles to help people collaborate more effectively. Conversely, IBM, which has numerous business methods in its patent portfolio, now maintains it is opposed to this type of patenting because it is not essential for encouraging innovation.

To solve the outstanding debate, the Supreme Court has agreed to reconsider the Bilski case – involving a patent first applied for in 1997 and rejected during the appeals process ever since – and to decide more exactly what constitutes patentable subject matter.

Case in point

Bernard Bilski and Rand Warsaw applied for a patent on their "capped bill systems, methods and products," a process for hedging risks in commodities trading. The system proposed offering an individual a fixed payment rate for a product, with the payment over time not exceeding a predetermined capped rate. However, an appeals court examiner rejected claims 1 through 11 of 35 U.S.C. §101, asserting that "… the invention is not implemented on a specific apparatus and merely manipulates [an] abstract idea and solves a purely mathematical problem without any limitation to a practical application; therefore, the invention is not directed to the technological arts."

Bilski and Warsaw argue that the Supreme Court should reconsider protecting their rights and those of others whose business methods may be denied a patent in the future. They believe technological strategies that could benefit the economy depend on the court's decision.

The federal government disapproves of the Supreme Court's willingness to hear the case. The administration believes that, because the business method was ineligible for a patent and is not relevant to software or other complex business processes, it is not significant.

Nevertheless, the Supreme Court will hear the Bilski case next term, in October. Many business method patent holders and others are wondering whether the Court of Appeals' October ruling will be upheld or whether the requirements for obtaining a business method patent will again depend less strictly on technological and tangible criteria.

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Aperio Files Infringement Lawsuit

Aperio Technologies Inc. of Vista, Calif., a digital pathology services provider, has filed a lawsuit against Hamamatsu Photonics KK, Hamamatsu Corp. and Olympus America Inc. for infringement of US Patent Nos. 6,917,696, 7,457,446 and 7,518,652. Filed in the US District Court for the District of Delaware, the lawsuit alleges that Hamamatsu's NanoZoomer, a digital pathology system distributed by Olympus America, infringes the three patents.

XP Vehicles to License Coal Ash Converter Patent

XP Vehicles Inc. of San Francisco, an electric vehicle developer and spinoff of Clever Industries LLC, has agreed to license a patent owned by its founder, Scott Redmond, on technology that enables the conversion of coal ash to an energy storage medium for use in electric cars.

Patent Application Filed for MOR103 Program

MorphoSys AG of Martinsried, Germany, and Melbourne Ventures Pty. Ltd., a wholly owned commercial subsidiary of the University of Melbourne in Australia, have formed a joint venture in the investigation of the therapeutic applications of MorphoSys' MOR103 program, a HuCAL (Human Combinatorial Antibody Library) antibody against human GM-CSF (granulocyte macrophage-colony stimulating factor) being developed for the treatment of rheumatoid arthritis. MorphoSys also has been issued patent No. 4,312,403 from the Japanese Patent Office for its CysDisplay, a component of the HuCAL platform. The patent, titled "Novel Methods for Displaying (Poly) Peptides/Proteins on Bacteriophage Particles," describes a technology-based phage display screening system for selecting high-affinity antibodies.

Hexagon Metrology Wins Intellectual Property Suit

Hexagon Metrology of London, a provider of portable measuring systems, handheld instruments and metrology software licenses, has won a suit against Xspect Solutions Inc., Wenzel Group GmbH & Co. KG, Wenzel Prazision GmbH and Wenzel Metromec AG for the alleged misappropriation of trade secrets of its PC-DMIS inspection and measurement software. The US District Court of the Eastern District of Michigan issued an injunction against the parties, prohibiting them from using or releasing information regarding the product, which is a development of Wilcox Associates Inc., a division of Hexagon.

OneLight Patents Disposable Endoscope Technology

US Patent No. 7,544,163, titled "Apparatus and Methods Relating to Expanded Dynamic Range Imaging Endoscope Systems," has been granted to Tidal Photonics Inc., parent company of OneLight Corp. of Vancouver, British Columbia, Canada, an illumination and imaging systems provider for health care and life sciences applications. The new technology, a disposable endoscope, offers high-quality imaging and enhanced diagnostic capabilities and is expected to reduce the costs of minimally invasive surgery.

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1 ☐ My principal job function is: (Please insert one letter only.)

Engineering- and Science-Related

A research & development
B design
C application
D manufacturing or production
E measurement (testing, quality control or safety)
F other engineering or science function (please specify) _____

Management- or Business-Related

G corporate
H engineering/technical
J manufacturing or production
K purchasing
L other management function (please specify) _____

Other

M consultant
N educator
P other functions (please specify) _____

2 ☐ Please indicate the primary end product or service of your company at this location. (Please insert one letter/number only.)

A aerospace/aviation systems
B agriculture, food, forestry & mining
C analytical, test or measurement instrumentation
D automotive or transportation
E cable TV/video/broadcasting
F cameras, detectors, sensors & electro-optical components
G chemical or pharmaceutical products
H communications equipment or services (incl. telcos, RBOC & other carriers)
J computer displays, peripherals, office & business equipment
K consumer electronics & appliances
L electronics, semiconductors & IC
M environmental monitoring
N fiber optic components or systems
P hospital/medical university or office
Q industrial control systems & robotics
R laboratory, government
S laboratory, industrial
T lasers/laser systems
U manufacturing equipment, machinery or metal products
V medical & biotechnology equipment
W military equipment
X navigation & guidance systems or equipment
Y optical components, materials or systems
Z plastics, polymers, rubber
1 printing, publishing, graphic arts
2 university/institution/college
3 utilities, energy, petroleum & coal
4 government personnel not classified elsewhere
5 industrial company or commercial user incorporating photonic products not classified elsewhere
6 other _____

Principal Product or Service _____

3 Which of the following publications do you read regularly? (Please check all that apply.)

A ☐ Advanced Imaging
H ☐ Laser Focus World
K ☐ Lightwave
M ☐ NASA Tech Briefs
N ☐ Nature
P ☐ OLE
R ☐ Physics Today
S ☐ Science
T ☐ Semiconductor International
V ☐ Vision Systems Design
X ☐ None of the above

4 ☐ The number of employees at this location is: (Please insert one letter only.)

A 1-10
B 11-25
C 26-50
D 51-100
E 101-500
F 501-1000
G 1001-5000
H over 5000

5 Which of the following technologies/sciences do you and/or your organization work with? (Please check all that apply.)

A.
A ☐ aerospace/aviation
C ☐ astronomy
D ☐ automotive
E ☐ biotechnology
G ☐ chemistry, chemical engineering
J ☐ chromatography
L ☐ communications
N ☐ computer engineering
P ☐ displays
R ☐ environmental monitoring/sensing
T ☐ forensic science
V ☐ holography
W ☐ lighting/illumination
X ☐ imaging
Z ☐ inspection/identification

B.
A ☐ machine vision
C ☐ materials processing/production
E ☐ materials research
G ☐ medical/biomedical
J ☐ microscopy
L ☐ military/tactical
N ☐ nondestructive testing
P ☐ optical character recognition
R ☐ optical computing/data storage
T ☐ photonic component mfg.
V ☐ process control
X ☐ quality control
Z ☐ remote sensing/lidar

C.
A ☐ reprographics/printing
C ☐ robotics
E ☐ semiconductor processing
G ☐ simulation/modeling
J ☐ signal processing
L ☐ spectroscopy
N ☐ test & measurement
P ☐ ultrafast/time-resolution studies
R ☐ other _____

6 Which of the following products do you buy, use, recommend and/or specify? (Please check all that apply.)

A. Optical Components & Software
A ☐ coatings
C ☐ filters & beamsplitters
E ☐ gratings
G ☐ infrared optics
J ☐ laser optics
L ☐ lenses
N ☐ mirrors & reflectors
P ☐ optical design software
R ☐ polarizing optics
T ☐ prisms
V ☐ ultraviolet optics
X ☐ windows & domes

B. Lasers
A ☐ semiconductor, diode
C ☐ solid-state, diode-pumped
E ☐ solid-state, Nd:YAG
G ☐ solid-state, Ti:sapphire
J ☐ solid-state, tunable
L ☐ solid-state, VCSELs
M ☐ fiber lasers
N ☐ gas lasers, CO_2
P ☐ gas lasers, excimer
R ☐ gas lasers, HeNe
T ☐ gas lasers, ion
V ☐ gas lasers, other
X ☐ dye
Z ☐ other lasers _____

C. Laser Systems
A ☐ biometric/forensic
C ☐ biotechnology
E ☐ communications
G ☐ industrial (cutting/welding/marking)
J ☐ entertainment
L ☐ environmental monitoring
N ☐ holography
P ☐ materials processing
R ☐ medical
T ☐ military
V ☐ remote sensing
X ☐ reprographics (printing/graphic arts)
Z ☐ spectroscopy & photochemical analysis

D. Fiber Optics
A ☐ cables
C ☐ communications lasers
E ☐ connectors or couplers
G ☐ detectors or receivers
H ☐ fiber
K ☐ gratings
M ☐ lightguides
N ☐ network components
O ☐ optical amplifiers
Q ☐ optical switches
S ☐ splicing & polishing equipment
U ☐ test equipment
W ☐ transmitters
Y ☐ WDM or DWDM
Z ☐ other fiber optic components _____

E. Cameras
A ☐ CCD or CID
C ☐ CMOS
E ☐ high speed
G ☐ infrared
J ☐ line scan
L ☐ other camera _____

F. Detectors/Sensors
A ☐ CCD or CID
C ☐ CMOS
E ☐ detector arrays
G ☐ infrared
J ☐ photodiodes
L ☐ photomultipliers
N ☐ semiconductor

G. Imaging Equipment & Software
A ☐ frame grabbers
C ☐ image intensifiers
E ☐ imaging software
G ☐ infrared imagers
J ☐ illumination equipment
L ☐ vision systems
N ☐ x-ray imaging

H. Manufacturing Equipment for Photonic Components
A ☐ assembly or packaging equipment
C ☐ cleanroom equipment
E ☐ coating equipment
G ☐ cooling & cryogenic equipment
J ☐ diamond machining equipment
L ☐ grinding & polishing equipment
N ☐ optical design software
P ☐ photonics test equipment
R ☐ vacuum equipment
T ☐ other manufacturing equipment _____

J. Positioning/Vibration Isolation Equipment
A ☐ benches, rails & slides
C ☐ micropositioners
E ☐ mounts for photonic components
G ☐ positioning equipment
J ☐ position-sensing equip.
L ☐ stepper motors & drivers
N ☐ tables, optical
P ☐ vibration-isolation equipment

K. LEDs and Displays
A ☐ CRTs
C ☐ flat panel
E ☐ LCDs
G ☐ LEDs
J ☐ light valves
L ☐ OLEDs
N ☐ plasma

L. Test & Analysis Equipment
A ☐ interferometers
C ☐ microscopes, optical
E ☐ microscopes, other
G ☐ monochromators
J ☐ optics testing equipment
L ☐ power/energy meters/wavelength meters
N ☐ radiometers/photometers
P ☐ spectroscopy equipment
R ☐ spectrum analyzers
T ☐ telescopes

M. Electronics & Signal-Analysis Equipment
A ☐ amplifiers
C ☐ oscilloscopes
E ☐ power supplies
G ☐ pulse & signal generators
J ☐ signal analyzers
L ☐ time-delay generators

N. Laser Accessories
A ☐ beam analysis
C ☐ flashlamps
E ☐ laser chillers
G ☐ laser dyes, gases or rods
J ☐ laser power & energy meters
L ☐ laser power supplies
N ☐ laser safety
P ☐ laser scanners

P. Light Sources
A ☐ arc sources
C ☐ flashlamps
E ☐ infrared
G ☐ LEDs
J ☐ ultraviolet

Q. Materials & Chemicals
A ☐ cements, adhesives & epoxies
C ☐ coating materials
E ☐ crystals
G ☐ grinding & polishing materials
J ☐ transmissive materials, IR
L ☐ transmissive materials, UV
N ☐ transmissive materials, visible

R. Computers & Software
A ☐ computer hardware (PCs, servers, workstations, mainframes)
C ☐ data acquisition
E ☐ scientific/engineering software

S. Nanophotonics
A ☐ microscopes
C ☐ nanophotonic devices
E ☐ nanophotonic materials
G ☐ quantum dots

T. A ☐ Other _____

X. ☐ None of the above (6A-6S inclusive)

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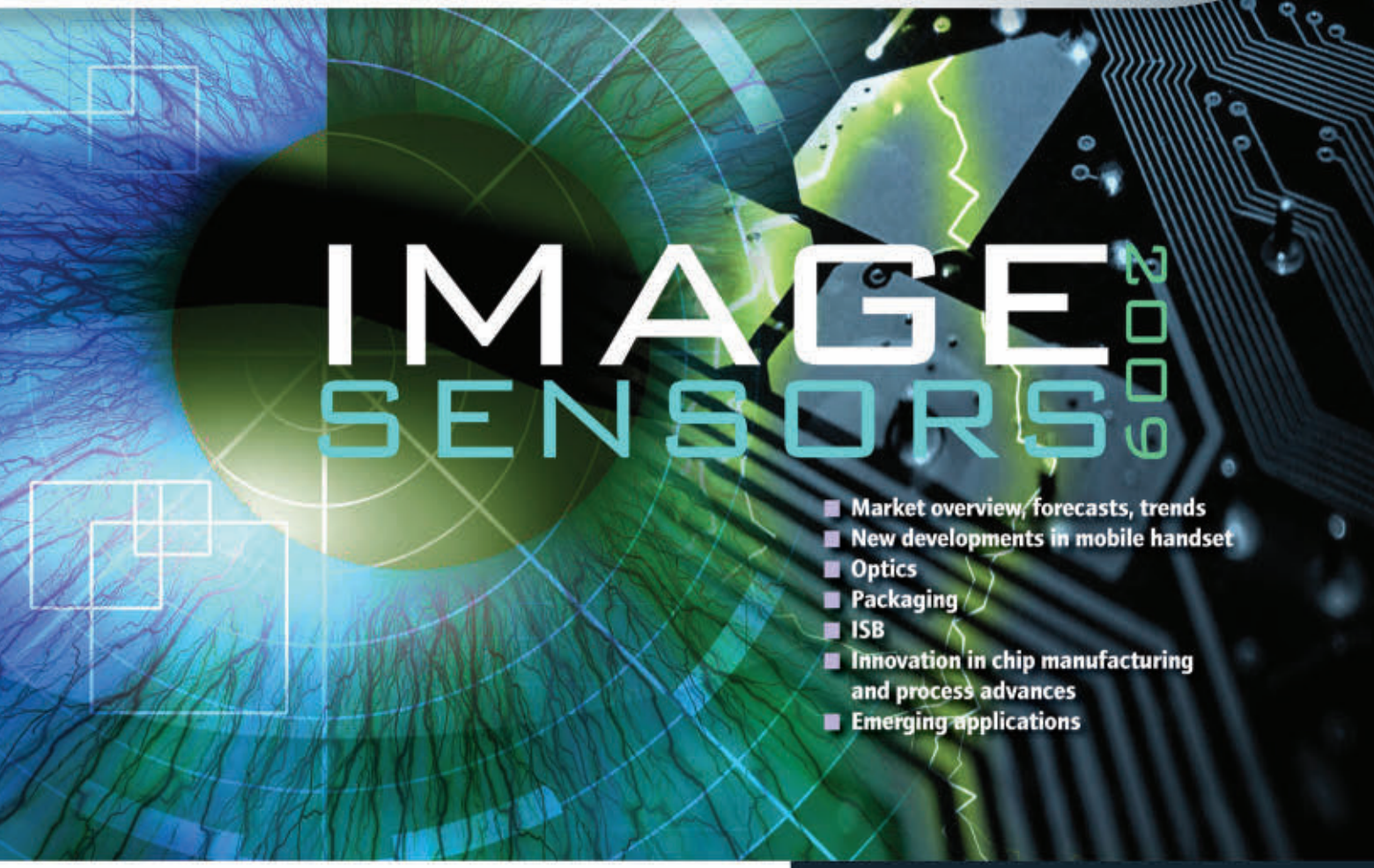

The highly anticipated **Image Sensors 2009** conference is set for October 13–16, 2009 in San Diego, CA. The 3rd edition of this international event will address the latest trends and technologies within the image sensors industry and will focus on the most advanced application areas including security, surveillance, broadcasting, medical equipment, machine vision and automotive. Key challenges in achieving slimmer packaging, pixel size, and depth of field and resolution are only a few of the topics featured in this year's program. You won't want to miss out!

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Plus! Don't miss this new event on October 16!

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joan.woodbrey@pira-international.com

www.imagesensorsconference.com

INTERTECH pira

BRIGHT IDEAS

MACHINE VISION CONTROLLER

LMI Technologies Inc. has introduced the maestro controller to connect, configure and conduct machine vision applications. It comprises two modules. The P800 is the master controller that interfaces with the encoders and with the input/output and delivers microsecond synchronization as well as power and safety on CAT5e cables for up to eight or more cameras and light sources. It completes all timing, triggering, synchronization, sorting and reject activations. Camera image data is delivered to the host computer with standard interfaces and communicated via Gigabit Ethernet. The C12 camera and light controller connect to the P800 with a 100-m CAT5e cable to power and trigger the camera and to provide synchronized configurable high-current pulses for LEDs or lasers.

LMI Technologies
info@lmitechnologies.com

MIRROR MOUNT

Newport Corp. has launched the V100-CP CenterPoint, a mirror mount that holds the mirror directly above and in line with the mounting hole while maintaining a standard 1-in. optical axis height. With the mirror's reflective surface sitting on the rotation axis of the mounting post, research setups can be done more quickly and without the need for additional adaptor plates. If the optical path must change, a simple rotation can steer the reflected beam by more than 270°. The compact and clear quadrant mount is English or metric mounting-compatible and easy to integrate into a custom design, and it can be modified with hex screws for OEM applications. Angular range is ±4°, and sensitivity is 3.8 arcsec.

Newport
rick.sebastian@newport.com

CONNECTOR CLEANER

US Conec Ltd. has released the IBC Brand Cleaner MPX for use in cleaning Lightray MPX connectors. The cleaner, an all-dry solution for cleaning the connectors through an adapter or a cable assembly, uses woven micro-fibers to absorb liquid contaminants and a custom weave pattern to trap dry particles. It is keyed for aligning the cleaning fabric with the ferrule end face, and it provides 600 engagements.

US Conec
customerservice@usconec.com

VCSEL CHIP

The V20-850C from VI Systems GmbH is a low-power vertical-cavity surface-emitting laser (VCSEL) chip for the short-range fiber optic transceivers used in data communications and interconnect applications. It operates at up to 20 Gb/s in 850-nm multimode fiber systems. Current density is <3 kA/cm^2. The company says that it can be operated at much higher modulation speeds than traditional VCSELs can, but with the same current density, and that there is essentially no temperature dependence in the device's performance up to 100 °C.

VI Systems
sales@v-i-systems.com

NEAR-IR TRANSMISSION ANALYZER

The Series 2000 near-IR transmission analyzer manufactured by NIR Technology Systems is a spectrophotometer suitable for use in the pharmaceutical, petrochemical, plastics, polymers, textiles, chemical and biofuel industries. The diode array spectrometer uses a selection of sample cells to collect near-IR transmission spectra through liquid, suspensions and emulsions. It scans from 720 to 1100 nm in transmission and transflectance modes. It is available as the base spectrometer and two application-specific analyzers. The Tablet Analyzer examines tablets for uniformity, coating thickness, active incipient and authentication. The Creams and Lotions Analyzer analyzes for moisture, lanolin, petroleum jelly, active components, alcohol, stabilizers and emulsifiers.

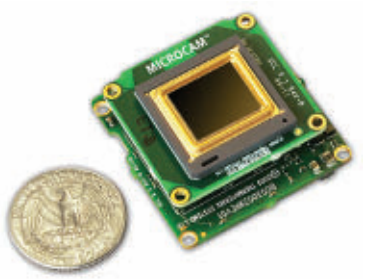
NIR Technology Systems
nirtech@nirtech.net

COLD LIGHT SOURCES

Combining fiber optics with LED technology, Schott AG has expanded its direct LED illumination VisiLED and EasyLED series to include products developed for use in stereomicroscopy applications. The 20-W halogen KL200 and the 150-W KL1500 light sources have been replaced by KL200 and KL1500 LEDs. They combine the high level of light intensity for small areas with the advantages of LEDs. Offering lifetimes of 50,000 h and energy savings of up to 80%, the light sources reduce operating costs and downtime. They generate neutral white light with a color temperature of ~6000 K and do not require daylight filters. They are supplied with wide-range power supply units and universal connector systems.

Schott
info@schott.com

THERMAL IMAGER



Thermoteknix Systems Ltd. has launched the Miricle MicroCam, an uncooled thermal imager that produces 384 × 288-pixel resolution with 25-μm pixel pitch. Weighing 26 g and measuring 4 × 4 cm, it consumes <0.6 W and operates from a 1.8- to 5.5-V supply. Designed for low-power OEM applications, it offers good night-vision capability and delivers a 60-Hz composite video signal. Based on proprietary XTi shutterless technology, the imager runs silently and at temperatures from −20 to 60 °C. It is supplied with an RS-232 remote command interface.

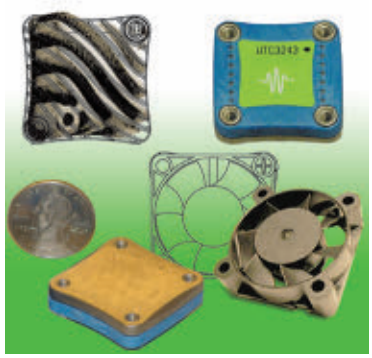
Thermoteknix Systems
sales@thermoteknix.com

FIREWIRE CAMERA

The CS8581QF remote-head FireWire camera system manufactured by Toshiba Teli America Inc. operates at 133 fps at full 640 × 480-pixel resolution (8-bit monochrome) and at 430 fps in partial-scan mode. Based on a ⅓-in. progressive-scan CCD, it features 7.4-μm square pixels, an electronic shutter and a random trigger shutter. The remote-head camera and central control unit can be mounted up to 2 m apart by a cable. It is suitable for use in high-speed industrial imaging applications where mounting space is restricted.

Toshiba Teli America
doug.freck@ttai.toshiba.com

TEMPERATURE CONTROLLER



The WTC3243 from Wavelength Electronics is a 2.2-A temperature controller designed into electro-optical systems, airborne instrumentation, spectroscopic monitors and medical diagnostic equipment to provide stability, even across ambient. It achieves on-ambient stability of 0.0014 °C with thermistors. The linear proportional integral control loop provides maximum stability, and the bipolar current source is designed for high efficiency. The system maintains precision temperature regulation via an adjustable sensor bias current and error amplifier circuit. The proportional gain and integrator time constant are set by external resistors and can be modified to optimize temperature overshoot and stability.

Wavelength Electronics
sales@teamwavelength.com

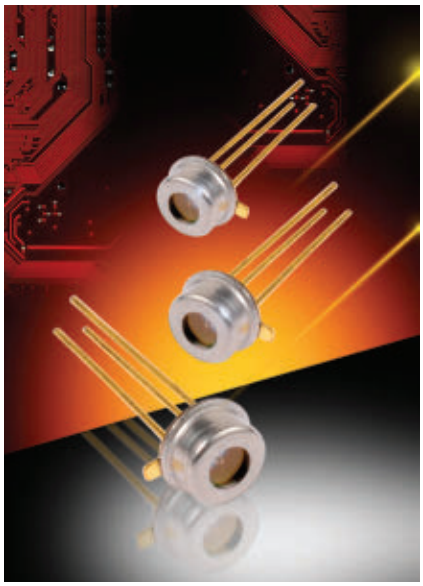
FOAM SWAB

To facilitate equipment cleaning, Qosina has introduced a foam swab with a 3.6-mm head that is ultrasonically welded onto a polypropylene handle for adhesive-free processing. The polyurethane foam head minimizes contamination from cotton lint and is good for particle entrapment and solvent distribution. The swab is 2¾ in. long and is useful for cleaning hard-to-reach areas such as optics and other small-angled corners.

Qosina
info@qosina.com

b BRIGHT IDEAS

RED VCSEL



Optowell Co. Ltd. has released the PM67-F1PON, a visible red 670-nm vertical-cavity surface-emitting laser (VCSEL) that provides typical output power of 1 mW at an operating current of 4 mA and a maximum operating voltage of 2.5 V. The circular output has a minimum beam divergence of 14° and a maximum of 30°. Maximum spectral bandwidth is 0.85 nm rms. Packaged in a TO-46 housing with a flat window, the device operates from −20 to 50 °C. Applications include position sensors, medical instrumentation, bar-code scanners, plastic optical fiber and battery-operated optoelectronic equipment.

Optowell
sales@oe-company.com

TRACE GAS ANALYZER

Picarro Inc. has launched the G1302 trace gas analyzer, a turnkey instrument that simultaneously measures CO and CO_2 in real time and with minimal calibration required. It is suitable for use in remotely operated greenhouse gas monitoring applications, including tall-tower measurements, and for research and reference laboratory use. It delivers measurement precision down to 2 parts per billion by volume (ppbv) for CO and 50 ppbv for CO_2. Based on

proprietary wavelength-scanned cavity ringdown spectroscopy technology, the analyzer can monitor multiple gas species simultaneously. It also provides quantitative data on H_2O concentration levels.

Picarro
igreen@picarro.com

LASER OPTICS

Laser Research Optics is offering a line of replacement CO_2 laser optics for use by plaque and trophy engravers. The optics can be supplied premounted into OEM-compatible aluminum mounts and also are available in standalone versions. The lenses and mirrors are optimized for 10.6 μm and meet OEM and ISO-10110 specifications. Outer diameter sizes are ½ and 1 in., and focal lengths range from 1 to 10 in. in ½-in. increments. The optics provide <0.2% total absorption values and are offered with coatings to match specific phase and polarization requirements.

Laser Research Optics
steve@laserresearch.net

LOW-LIGHT CAMERA

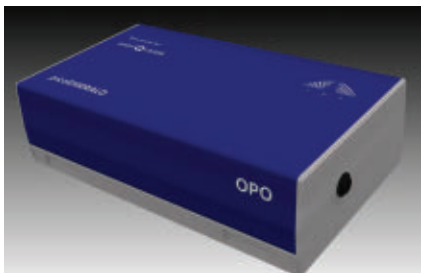
Toshiba America Information Systems Inc. has released a night-vision camera that captures color surveillance video at 30 fps in starlight conditions. The IK-1000 has a Peltier-cooled electron-multiplying CCD and exhibits minimum light sensitivity of 0.00025 lx. Its 50-dB signal-to-noise ratio provides sharp imaging in all

b BRIGHT IDEAS

lighting conditions. Coupled with the camera's 12-dB gain control function, the ½-in. sensor produces images with resolution of up to 658 × 496 pixels. Features include RS-232C camera control, 16-area selectable backlight compensation and adaptive recursive noise reduction. Applications include homeland security, military, aviation, public utility, coastal ports and border patrol surveillance.

Toshiba America Information Systems
tri.nguyen@tais.toshiba.com

CARS LIGHT SOURCE



APE Angewandte Physik und Elektronik GmbH and High Q Laser have introduced the pico-Emerald, a remote-controlled hands-free one-box light source that provides Stokes and pump pulses overlapped in space and time for use in coherent amplified Raman spectroscopy (CARS) applications. The system comprises a 1064-nm picosecond oscillator with a frequency doubler

and a synchronously pumped optical parametric oscillator (OPO) in a single housing. The device supplies three temporally and spatially overlapping ultrafast pulse trains: 1064 nm out of the laser oscillator, a 690- to 990-nm signal range and an 1150- to 2300-nm idler range from the OPO. It delivers 7 ps at 1064 nm and 5 to 6 ps from the OPO.

APE
ape@ape-berlin.de

532-NM LASER

Manufactured by Elk Industries LLC, the 532 C-50 is a 532-nm laser that produces >50 mW of output radiant flux in a highly collimated 0.53-mm TEM_{00} beam. It measures ~50.8 × 101.6 × 152.4 mm and weighs <3 lb. Beam divergence is <1.5 mrad, power stability is better than 2%, noise is <5%, and operating temperature is from 0 to 40 °C. Beam pointing stability is better than 1.5%, and mean time between failures is >20,000 h.

Elk Industries
laserob@aol.com

HIGH-FLEX CABLES

For use in robotics, assembly line, cable track, automation, materials handling equipment and other applications that involve constant flexing, Alpha Wire Co. has introduced its Xtra-Guard cables. Hazard-matched for operating in harsh environments, the cables can withstand extreme heat and cold; abrasion; flexing; immersion in oils, chemicals, solvents and fuels; UV exposure; electromagnetic and radio-frequency interference; and direct burial. They carry UL recognition and CSA certification. Customers can use the company's online SeleXion Guide to enter environmental parameter requirements, including operating temperature, chemical and abrasion resistance, and flex requirements to select the appropriate cable.
Alpha Wire
sales@aerco.co.uk

TELECENTRIC LENSES

Edmund Optics Inc. has introduced TechSpec, 5-megapixel telecentric lenses that provide up to ⅔-in. sensor coverage. They also integrate good light-collecting f/6 designs and achieve high contrast at 72 line pairs per millimeter across the full sensor field. The lenses feature a locking iris and focus to prevent unintentional adjustments in high-vibration environments. Available in 1.7×, 0.9×, 0.5× and 0.28× magnifications, they use an image side telecentric design that eliminates

illumination roll-off. An optional mounting clamp secures the lenses to benchtop setups.
Edmund Optics
medmund@edmundoptics.com

REMOTE ASSISTANT

For remote tracking, diagnostics and repair of its Phenom personal scanning electron microscope, FEI Co. has announced the Phenom remote assistant. It is powered by the proprietary Remote Access Program for Interactive Diagnostics, a secure infrastructure that provides encrypted virtual private network connection between the customer and the company's service engineer. All remote connections are initiated from the Phenom side, providing customers with complete control. The company's service engineers can remotely track performance over time, run test diagnostics, check and modify tool settings, and view images to assess quality.
FEI
fei_info@fei.com

MIRROR CONTROLLER

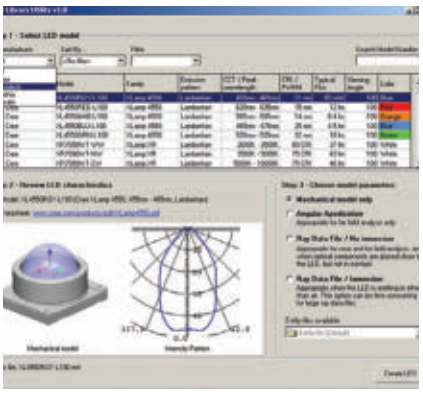
Boston Micromachines Corp. has unveiled a high-speed, high-precision controller for its Mini-DM deformable mirror. The device provides 14-bit resolution in position control at greater than an 8-kHz frame rate and is five times smaller than its predecessor. It has applications in adaptive optics and proof-of-concept experiments for laser beam shaping and can improve resolution in microscopes, telescopes and ophthalmic instruments.
Boston Micromachines
moreinfo@bostonmicromachines.com

BRIGHT IDEAS

FIBER AMPLIFIERS

Second-generation NuAmp polarization-maintaining fiber amplifiers have been introduced by Nufern. Powered by proprietary double-clad fibers, the devices are housed in a compact package. Featuring integrated diode drivers and an output power monitor, they offer >1- or >50-mW input and optional e-stop and USB control. Operating from 1040 to 1090 nm or from 1540 to 1570 nm, they can be water- or air-cooled. They produce a high signal-to-noise ratio, a high-quality near-diffraction-limited beam and high open-loop stability, and they are immune to shock and vibration.
Nufern
info@nufern.com

ILLUMINATION SOFTWARE



Optical Research Associates has released its LightTools 6.3 illumination design and analysis software for optical system modeling. It features an alternate optimization engine that supplements the existing one and permits optimization with user-defined variables, merit functions and constraints. It incorporates an expanded LED library that contains mechanical models for LEDs from major manufacturers, including apodization files for accurate far-field modeling

of source output, and ray data files for near- and far-field output. The ray data files include color information to model the spatial and angular output characteristics of the source as a function of color. The software includes an enhanced thin-film modeling utility.
Optical Research Associates
info@opticalres.com

ACTUATORS

The P/S13 series hermetically sealed actuators from piezosystem jena inc. has been expanded to include models with an internal preload. Translators are available with a stroke of 18 to 70 µm, and working voltage ranges from −20 to 130 V. The actuators are free of mechanical play and have an M3 threaded screw hole in the base plate to facilitate installation into any existing setup. They are designed to work in wet and high-humidity environments as well as under cooling liquids. Positioning can be carried out in tool machines where coolants flow directly around the actuator.
piezosystem jena
sales@piezojena.com

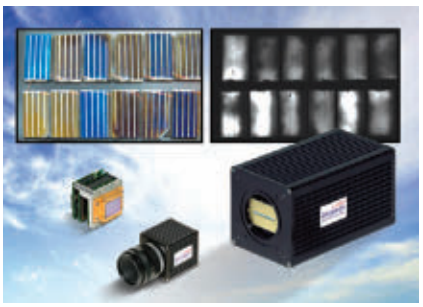
MULTICOLOR LED

Osram Opto Semiconductors Inc. has introduced the smallest model in its RGB multi ChipLED line to bring high-definition picture quality to the large full-color video screens found in TV studios, conference rooms, trade fairs and concert halls. It produces bright color and high contrast from all viewing angles. Its 1.6 × 1.6 × 0.9-mm footprint accommodates a large number of pixels in a small display area. Housed in a black package that is mostly impervious to ambient light, the LED contains a red, a green and a blue chip, which, when operated at 20 mA, produce typical luminous intensities of 250, 350 and 70 mcd, respectively.
Osram Opto Semiconductors
support@osram-os.com

PICOSECOND LASER

The APL-500-1064 from Attodyne Lasers is a picosecond fiber-based diode-pumped solid-state laser that can be pulsed on demand from 0 to 500 kHz. The compact air-cooled device can be customized to meet the user's need for power, pulse energy, repetition rate and wavelength. Near-IR units are available with energy levels of ~50 mJ at low repetition rates, while the mid-IR versions have pulse energies similar to those of free electron lasers. Applications include thin-film processing; the repair of thin-film transistors, printed circuit boards, masks and flat panel displays; dicing; scribing and interconnecting wafers; and spectroscopy, microscopy, nonlinear optics and cell lysis.
Attodyne Lasers
attodyne@rpmclasers.com

SWIR CAMERAS



For use in solar cell inspection, Sensors Unlimited Inc., part of Goodrich Corp., has released InGaAs-based shortwave infrared (SWIR) area- and line-scan cameras that operate between

0.9 and 1.7 μm. They reveal voids in silicon boules, bricks and ingots before those materials are sliced into wafers to produce mono- and multi-crystalline solar cells. The cameras detect hidden cracks by mapping stress in raw wafers, finished cells and thin films made for solar electricity-generating panels. They spot saw marks on the opposite side of a silicon wafer as well as defects inside the material. By applying forward bias to cells to generate electroluminescence, the cameras can gauge cell efficiency and uniformity.

Sensors Unlimited
sui_info@goodrich.com

INDUSTRIAL LASER

Newport Corp.'s Spectra-Physics Lasers Div. has introduced the 100-W Alliant industrial fiber laser with a high-quality single-mode beam and wall-plug efficiency that delivers maximum power at the smallest focused spot for high brightness. Based on proprietary Pro-Lite Xt laser diodes, the device operates in continuous-wave or modulated mode, with random polarization and a central emission wavelength of 1075 ±5 nm. Maximum modulation frequency is 80 kHz. It produces a TEM_{00} beam with M^2 of ≤1.1 and uses closed-loop power control for consistent operation. Output power tunability is 10% to 100%, output power variation is ±1%, power consumption is <800 W, and operating temperature is 15 to 35 °C.

Spectra-Physics
scott.white@spectra-physics.com

b BRIGHT IDEAS

HIGH-SPEED MICROSCOPY

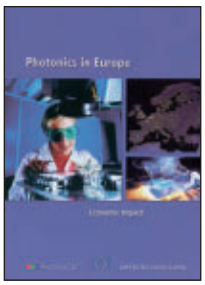
The VW-6000 series motion analysis microscope from Keyence Corp. has high-speed magnified video capture capabilities that can record at speeds of up to 24,000 fps. The instrument has a built-in light source, an 8.4-in. LCD monitor and a controller that supports both color and monochrome cameras. Recorded footage can be edited and analyzed on the controller. The portable device also offers a "time advance" function, enabling users to record video at predetermined intervals for targets that are in continuous motion.
Keyence
keyencepr@keyence.com

LASER SYSTEM

Onyx Optics Inc. has released the Hyrax, a Ho:YAG end-pump laser system that operates at 2.1 μm and uses Adhesive-Free Bond patented technology. The system offers a 2090-nm wavelength (with 2097 nm available upon request), a <4-nm linewidth, a 25- to 50-ns pulse width and a repetition rate of up to 50 KHz. It delivers output power of 18.6 W and beam quality of M^2 <1.2. The system can be operated at a variety of rates or in continuous-wave mode without significant alterations to power levels. The lasers can be used for pumping mid-IR ZGP optical parametric oscillators, for laser remote sensing and for medical surgery.
Onyx Optics
sales@onyxoptics.com

CO_2 LASER

Synrad Inc. has unveiled CO_2 laser models with a wavelength of 9.3 μm, as opposed to the standard 10.6 μm. The instruments can be used with organic or semiorganic materials that have a higher absorption in the 9-μm band. For these applications, the company offers the 48-1, 48-2 and firestar v30 lasers, all in the 9.3-μm range. Output power ranges from 8 to 20 W, beam divergence from 4 to 7 mrad, and beam diameter from 3.5 to 2.5 μm, depending upon the model.
Synrad
synrad@synrad.com



EUROPEAN PHOTONICS

Published by European Technology Platform Photonics21, the second edition of *Photonics in Europe: Economic Impact* is available in print copy or as a download from the Photonics21 Web site. Written by Arnold Mayer of Optech Consulting, the 62-page illustrated publication provides an overview of the photonics industry in Germany, France, Italy, the Netherlands, the UK and other European countries. It spotlights sectors within the industry, including lighting, solar energy, medical technology, flat panel displays and optical communications.
Photonics21
www.photonics21.org

MOTION SYSTEMS SITE

Steinmeyer Inc. has launched an enhanced Web site to showcase its high-precision positioning stages. The portal details the company's offerings, which include standard as well as more complex customized systems. Examples of its systems are shown in application areas such as semiconductor production, medical engineering, scientific research, and test and measurement equipment. Password-protected log-in is possible.
Steinmeyer
www.feinmess.com

GREEN ROBOTICS

Green manufacturing with robotics is the main topic of the Robotic Industries Association's *Robotics Industry Directory 2009*. Published with environmentally friendly ink on recycled paper, the directory provides information on top makers of robots and accessories and includes a guide to robot systems integrators. Print copies of the directory are available upon request through Robotics Online; members of the association can download it from the Web site.
Robotic Industries Association
www.robotics.org

OPTICS PORTAL

Edmund Optics has launched a Chinese language Web site, bringing the company's total global portals to nine in five languages. The resource features its entire online product catalog translated into Chinese and RMB pricing. Customers and site visitors also can contact representatives for free technical support and customer service in Chinese via telephone or e-mail. The portal also features downloadable technical drawings, online discussion forums and engineering downloads.
Edmund Optics
www.edmundoptics.cn

n NEW MEDIA

VACUUM PRODUCTS

The ninth edition of the *Global Vacuum Product Guide* from Kurt J. Lesker Co. provides specifications, photos and drawings for the company's offerings, which include standard and custom components, deposition materials, sputter and thermal sources, chambers and subsystems, thin-film deposition systems, motion and manipulation products, hardware and feedthroughs, and pumps, oils, traps and filters. Featuring nearly 1000 pages, the publication is relevant for both developers and users of vacuum equipment.
Kurt J. Lesker
catalog@lesker.com

SAFE MACHINERY

Sick Inc., a manufacturer of sensors, safety systems, machine vision and automatic identification products for factory and logistics automation, has released the *Guidelines for Safe Machinery – Six Steps to a Safe Machine*. The downloadable, illustrated, 116-page publication briefly outlines laws, regulations and standards for machine safety in the US, Canada and Mexico. Risk assessment, machine design, engineering controls, administrative measures, and machine validation and operation are addressed. Application examples are included.
Sick Inc.
www.sickusa.com/safetyguide

ANALOG ELECTRONICS

Analog Modules Inc., a specialist in analog electronics for the electro-optics industry, has announced that its Web site has been redesigned to facilitate access to its products for sensing and laser applications. The company's offerings, which include laser diode drivers, laser rangefinder receivers, fiber optic links and photodetector amplifier modules, have applications in the medical, military, scientific and industrial markets.
Analog Modules
www.analogmodules.com

PHOTOVOLTAIC MATERIALS

Available from Alfa Aesar, a Johnson Matthey Company, an eight-page brochure titled *High Purity Materials for Photovoltaics* highlights the company's chemicals and metals for use in the photovoltaics industry. It lists more than 150 products used in the development of a variety of solar cells, including crystalline silicon, cadmium telluride and copper indium gallium selenide. Products listed include both compounds and pure metals in a variety of forms, purities and quantities.
Alfa Aesar
info@alfa.com

TEST, MEASUREMENT

Yokogawa Electric Corp. has launched a Web site dedicated to the offerings of its Yokogawa Test & Measurement Div. The resource details oscilloscopes, data acquisition systems, digital power meters, signal sources, and optical and wireless communications test equipment. It features a service and support section, an industry application area, and a technical library with white papers, application notes, Webinars, manuals and videos.
Yokogawa Test & Measurement
tmi.yokogawa.com

HAPPENINGS

SEPTEMBER

China International Optoelectronic Exposition 2009 (Sept. 6-9) Shenzhen, China. Contact Nancy He, CIOE, +86 755 8629 0819; nancy@cioe.cn; www.opto-china.com.

InterOpto'09 (Sept. 9-11) Chiba, Japan. Contact OITDA, +81 3 5225 6431; interopt@oitda.or.jp; www.oitda.or.jp.

SPRC 2009 Symposium (Sept. 14-16) Stanford, Calif. Contact Stanford Photonics Research Center, +1 (650) 723-5627; photonics@stanford.edu; www.photonics.stanford.edu.

Eurodisplay 2009 (Sept. 14-17) Rome. 23rd International Display Research Conference. Contact J. Kimmel, Nokia Research Center, +358 7180 35484; jyrki.kimmel@nokia.com; www.eurodisplay.org.

SPIE Photomask (Sept. 14-17) Monterey, Calif. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

ECOC 2009 (Sept. 20-24) Vienna, Austria. 35th European Conference and Exhibition on Optical Communication. Contact Hatice Altintas, VDE Conference Services, +49 69 63 08 477; ecoc2009@ove.at; www.ecoc2009.at.

Ninth International Conference on Correlation Optics (Sept. 20-24) Chernivtsi, Ukraine. Contact Oleg V. Angelsky, Chernivtsi University, +1 380 3722 44730; oleg@optical.chernovtsy.ua; www.itf.cv.ua/corropt09.

SPIE Laser Damage (Sept. 21-23) Boulder, Colo. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

ISOT 2009: International Symposium on

PAPERS

SPIE Defense, Security + Sensing (April 5-9) Orlando, Florida
Deadline: abstracts, September 21
Papers will be accepted in the area of sensing systems and platforms, which includes displays, nanosensors, biomimetics, energy harvesting, cyber sensing, laser sensors and systems, unmanned and layered systems, space technologies and operations, and IR, radar, passive millimeter-wave and terahertz imaging. Image and data processing and visual analytics situation management also will be discussed. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

META'10 (February 22-25) Cairo, Egypt
Deadline: abstracts, October 9
Organizers of the META'10 International Conference on Metamaterials, Photonic Crystals and Plasmonics invite abstracts for oral and poster presentations in fields such as nano- and near-field optics, extraordinary transmission through subwavelength apertures, and the theory and modeling of structured, periodic and disordered media. Application areas to be considered include optical sensing, nanoscale imaging and optical communication systems. Contact META'10 Secretariat, Laboratoire de Génie Electrique de Paris, +33 1 698 516 60; meta10@lgep.supelec.fr; meta10.lgep.supelec.fr.

OFC/NFOEC 2010 (March 21-25) San Diego
Deadline: abstracts, October 13, noon EDT (16:00 GMT)
Submissions are sought for the Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference. Among the topics to be considered are optical grids, FTTx, data communications, test and measurement, green technology, and carrier/transport/telecom. Contact The Optical Society, +1 (202) 416-1975; info@ofcconference.org; www.ofcnfoec.org.

HAPPENINGS

Optomechatronic Technologies (Sept. 21-23) Istanbul, Turkey. Contact Bogazçi University, +212 359 54 00; isot09@boun.edu.tr; www.optomechatronics.org.

IRMMW-THz 2009: 34th International Conference on Infrared, Millimeter and Terahertz Waves (Sept. 21-25) Busan, South Korea. Contact irmmwthz2009@gmail.com; www.irmmw-thz2009.org.

Diskcon USA 2009 (Sept. 23-24) Santa Clara, Calif. Contact Trudy Gressley, IDEMA, International Disk Drive Equipment and Materials Association, +1 (408) 719-0082; tgressley@idema.org; www.idema.org.

13th Topical Meeting on the Optics of Liquid Crystals (Sept. 28-Oct. 2) Erice, Italy.Contact Paolo Pasini, National Institute of Nuclear Physics (Istituto Nazionale di Fisica Nucleare), +39 0694 031; pasini@bo.infn.it; olc2009.fisica.unina.it.

OLEDs World Summit 2009 (Sept. 29-Oct. 1) San Francisco. Contact Brian Santos, Intertech-Pira, +1 (207) 781-9618; brian.santos@pira-international.com; www.intertechpira.com.

OCTOBER

ISOM'09: International Symposium on Optical Memory (Oct. 4-8) Nagasaki, Japan. Contact Secretariat, secretary@isom.jp; www.isom.jp.

OFS-20: 20th International Conference on Optical Fiber Sensors 2009 (Oct. 5-9) Edinburgh, UK. Contact Jenny Bremner, OFS-20 Secretariat, Institute of Physics, +44 20 7470 4908; ofs20@iop.org; www.ofs20.org.

OPTO 2009 (Oct. 6-8) Paris. Contact Nadège Venet, GL Events, +33 1 44 31 82 57; nadege.venet@gl-events.com; www.forum4s.com.

SEMICON Europa 2009 (Oct. 6-8) Dresden, Germany. Contact Kelli Torres, SEMI Global Headquarters, +1 (408) 943-6979; ktorres@semi.org; www.semiconeuropa.org.

Second All-Russian Conference on Fiber Optics (Oct. 8-9) Perm, Russia. Contact Mikhail Averkiev, +7 342 240 05 93; root@ppk.perm.ru; www.fibopt.ru/rfo-09/index_eng.html.

Frontiers in Optics 2009/Laser Science XXV (Oct. 11-15) San Jose, Calif. Collocated with the Fall OSA Optics & Photonics Congress, which includes the meetings Advances in Optical Materials (AIOM); Adaptive Optics: Methods, Analysis and Applications (AO); Computational Optical Sensing and Imaging (COSI); Femtosecond Laser Microfabrication (LM); and Signal Recovery and Synthesis (SRS). Contact The Optical Society, +1 (202) 416-1907; custserv@osa.org; www.frontiersinoptics.com.

Brushstrokes across the sky

In 1745, Swiss astronomer Jean-Philippe Loys de Chéseaux discovered a new object in the sky that somewhat resembled the Greek letter "omega." Or maybe it looked like a swan of sorts. In actuality, it's a nursery for a multitude of newly born stars.

Now known as the Omega Nebula, the 17th member of Charles Messier's famed catalog has also been called the Swan, the Lobster and the Horseshoe and is a favorite object to view among professional and amateur stargazers alike. Set your sight toward Sagittarius, and look for a region of gas and dust about 15 light-years across. It should appear as a spectral light framed against the background provided by the Milky Way itself. In very good observing conditions, the approximately 6.0-magnitude nebula can even be seen with the naked eye.

The popularity of the Omega Nebula is largely due to its proximity – only about 5500 light-years away – and to its prolific ability to create new stars. It is one of the youngest stellar nurseries, and it continues to birth new suns even now. The space-borne winds and brilliantly burning infant stars form streaks of glowing gases like paint strokes against a dark canvas.

In a newly released image, shown here, the central region of the nebula is displayed with more detail than ever seen before. The watercolorlike palette indicates billows of hydrogen, oxygen, nitrogen, sulfur and other gases glowing under the ultraviolet light being emitted by the bright young stars in the region. The hydrogen, in particular, is responsible for the red to dusty pink hues in the formation.

The image was acquired by the European Southern Observatory Multi-Mode Instrument (EMMI) on the New Technology Telescope located at the La Silla Observatory in Chile. The EMMI is a collection of detectors that aid imaging in the 300- to 1000-nm range with the 3.58-m telescope.

Lynn Savage
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Photo courtesy of the European Southern Observatory.

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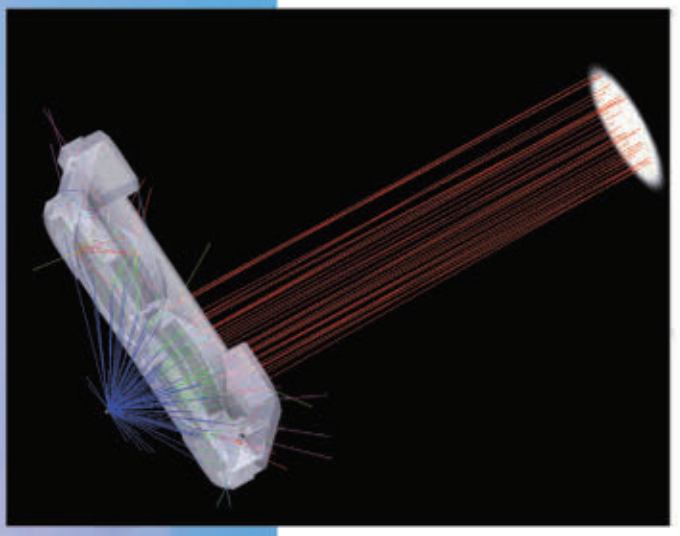

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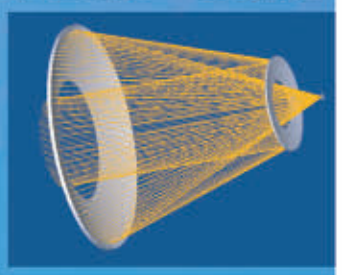
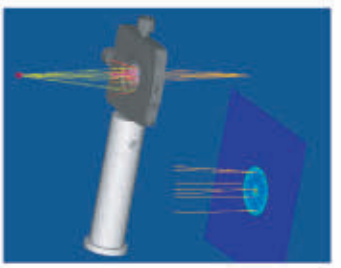
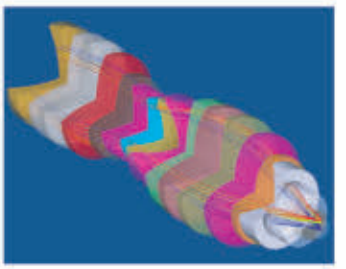


illumination CAD import/export



complex geometries



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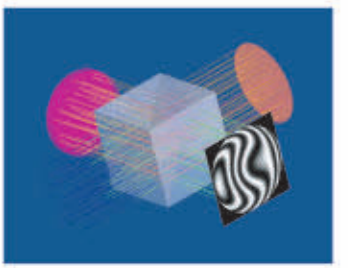

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