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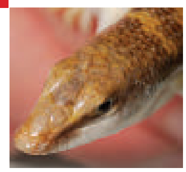
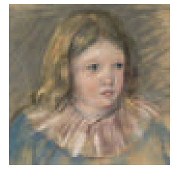

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This month's cover was inspired by the military laser feature on page 34; designed by Art Director Lisa N. Comstock.

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And the Nobel goes to ...

Photonics was in the spotlight last month as the Royal Swedish Academy of Sciences announced that the 2009 Nobel Prize in physics would be awarded to three legends in the field: Charles K. Kao, a founding father of fiber optics, who received half of the award, and Willard S. Boyle and George E. Smith, fathers of digital imaging.

Kao was cited for discovering how to transmit light through fiber optics efficiently using higher purity glass and for presenting single-mode fibers as the best transmission medium. He suggested that fused silica has the required purity, but because the material has a high melting temperature, it is not easily fabricated or manipulated. But in 1970, Corning Inc. doped titanium in the fused silica core and used pure fused silica in the cladding to make low-loss fused silica fibers using chemical vapor deposition.

Today, optical fibers carry almost all telephone and data traffic, from calls to text, music, images and video.

Before his retirement in 1996, Kao, a British and US citizen, served as director of engineering at Standard Telecommunication Laboratories in Harlow, UK, and was vice chancellor at the Chinese University of Hong Kong.

Boyle and Smith were working at Bell Laboratories in Murray Hill, N.J., in 1969 when they designed the first digital imaging sensor, used today in everything from consumer cameras to surgical devices.

Their CCD used the photoelectric effect theorized by Albert Einstein to transform light into electric signals. The major challenge was determining how to gather and read out those signals into a large number of pixels in a short burst of time. The first consumer camera with a CCD was designed in 1981, eliminating the need for film for image capture and leading to a revolution in digital photography.

"Taken together, these [two] inventions may have had a greater impact on humanity than any others in the last half century," said H. Frederick Dylla, executive director of the American Institute of Physics.

We at Photonics Media couldn't agree more, and we extend our hearty congratulations to the Nobel laureates – and to all who strive for innovation in the field of photonics.

This 1974 photo shows Bell Laboratories researchers Willard S. Boyle (left) and George E. Smith with their CCD that led to a revolution in digital imaging. Credit: Alcatel-Lucent/Bell Labs.

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The science sex gap

I read Gary Boas' article ("Understanding the 'sex gap' in science and math," September, p. 45) with interest. I have been interested in science since I was a child. While in middle school, I remember my math instructor teaching probability and statistics using baseball statistics. I had no idea what he was talking about, nor did I care as a young girl to hear about batting averages.

In college, one of my very first physics homework problems involved a "dashpot." I had to look up the word in the dictionary. It described a shock absorber, so I went to the nearest tire store and took a look at a dissected shock absorber.

I have to admit I gained no insight into how to solve the problem because a modern shock absorber is much more complicated than the simple dashpot that involved my problem.

Girls experience many subtle things throughout their school years. Maybe no single event happens to result in their losing interest in science and/or math, but, accumulatively, the end result is a lack of interest in science and math among the female population. Lucky for me, I'm too stubborn to pass over something I don't understand.

Teresa Lappin
Tucson, Ariz.

California dreaming

Your August editorial in support of University of California faculty protesting state budget cuts ("Biting the hand that feeds you") is misguided. You seem to be listening to just one side of the story – the self-interests of a few public employees who happen to be an asset to the photonics industry – and entirely disregarding the context of California's financial crisis.

California's problems go way back, and although this letter cannot adequately describe them in detail, they frequently have made national news. Some contributing factors include domination of the political process by public employee unions, overgenerous subsidies to public education, fashionable rules and restrictions on automobiles and emissions, requirements for certain percentages of public power to be generated from fashionably small or uneconomic power plants – e.g., hydro, wind or solar – bond measures for wasteful projects such as high-speed rail and a state-sponsored stem-cell research program, intrusive and counterproductive regulations on most aspects of life and business, high taxes and broad restrictions on land use.

The state government is entirely the captive of its beneficiaries, who have every incentive to raise taxes and little to control spending. In this year's crisis, the state again raised taxes and made marginal budget cuts, yet it still could not balance the budget without massive borrowing, adding to the debt burden of the many previous bond issues and compounding future problems. It is no wonder that the state has a falling bond rating, high unemployment and massive business flight to neighboring states, while Gov. Arnold Schwarzenegger veers off into nonsense about California doing its part to stop global warming.

In brief, California, its government captive to special interests and delusional zealots, is perennially a financial basket case.

As with all of the other public-sector employees in that pitiable state, the university faculty have been spoiled, living high on the taxpayers for a long time. Being a scientist myself, I would join you in applauding the value of their work. But given the magnitude of the state's problems, whatever marginal discomfort the state is now imposing on them is relatively trivial, and they do not deserve your full-page sympathy.

Laurence N. Wesson
Broad Axe, Pa.

Fraud, or Not

Speech should be free, and a wide range of opinions in the press is healthy. Having said this, I still am surprised that you published a letter (A solar fraud? *Letters*, September) on a serious topic, written by someone who, in my opinion, is unqualified. Giving this letter space in a technical magazine reduces your credibility and lowers the tone of our profession.

Orbiting solar power stations have been mooted for decades. The technology and its economics are certainly a subject for open debate, but allowing the uninformed to participate in the debate on your pages does not help clarify the issues.

Andrew Sabersky
fotoSAB LLC

Erratum

The manufacturer of the Jenoptik-Votan Solas 1800 laser system was incorrectly identified on page 87 of the September 2009 issue. The system is made by Jenoptik's Lasers & Material Processing Div. (www.automation-jenoptik.com).

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WEB EXCLUSIVES:

Science in the City of Angels

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

UV Curing Makes Inroads into PV Materials

UV curing of polymers is well-known for many applications, including wood coatings, graphic arts, electronics and optics. In the photovoltaic industry, however, with some notable exceptions, UV curing has not been accepted commercially. Raw materials and UV-curable formulations previously could not meet the stringent requirements for photovoltaic applications. Now, new development projects by raw materials suppliers, formulators and solar panel producers are resulting in superior-performing UV-curable products for this growing industry.

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

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

In the December issue of Photonics Spectra …

LCD Test & Measurement

LCD displays are saturating markets from cell phones to televisions, but even as new uses are being found, keeping them cost-effective requires better testing procedures during manufacturing. This feature article will look at the current state of LCD test and measurement around the globe.

Life on Mars

Laser-induced fluorescence emission has been used to detect bacteria in frozen Antarctic lakes. The technique could be used to detect signs of life in ice formations on Mars or on other nearby planets.

Uncooled Infrared Detectors

Better Performance, Lower Cost: Uncooled infrared detectors have seen many significant technology advances – improved reliability, better manufacturability and lower costs – that have fueled the availability of a wide variety of IR cameras for commercial, industrial and military products.

GreenLight

Researchers from Eindhoven University of Technology in the Netherlands and the University of Ulm in Germany have released high-resolution 3-D images of the inside of a solar cell, helping to understand how polymer solar cells operate and to improve their efficiency.

Detecting Biochemical Agents

It isn't time to retire the bomb-sniffing dogs yet, but advances in spectroscopy and other photonic techniques are moving that day closer. Thanks to innovations in such tools as surface-enhanced Raman spectroscopy, police and military personnel soon could be able to do quick checks to uncover explosives and chemical or biological agents. This feature article shows what's being done now and what may be possible soon.

EuroPhotonics

Makers of optical components have largely relied on Fizeau interferometers to check the quality of their surfaces, but these devices require very accurate references, that must be tailored for every type of surface. Twyman-Green interferometers don't have this requirement. Supporters say these offer more flexibility and rely on electronic processing of the test data.

You'll also find all the news that affects your industry, from tech trends and market reports to the latest products.

You can't afford to miss this issue.

Making Virtual Games:
In, Around and Out of the World

BY CAREN B. LES
NEWS EDITOR

Ask these Girl Scouts how they spent their summer vacation, and you'll hear about video games. But they didn't spend the summer playing them – they spent it making them.

A group of 22 sixth- to 10th-grade Girl Scouts at ASA Academy & Community Science Center in West Oakland, Calif., worked this summer to create online games in an immersive 3-D "in world" setting and, in the process, learned about technology, astronomy and global networking.

One goal of the pilot after-school and summer program "Universe Quest" is to seek out the talents and interests of girls in socioeconomic groups that traditionally don't pursue careers in science and technology. "Its main mission is to inspire girls to build a personal connection with science and technology using astronomy and game development, while empowering them with the skills they need to succeed in their education and life," said Heather Vilhauer, Universe Quest program manager at Girl Scouts of Northern California. Girls in middle school tend to thrive in all-girl educational environments, and this program allows them to explore science in a new and exciting way, she added.

The program represents collaboration between the Space Sciences Laboratory at the University of California, Berkeley, the Girls Go Tech program of Girl Scouts of Northern California and the Astronomical Society of the Pacific. The project is made possible by a $1.5 million National Science Foundation Innovative Technology Experiences for Students and Teachers (ITEST) grant to the University of California, Berkeley.

Through the game creation process, the girls are introduced to careers in areas such as software development and information technology. Creating the games helps them gain scientific knowledge, confidence in using technology, and soft skills such as teamwork, said Carl Pennypacker, UC Berkeley principal investigator of the Universe Quest project.

Girls get hands-on experience with telescopes as part of the pilot "Universe Quest" program, which enables them to author games in a 3-D virtual setting while learning about astronomy, technology and global networking. Photo courtesy of Heather Vilhauer.

The program welcomed approximately 15 girls last spring and will have up to 40 participants this year, when it will be held at two sites in Oakland, Vilhauer said. She added that the team is currently developing a formal curriculum for the two-year program, which will be available online to the general public. "We would like to see after-school programs from around the world adopt this program and use it as an opportunity to expand girls' interest in science and math," she said.

The games are not available online. This year girls in Oakland will be piloting their games by sharing them with girls in Portugal and Kenya.

Learning in the world

The Universe Quest games allow girls to put characters, objects, characters' paths and questions together so that a player learns something before advancing to the next level, according to Pennypacker who is also an astrophysicist at the University of California, Berkeley, and the Lawrence Berkeley National Laboratory. There eventually will be a "leveling up" system where, when students get correct answers, they can have access to new resources, such as a remote robotic telescope, he said.

The Universe Quest game uses the Thinking Worlds 3-D game authoring engine, but the project has added a lot of custom features.

As part of the program, the girls are learning how to operate telescopes remotely from their computers. Online, for example, they can point these devices at celestial objects and take exposures. The project shares ownership of a remote telescope with Perth Observatory in Australia and makes use of Frank Pino's Ironwood North Observatory in Queen Creek, Ariz., and the Tzec Maun Foundation Internet telescope.

With the online assistance of Lech Mankiewicz, an astrophysicist in Warsaw, Poland, educator Susan Murabona of Nairobi, Kenya, captured images of galaxy M51 remotely using Pino's telescope and shared them online with the girls in California. These images will become part of the game framework. The girls are also learning about simple optics and will build their own simple "Galileoscope."

Image processing

The girls' image processing experience might involve measuring the moons of Jupiter and the planet's mass from the orbits found in successive pictures. Or it might involve measuring the brightness of asteroids as they rotate and reflect varying amounts of sunlight, Pennypacker said. The girls use the SalsaJ image processing software, which sits on top of National Institutes of Health's ImageJ medical software.

Pennypacker said that Universe Quest girls will be linked to mentors in the industry and that project leaders also work with local programs to bring in role models in the fields of astronomy and technology to share the successes and challenges of their careers.

Linking the project to activities in the classroom has been easy, he added. "Simply put, the girls love authoring games, they love the astronomy, and they love making learning challenges within the games to teach other girls," Pennypacker said.

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Lighting the way to ultrafast microprocessors

MUNICH, Germany – The first milestone toward lightwave electronics has been achieved, thanks to a collaboration among physicists at Max Planck Institute of Quantum Optics in Garching, FOM Institute AMOLF (Institute for Atomic and Molecular Physics) in Amsterdam, the Netherlands, and chemists at Ludwig Maximilians University (LMU) in Munich.

Now, for the first time, light has been used to control single electrons within a molecular compound. The ability to pick out and guide individual electrons is the first step on the road to light-waveform electronics in which microprocessor speeds could reach attosecond timescales.

Attosecond research is at the frontier of laser physics, and the generation of short, phase-stable light pulses has been a key goal. Because electrons naturally travel at speeds on the order of attoseconds, marrying attosecond physics with electron motion was an obvious avenue of research.

"So far, attosecond control of electron dynamics has only been demonstrated for simple molecules containing two atoms and a single electron," said professor Regina de Vivie-Riedle at LMU. "We extended this control to multielectron systems, where it becomes increasingly difficult to 'pick out' a single electron and control its motion."

The ability to control electrons in multielectron systems not only opens the door to high-speed microprocessors but also marks an important step toward the control of chemical reactions using light as well as the control of electron motion in nanostructures.

In the German-Dutch collaboration, published in the journal *Physical Review Letters* on Sept. 4, 2009, individual electrons were singled out from a system containing 14 electrons. The key to the approach was to alter the waveform of the electromagnetic field of laser pulses to modify the forces that act on the electrons.

"The pulses that were used in our study are the shortest such pulses used for molecular control studies thus far," said Dr. Matthias Kling of Max Planck. "Using laser pulses of just four femtoseconds, it also becomes feasible to image the structure of the outermost occupied molecular orbitals."

In the experiment, a neutral carbon monoxide molecule is ionized at the peak of the laser field so that an electron detaches. This released electron is driven by a strong, few-cycle laser field away and back to the molecule, and, upon recollision, the parent molecular ion gets excited. The resulting strongly coupled electron-nuclear motion can be steered by the remaining laser field.

"The speed of control is much faster compared with conventional electronic devices," Kling said. "And the degree of control of electron dynamics increases with decreasing pulse duration."

Although the commercial potential of the technique is promising, de Vivie-Riedle emphasized that, before electronic devices can be built, much more research is needed. "Our next step is to apply the newly developed techniques to more complex molecules and nanostructures."

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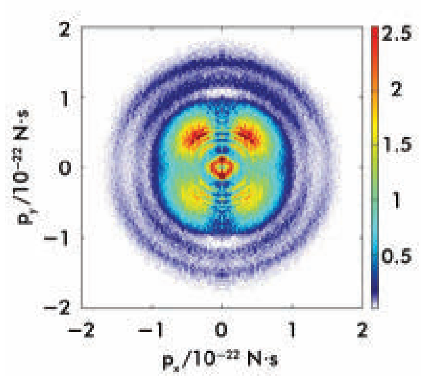
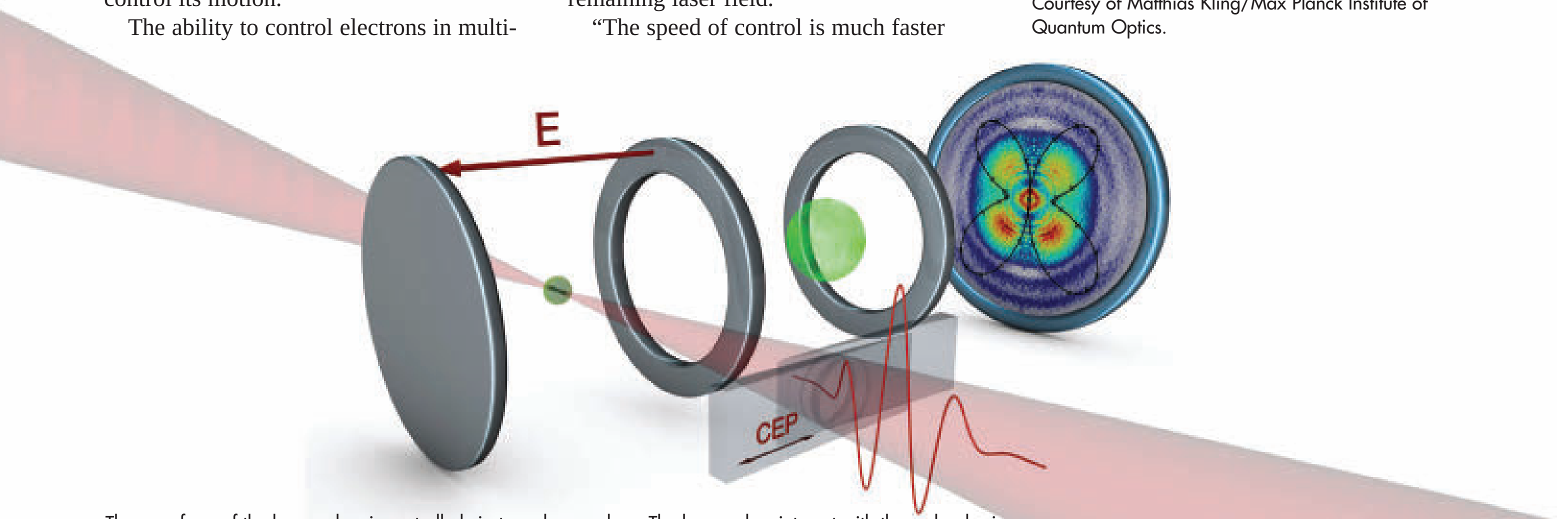


Shown is a view into the microcosm of carbon monoxide molecules. The detachment of electrons from carbon monoxide molecules by femtosecond laser pulses leads to a characteristic angular distribution of the molecular ions and their fragments. Courtesy of Matthias Kling/Max Planck Institute of Quantum Optics.



The waveform of the laser pulses is controlled via two glass wedges. The laser pulses interact with the molecules in a velocity-map imaging spectrometer, in which the resulting distribution of ions (here, C ions) after the breakup of the molecules is imaged onto a detector (right). The image on the detector displays an up-down asymmetry along the vertical polarization axis of the laser. The symmetry of the ionized orbitals of CO becomes visible by the 45° contributions in the angular distribution, which can be predicted by theoretical calculations (black line). Courtesy of Christian Hackenberger/Ludwig Maximilians University.

The art of SERS

CHICAGO – Surface-enhanced Raman spectroscopy (SERS) could help identify forged artworks. Researchers are using it to analyze paintings by 19th-century artist Mary Cassatt and the pastels she used to identify whether the materials were natural, synthetic or organic colorants. Determining the pastels' chemical classes will help the scientists to distinguish between specific dyes, revealing the era in which a work of art was created and perhaps whether it is authentic.

Richard Van Duyne, a chemistry professor at Northwestern University, and colleagues have accomplished the first direct, extractionless and nonhydrolysis SERS study of delicate pieces of art.

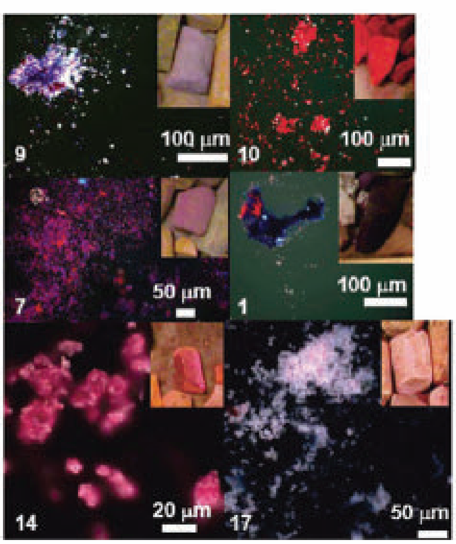
Raman spectroscopy has been one method of analyzing pigments in artworks. However, SERS is one to 100 million times more sensitive, Van Duyne said. "Normal Raman spectroscopy and resonance Raman spectroscopy were shown to be very useful for studying inorganic but *not* organic pigments in artworks," he said. SERS and surface-enhanced resonance Raman spectroscopy both work with organic because the fluorescence of the pigments doesn't interfere with the Raman. He added, "About half of all the pigments used are organic."

A sample from the flesh tone color of the face in Cassatt's "Sketch of Margaret Sloane, Looking Right" revealed purple pastel colorants, including lead-white and chrome yellow-orange. The mauve ruff of the subject's blouse revealed a pink colorant and an unknown second component.

For the first experiment, the researchers applied SERS to powder samples of pastel sticks taken from a pastel box owned by Cassatt. They painted grains from the sticks with sodium citrate-reduced silver colloids and used a 632.8-nm HeNe laser to excite the molecules. The 632.8-nm excitation wavelength gave the most intense signal with a lesser fluorescence interference.

They discovered that the shade called "carmine lake" was in the lilac, bright-red and light-pink pastel sticks, creating a purple hue. The pink pastel stick had a fuchsia pigment containing the chemical classes of rhodamine B and rhodamine 6G, with a presence of the mineral binder magnesite. Van Duyne identified that the pastels were made of synthetic organic pigment belonging to either or both of the dye classes β-naphthol and monoazo.

In a second experiment, performed on Cassatt's "Sketch of Margaret Sloane, Looking Right," two samples were taken with a tungsten needle, one from the flesh tone color of the face and the second from the mauve coloring within the white ruff. The strongest SERS spectra confirmed that the colors for the face contained the same dye as the purple pastel sticks, while the ruff revealed pink colorants and an un-



Photomicrographs of pastel sticks used in Mary Cassatt's artwork are pictured. Using SERS, investigators analyzed the grains of each stick to identify their chemical class and to determine whether the colorants were natural, organic or synthetic.

known component. The researchers reported that many of the colors were produced by mixing pastels instead of layering them on the canvas; therefore, it is common to find spectra with more than one colorant.

Other methods of identifying colorants include high-performance liquid chromatography and UV-VIS spectroscopy, but chromatography requires a large sample, which may not be available when studying artworks, and UV has poor specificity and difficulty with matrix interferences.

SERS can cause minor photodegradation from the laser, but it demonstrates photostability and can determine chromophores in an array of complex matrices, even in the presence of binders such as animal glue found on glass. Most importantly, SERS has provided a more sensitive examination of complex matrices and reduced sample sizes down to a single molecule. The team's findings were published Sept. 1 in the journal *Analytical Chemistry*.

Amanda D. Francoeur
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Going negative for a fast switch

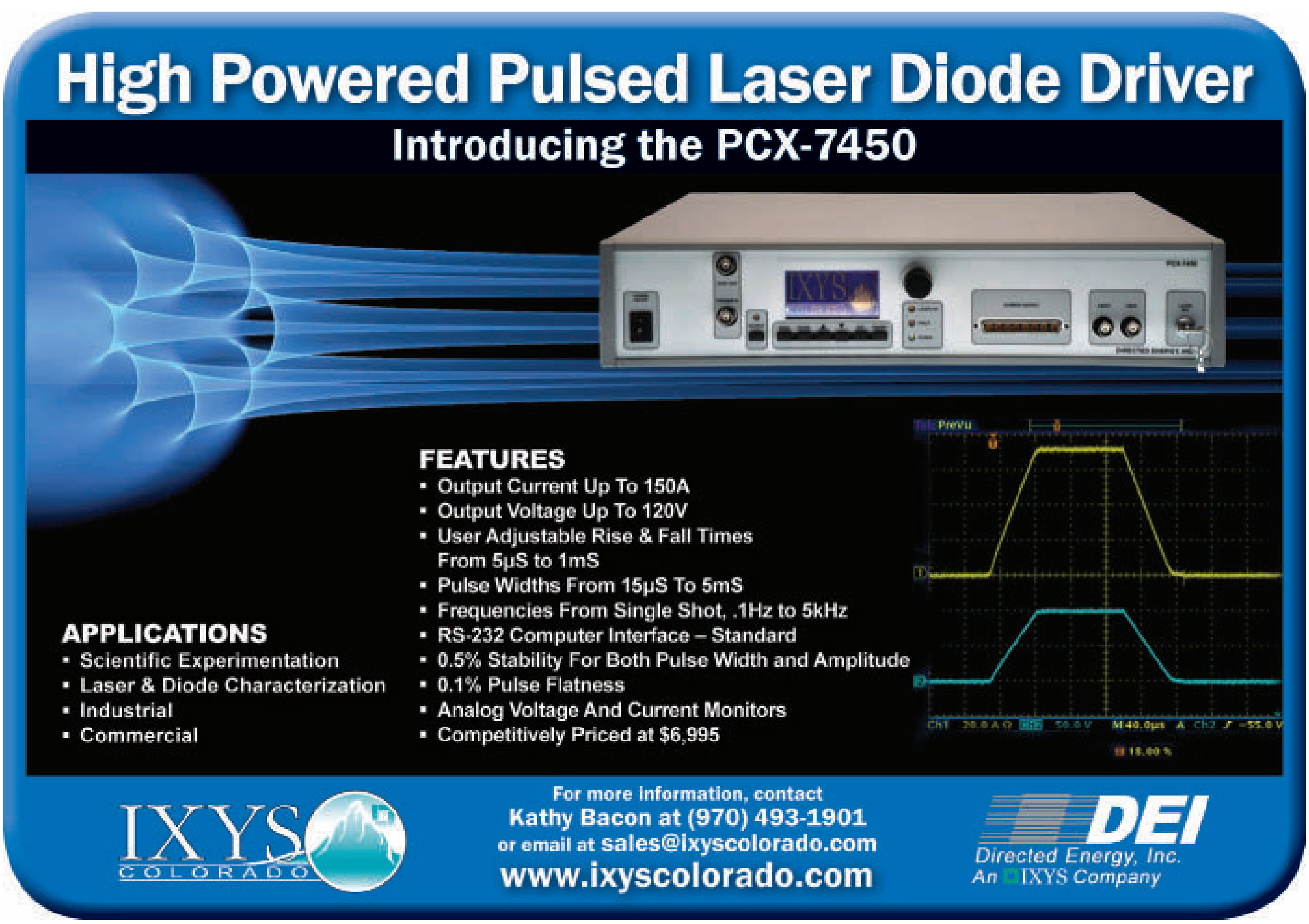
LOS ALAMOS, N.M. – The days of high-speed, all-optical communication are literally a bit closer. Researchers at Los Alamos National Laboratory and at the University of New Mexico in Albuquerque have demonstrated a nanoscale negative-index metamaterial device that can switch a bit on or off in 600 fs – 100 times faster than any previously reported.

"In principle, this gives us more than a terabit per second communication speeds," said Keshav M. Dani, a postdoctoral fellow at Los Alamos and lead author of a September 2009 *Nano Letters* paper describing the research.

He cautioned that the demonstration involved only a single bit and thus is still far from a commercial switch capable of modulating a trillion bits per second. However, with structural tuning, the demonstration device will work in the near-IR from 1 to 2 µm – a wavelength range widely used in telecommunications. Thus, all-optical switching based on this operating principle could be of interest to industry. Dani doesn't foresee fundamental barriers to producing such products, although many engineering hurdles may have to be overcome.

The negative-index metamaterial devices were composed of two 28-nm-thick layers of silver sandwiching a 60-nm layer of amorphous silicon. Using a liftoff process, the researchers created elliptical holes in the film stack, with a spacing of about 100 nm between the roughly 200-nm holes. The combination of film and hole geometries resulted in a metamaterial with a negative index of refraction at wavelengths of 1.13 and 1.68 µm. Other geometries would shift those regions around, allowing anything between 1 and 2 µm to be covered.

The key to the rapid switching was the use of amorphous silicon, a semiconductor. When the researchers photoexcited the silicon with a laser pulse at a wavelength short enough for the photon energy to be



above the bandgap, they flooded the silicon temporarily with holes and electrons. That altered the optical behavior of the metamaterial. The change lasted only as long as the carriers did, or 600 fs in the demonstration device.

The researchers used a laser and an optical parametric amplifier to generate a visible pulse for photoexcitation. Using a different optical parametric amplifier, they generated a near-IR pulse and measured its transmittance through the material. They were able to alter transmission at the shorter negative refraction wavelength by 20 percent, a figure determined by the photoexcitation pulse power.

Besides telecom applications, other possible uses involve data communications. The demonstration device involved transmission, but other optical properties could be used, such as phase or polarization.

As for the future, University of New Mexico graduate student Zahyun Ku noted that the fabrication of the devices could be improved, resulting in more nearly vertical hole sidewalls, better film quality, additional functional layers and greater device uniformity. These enhancements would increase resonance intensity and improve device performance, he said.

"If we would have stronger resonance peaks at the negative refractive index region, we could expect a larger switching ratio for applications," he added.

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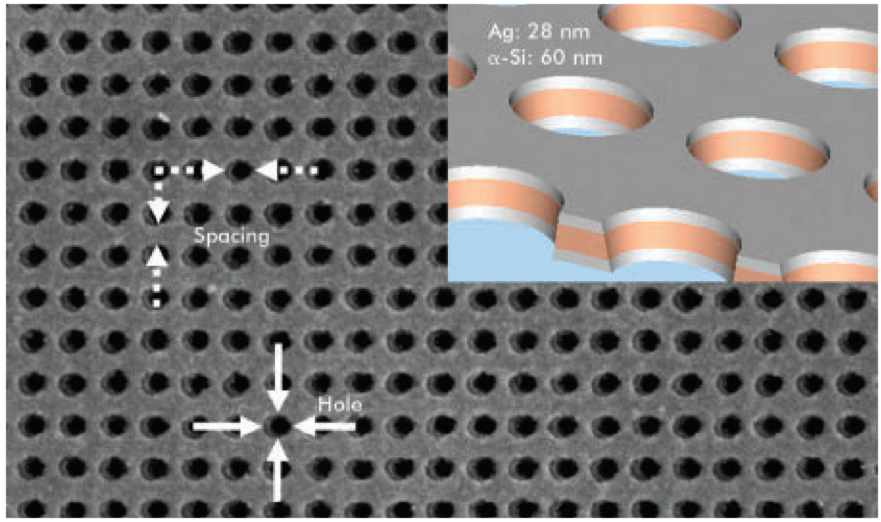
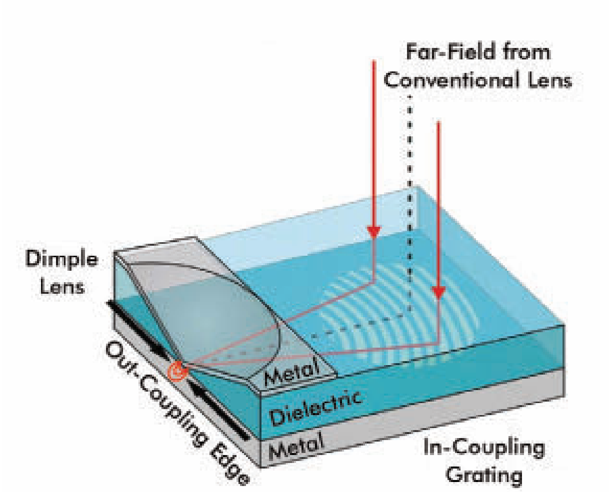


Shown is a nanoscale fast-switching metamaterial composed of three layers: silver, amorphous silicon and silver (inset). A visible pulse changed this fishnet metamaterial's near-IR transmission, opening up the possibility of all-optical ultrafast switching. Courtesy of Zahyun Ku, University of New Mexico, and Keshav M. Dani, Los Alamos National Laboratory.

Dimple lens goes beyond the diffraction limit

LOS ANGELES – University of California scientists have created a new type of lens that can focus light down to a sub-100-nm spot. This record-breaking focusing power could open up new areas of research in biological sciences, nonlinear optics and near-field scanning optical microscopy (NSOM) techniques.

Until now, conventional optics could focus light to a spot size of only around half a wavelength. By exploiting the novel properties of surface plasmonic modes, the UCLA team has not only surpassed the diffraction limit but has also built the first plasmonic dimple lens, paving the way to widespread applications.



The plasmonic dimple lens uses a grating coupler to couple free-space photons into surface plasmons. These plasmons are focused into a nanoscopic volume by a 3-D dimple lens. Image courtesy of UCLA.

Heat-assisted magnetic recording is a much-anticipated technology that will be used in next-generation magnetic hard disks. In the device, a sub-50-nm optical near-field source would serve to heat up the magnetic domains of the hard disk, and a dimple lens would be an ideal candidate for the job.

"Our dimple lens is best compatible with the industry-established fabrication process sequence of the magnetic hard disks," explained co-inventor Shantha Vedantam. "What's more, the smallest critical dimension of our dimple lens is not limited by the standard available lithographic techniques."

Another important application that could benefit from the strong near-field light created by the dimple lens is NSOM, which is a scientifically important tool in material, physical and biological sciences.

"As far as NSOM is concerned, our dimple lens design scores over the commercially available pulled metal-coated aperture fiber probes both in terms of achievable spot size as well as energy/field concentration," Vedantam added. "Of course, the fabrication process sequence for this application would be slightly different from that of the [heat-assisted magnetic recording] application."

The dimple lens, which is described in the September issue of *Nano Letters*, is a semicircular tapered metal-insulator-metal structure containing a grating in-coupler. When incident light reaches the grating, surface plasmons are generated. These surface plasmons travel radially along the tapered metal-insulator-metal stack and are eventually focused to a sharp point at the center of the semicircular dimple.

A precise measurement of the final spot size produced by the dimple lens was not possible due to the resolution limit of the pulled-fiber NSOM used in the experiment. But what the team does know is that the lens is capable of focusing light to spot sizes smaller than the aperture of commercially available pulled-fiber NSOM probes – in this case less than 100 nm.

According to Vedantam, the next step for the UCLA team is to identify new applications and fabricate the dimple lens structures accordingly. "We are also working toward improving our experimental measurement setup to allow us to measure not only the spot-size but also the electric field enhancement of our dimple lens for future nanostructural designs," Vedantam concluded.

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Diamonds sparkle in Raman application

SYDNEY, Australia – Researchers from Macquarie University and from the Defence Science and Technology Organisation (DSTO) in Edinburgh have developed a diamond Raman laser with 63.5 percent efficiency, taking diamond into the same conversion league as other Raman laser materials, but with a host of advantages.

Diamond's hardness makes it an attractive material for high-power lasers because the damage threshold is very high. Equally important, the thermal conductivity of diamond is a magnitude higher than similar materials. This reduces the effect of thermal lensing, which haunts high-power solid-state laser developers. What is more, diamond has exciting light-conversion properties, providing access to new wavelengths and related applications.

Raman lasers typically use silicon, barium nitrate or metal tungstate crystals to amplify light created by a pump laser. The pump light makes some of the photons exchange energy with them, leading to loss or gain of energy, with the scattered light having a different wavelength. A Raman laser takes this secondary light – called Stokes or anti-Stokes – and amplifies it by reflecting it into a cavity while pumping energy into the system to emit a coherent laser beam at the shifted wavelength.

Richard P. Mildren of Macquarie and Alexander Sabella of the DSTO built an efficient 532-nm pumped external-cavity diamond Raman laser generating output chiefly at the 573-nm Stokes line. They used a 6.7-mm-long artificial diamond as the Raman material, generating 1.2 W of output at a pulse repetition rate of 5 kHz with a conversion efficiency of 63.5 percent and a slope efficiency of 75 percent. The maximum output energy of the pulses was 0.67 mJ.

Their results, published in the Sept. 10 issue of *Optics Letters*, conclude that such efficiency is commensurate with the highest previously reported for other Raman materials pumped by Q-switched lasers.

This is a significant improvement over the first diamond Raman laser that Mildren and co-workers presented in 2008, a device that reached only 22 percent slope efficiency. In the past year, chemical vapor deposition has greatly improved, enabling the synthesis of larger diamond crystals with a lower birefringence, an effect that was a key limitation last year.

Diamond crystals also can be made to generate a wider variety of wavelengths of light, each of which has its own applications – from ultraviolet light at 225 nm to the far-infrared at 100 µm, with only a gap between 3- and 6-µm wavelengths.

The new device is being used to produce yellow laser light for medical applications including eye surgery. Additional applications range from trace gas detectors to defense technologies to satellite mapping of greenhouse gases.

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The microscopy market: Delivering to the desktop

WELLESLEY, Mass. – Worth about $2.4 billion in 2008, the global market for microscopes and accessories is projected to fall to $2.1 billion in 2009, then to rise to $3.6 billion in 2014 with a compound annual growth rate of 11.5 percent, according to a report from market analysis firm BCC Research.

The July 2009 report titled *Microscopy: The Global Market* indicates that the microscope segment, which makes up the bulk of the market, is expected to fall from $2 billion in 2008 to $1.7 billion in 2009 and then to rebound to $3.1 billion in 2014, with a compound annual growth rate of 12.4 percent. The accessories and supplies segment, the remainder of the market, which experienced sales of $360 million in 2008, is projected to increase to about $374 million in 2009 and to $513 million in 2014, for a compound annual growth rate of 6.5 percent.

"The global microscopy market is a complex landscape, encompassing at least eight sectors," noted Barbara Foster, master microscopist, president and senior strategic consultant for Microscopy & Imaging Place Inc., based in McKinney, Texas. "It includes instruments such as the light, confocal, scanning probe (SPM), and scanning and transmission electron (SEM and TEM) microscopes; components such as cameras, software and hardware; and accessories such as stages, slides and illuminators," she said. "This heterogeneity is the key challenge in accurately assessing this market," said Foster, who is experienced in new product and company launches.

When asked about the overarching business trend in today's market, Foster responded that the most critical concern is the drive to get new products to market faster. "Years ago, we had the luxury of five to 10 years for commercialization. Today, new sectors mature in two years. Manufacturers need to be alert to the trends, to be more flexible and responsive." She noted that new funding is emerging as science has become more politically driven, especially in nano- and clean technologies. Despite the current economic downturn, she predicts a rosy future.

Hybrids lead the way

"Over the past five years, we've seen a major shift toward integrated instrumentation," observed Foster, "especially combining spectroscopy with imaging." For nearly four decades, SEMs combined imaging with elemental analysis. The new technologies incorporate Fourier transform infrared (FTIR) and Raman to add molecular analysis. Renishaw's Structural and Chemical Analyzer pushes this envelope, uniting light microscopy, SEM and SPM with confocal Raman spectroscopy to enable morphological, elemental, chemical, physical and electronic analysis on one platform, eliminating the laborious and time-consuming process of moving the sample between instruments.

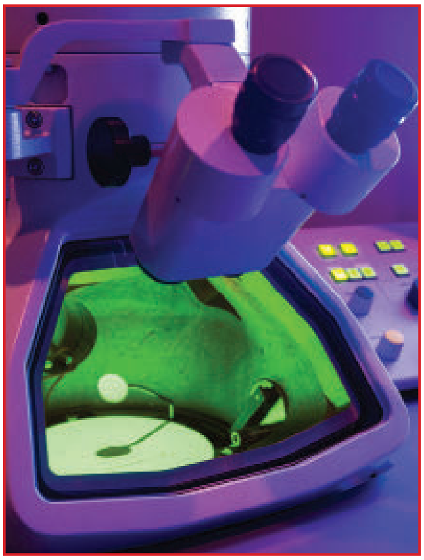
On the FTIR front, Smiths Detection's IlluminatIR accessory combines FTIR with the power of conventional light microscopy modes such as polarized light, fluorescence, and phase contrast and has been well accepted in polymer, pharmaceutical and forensics labs.

Foster said that high-throughput microscopy, used, for example, for characterizing paints and polymers, is becoming an important tool in the industrial, pharmaceutical and biotechnology sectors, while microscopes that can view whole live animals and critical organs in 3-D, all within the context of bodily systems, constitute a growing segment for the biomedical market.

From nanotechnology to new accessories

Nanotechnology has a double effect on microscopy, according to Foster. It extends microscopy into nanobiology and nanomaterials, and it enables smaller, sleeker, faster and more economical instrumentation.

Simplified instrumentation for broader mainstream use is another trend. "The last two years have seen a proliferation of desktop SEMs," cited Foster. "And SPMs, like the Solver Next dual-headed atomic force/scanning tunneling microscope from NT-MDT, are now joining the fray."



Microscope accessories showing promise in the market include LED illumination for fluorescence on light microscopes (Zeiss Colibri and CoolLED); a stage from the Zeiss SEM group that permits translation from a light microscope to a scanning electron microscope without losing sample location; special cameras with rapid acquisition capabilities for capturing motion in low-light environments (MotionX); Exfo's X-Cite radiometer, which measures illumination at the sample itself; and CytoViva's adapter for light microscopy, which drops the limit of resolution from ~300 nm to less than 90 nm and is especially valuable for intracellular live-cell work such as the study of apoptosis.

Greatest challenges?

"The microscopy business is not for the faint of heart," Foster noted. "On one side, manufacturers are being asked for affordable, easy-to-use instruments that will just about sell themselves and, on the other, for complex, hybrid instrumentation that requires intense technical support, all while making a profit." For the end user, the challenge is acquiring the science and practical expertise to adapt to more complex sample preparation and the growing arsenal of system components.

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Microscope Distributor To extend its reach and promote its products in the former Soviet Union, Asylum Research of Santa Barbara, Calif., has signed a distribution agreement with Intertech Corp. of Atkinson, N.H. The latter company will sell and support its partner's line of atomic force and scanning probe microscopes in the Russian Federation, Belarus, Georgia, Ukraine, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Armenia and Turkmenistan.

Satellite Contract Headwall Photonics of Fitchburg, Mass., has been awarded a contract by NEC Corp.'s Space Systems Div. in Tokyo. The American company will develop and supply the hyperspectral instrument payload for a Japanese remote sensing satellite, enabling Headwall to introduce a class of imaging sensors designed for small satellite payloads.

$10 Million Investment Anteryon of Eindhoven, the Netherlands, a provider of wafer-scale micro-optics, has received $10 million in new equity from Mentha Capital of Amsterdam, also of the Netherlands, and from BNP Paribas Private Equity of Paris. The capital will enable Anteryon to increase its global manufacturing facilities, expanding its existing factory in Eindhoven and building one in the Far East.

Laser Distribution Dortmund, Germany-based Klastech-Karpushko Laser Technologies GmbH has appointed an exclusive distributor for Japan. Indeco Inc. of Tokyo will supply its partner's diode-pumped solid-state laser product range throughout the country.

Fiber Spin-off Acreo Fiberlab of Hudiksvall has created Fibertronix AB of Stockholm, both in Sweden. The spin-off company will develop and manufacture specialty optical fibers and fiber-based solutions, targeting customers and applications in the oil, gas, military and avionics industries. Its portfolio currently includes a range of specialty fibers as well as custom fibers and preforms.

Lighting Agreement SphereOptics of Concord, N.H., has selected Sarah Technology Co. Ltd. of Gyeonggi-do, Korea, as a product reseller in South Korea. The latter company will market and sell its partner's complete line of products, including integrating spheres; lamp, LED and laser power measurement systems; and luminance/radiance standards.

Optical Start-up In Munich, Germany, Ludwig Maximilians University and Max Planck Society have created a company to manufacture specialized mirrors and other optical elements for use with pulsed laser light and x-rays. UltraFast Innovations GmbH offers all-inclusive service, from design to inspection, and will fabricate components to customer specifications.

Vision Partnership FSI Technologies Inc. of Lombard, Ill., and Eye Vision Technology AG of Karlsruhe, Germany, have agreed to collaborate on the introduction of EyeSpector smart cameras and EyeVision machine vision software to North America. FSI will be the North American headquarters of the technologies and will offer training programs and support services for them.

Solar Collaboration DuPont Photovoltaic Solutions of Wilmington, Del., and Applied Materials Inc. of Santa Clara, Calif., have announced a partnership to increase the efficiency of crystalline silicon photovoltaic solar cells. The companies will work together to advance multiple printing technology, potentially increasing absolute efficiency by more than 0.5 percent.

Sensor Platform Agreement SPECIM-Spectral Imaging Ltd. of Oulu, Finland, and Airborne Technologies GmbH of Wiener Neustadt, Austria, have signed an agreement to provide the airborne remote sensing market with turnkey multiple sensor platforms. The former company will supply hyperspectral sensors, while the latter will integrate them with laser scanners or digital cameras.

Laser Acquisition EO Technics Co. Ltd. of London, a developer and manufacturer of laser-based equipment, has acquired the laser business and assets of Powerlase Ltd. of Crawley, UK. As part of the agreement, the London-based company has established a wholly owned subsidiary, Powerlase Photonics Inc., to take over the business. The new company will retain the Powerlase and Starlase brand names.

Sapphire Facility Exotic Electro-Optics Inc. of Murrieta, Calif., a subsidiary of II-VI Inc., has begun building a facility next to its headquarters. The planned 24,000-sq-ft building will support fabrication of large sapphire windows for intelligence, surveillance and reconnaissance applications. The company plans to have the facility fully operational in 12 months.

Distribution Agreement Oxxius Inc. of Santa Clara, Calif., has named RPMC Lasers Inc. of O'Fallon, Mo., as the North American distributor for its family of continuous-wave diode-pumped solid-state lasers and laser diode modules. The devices can be used in a wide range of applications, including fluorescence excitation and metrology.

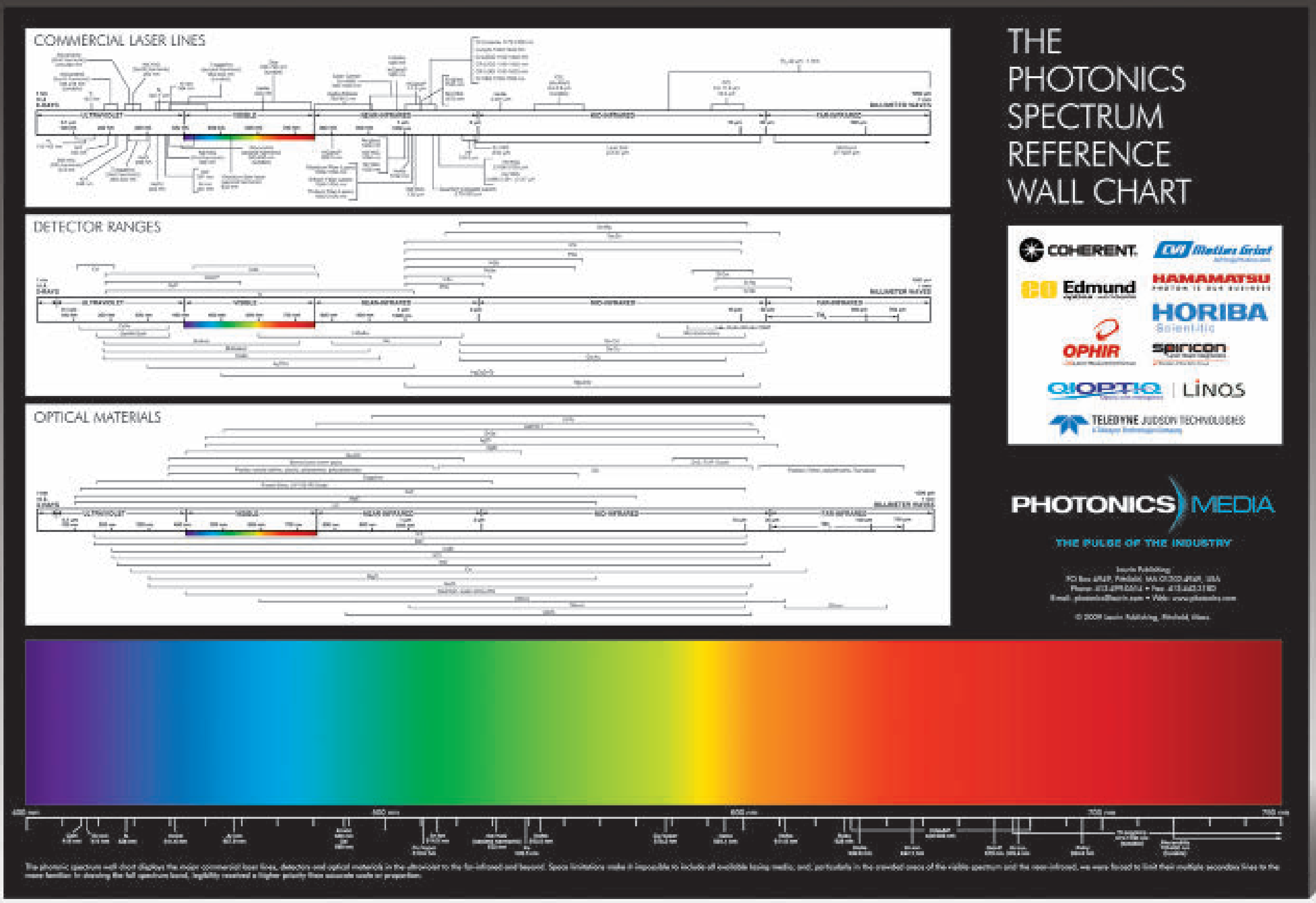
Optical Manufacturing San Jose, Calif.-based Sanmina-SCI Corp. and OneChip Photonics of Ottawa have announced a manufacturing partnership. They will collaborate to produce the Canadian company's photonics integrated circuit-based fiber-to-the-premises transceivers, which they plan to distribute globally.

German Relocation To further their integration, Cambridge Technology Inc. of Lexington and General Scanning Optical Scanning Products of Bedford, both in Massachusetts, have agreed to relocate the European sales and support operations of the former company. The operation, which provides sales, application and technical support for both companies' products, will be located just outside of Munich in Planegg, Germany.

THE PHOTONICS SPECTRUM REFERENCE WALL CHART

FROM LAURIN PUBLISHING

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



Actual Size: 30" x 20½"

THE PHOTONICS SPECTRUM REFERENCE WALL CHART

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10/09

Venture capital goes green

BY ANNE L. FISCHER
SENIOR EDITOR

Over the past few decades, venture capitalists have had plenty of waves to ride: computer technology, biotechnology, dot-com technology and nanotechnology.

For some of the waves, it was boom or bust – as was the case with the dot-com era – while others, such as computer technology, reached saturation. Biotechnology remains robust, however, and nanotechnology still is evolving.

But now there is clean technology. Despite economic times that would seem to dictate caution and the avoidance of high-risk alternative anything, clean technology is attracting serious investors who are in it for the long haul.

Clean technology is driven by rising energy prices and a shortage of natural resources – fossil fuels, clean water – coupled with strong government incentives. According to the National Venture Capital Association, in the first quarter of 2009, clean-technology investment increased 15 percent over the same quarter in 2008, with $274 million pumped into 42 deals.

Greentech Media of Cambridge, Mass., has reported that venture capital investment in green technologies totaled $1.2 billion in 85 deals in the second quarter of 2009, up from $836 million in the first quarter. Company analyst Eric Wesoff said that third-quarter venture capital investment will be even better.

He noted that it is not just government incentives that are boosting clean-technology investing, "although a stable, encouraging policy framework is a positive for investors."

Andrew Williamson, a director at venture capital firm Physic Ventures in San Francisco, said that clean technology is here to stay "because of the fundamental macroeconomic drivers." These include the "increased scarcity of natural resources and an increased awareness of the impact of economic development on the environment."

Williamson added that it is a lot easier to find a way to save a megawatt of electricity – a negawatt – than it is to find a clean way to produce one. And these negawatts are likely to come in the form of energy efficiency.

Following this sector is the San Francisco-based Cleantech Group, which publishes a global index of publicly traded clean-technology companies. The index rose 16.6 percent in the first half of 2009, surpassing other leading indices such as the Standard & Poor's 500.

What receives funding

It always seems safer to invest in a product you can see to assess its long-term viability. But some venture capitalists ante up the cash long before the production stage. Vinod Khosla, a co-founder of Sun Microsystems in Phoenix and a venture capitalist, has invested millions in green technology. In 2004, he launched Khosla Ventures, which has raised $1.1 billion to invest in green technology and information technology start-ups.

He plans to fund "science experiments" that address climate change, a big risk for venture capitalists, he said. He sees it as akin to 1980s' investing, when people took technical risks with a small amount of money and a small team. Khosla and four partners have invested at least $100 million of their own money in a seed fund for very high risk start-ups that they acknowledge have a high likelihood of failure.

Physic Ventures' Williamson noted that venture investments in clean technology span a range from early-stage research projects with a lot of technology risk to later-stage infrastructure projects. Early-stage investments typically are more capital efficient and offer the potential for high returns, while later-stage finance projects have less risk but provide lower rates of return. His position is that "the most attractive venture investments are found in disruptive technologies and business models, where, if the research pans out, they will have an impact on a large market."

Cleaning up

Wesoff listed smart grid, algae biofuels and energy efficiency as likely to continue to receive funding.

Williamson's list echoed that and added batteries and electrification of transportation as areas likely to make a difference. He also sees promise in water purification technologies. "Water is often described as the new oil, in that clean drinking water is becoming increasingly scarce."

Technologies he believes will be interesting to follow include low-energy desalination approaches and the use of UV LEDs as a way of disinfecting water. Progress in battery and desalination technologies has been "painfully slow," he said, but we are starting to see exciting technology solutions that may come from nanotechnology.

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Year	Total Venture Capital Investment in Green Technology	Number of Deals
2005	$820M	74
2007	$3.5B	222
2009 – August	$3B	227

Research provided by Greentech Media.

According to figures from Greentech Media, clean technology is on the rise, showing a strong second quarter in 2009 and an even better third quarter.

Painting the roof with solar ink

In Brian Korgel's lab at the University of Texas, researchers are working on a CIGS-based solar ink that can be spray-painted onto a variety of surfaces. Photo courtesy of the University of Texas at Austin.

Covering rooftops with solar cells came one step closer to reality recently when JA Solar of Yangzhou, China, announced plans to commercialize technology developed by Innovalight, a San Francisco Bay-area company that makes a silicon solar "ink."

The Innovalight concept puts a twist on traditional silicon solar manufacturing. The difference between making regular silicon solar cells and those with solar "ink" is that the ink process uses high-throughput atmospheric ink-jet manufacturing rather than low-throughput vacuum-based processing. Silicon ink is made by a process in which tiny silicon nanoparticles are suspended in a liquid that can be applied to rigid and flexible substrates.

What's most significant about this process, according to Innovalight CEO Conrad Burke, is that it produces nano particles that maintain their low melting temperatures while still remaining small enough to stay in solution. He added that, "By the nature of how small they are, we can exploit their quantum effects," and he noted that this quality may ultimately give rise to other long-range opportunities with quantum dots or silicon nanoparticles, such as higher efficiencies.

Recently Innovalight demonstrated the technology to have an almost 18.5 percent conversion efficiency. An efficiency of 18 percent was independently certified by the US Department of Energy's National Renewable Energy Laboratory (NREL) and the Fraunhofer Institute for Solar Energy Systems in Germany but, as Burke pointed out, because of the time lag, there's a difference between where they are currently and what's being measured by independent labs. He expects the technology can go well over 20 percent in the coming 12 months.

Silicon solar paint manufactured by Innovalight using an ink-jet process recently demonstrated an 18 percent conversion efficiency. Photo courtesy of Innovalight.

Interestingly, one of the founders of Innovalight, Brian Korgel, has moved his research from silicon-based solar ink to copper indium gallium selenide (CIGS). He cites several advantages that CIGS has over silicon, including the fact that it's a direct bandgap semiconductor, which ultimately uses less material in manufacturing. His team at the University of Texas at Austin has achieved efficiencies of 1 percent and is shooting for 10 before going the commercial route. Korgel estimates that it will take from three to five years before that happens, but if it works, he said, the inks could be applied to windows, effectively turning them into solar collectors.

CIGS on foil

At another Bay-area start-up back in 2002, researchers were already working with CIGS-based roll-to-roll processing. San Jose-based Nanosolar also uses a high-throughput printing process rather than a vacuum technique, but the company utilizes aluminum foil as the substrate and bottom electrode of the cell, with a wrap-through back contact and thin, transparent top electrode. NREL certified the active-area foil efficiency at about 15 percent, according to Keith Emery, device performance team leader at NREL.

Nanosolar recently announced completion of its panel assembly factory in Germany, which is expected to manufacture one panel every 10 seconds, with a potential annual capacity of 640 MW.

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Dual solar sailing projects eye circumnavigation

Sailing under wind power has always been green, but two solar boat projects bring the concept to a new level. Both boats are catamarans and plan to circle the globe powered solely by the sun.

Currently under construction in Kiel, Germany, is a double-hulled boat being built by PlanetSolar, complete with 38,000 monocrystalline polysilicon solar cells that will cover more than 470 sq m on the deck. The cells, from SunPower Corp. of San Jose, Calif., will have an efficiency of 22 percent. The boat will be 30 m long, will weigh 10 tons and will have a 15-m beam.

The goal is to circle the world in 2010 in 140 days at an average speed of 8 knots. The boat will carry two sailors for the voyage but will be able to accommodate as many as 50 visitors who may tour the boat at each stop.

In conjunction with the boat project, a PlanetSolar village was opened in Yverdon-les-Bains, Switzerland, where visitors can see demonstrations of renewable energy sources as well as learn about the solar boat. The project is being led by Raphael Domjan, who founded PlanetSolar and who will skipper the boat. Financing is provided by Rivendell Holding AG of Zug, Switzerland, a firm that invests in renewable energy.

In another project, a boat called the Solar Circumnavigator is being built under the guidance of Anthony Howarth, a designer/sailor who had the idea more than 20 years ago. At that time, however, he could find little backing. But, today, financing is a different story, as the undertaking recently received funding from the Peoples Projects Foundation, a nonprofit organization based in the Netherlands that is dedicated to advancing the use of alternative energies. If all goes as planned, the boat will embark on two voyages in 2011.

The Solar Circumnavigator's photovoltaic cells will have an efficiency of 30 percent, and their ability to self-orient toward the sun will make them, on average, from 25 to 50 percent more efficient than a fixed solar array. DC motors will be driven directly by the solar energy, excess daylight energy being accumulated in lithium ion batteries to maintain speed throughout the night. Two large-diameter, slow-speed cruising propellers have been designed for sustainable speeds of ~12 knots; they are effective between 8 and 16 knots. A second pair of propellers can be lowered into the water for bursts of higher speeds, and a third pair can be lowered for slow-speed maneuvering in ports and while docking.

The 20-m catamaran, with a 10-m beam, will have a maximum speed of more than 30 knots and will be capable of carrying up to 12 people for short cruises. Also onboard will be a fully solar-powered dinghy as well as two solar-powered vehicles for use in ports of call.

During the first 100-day trip around the world, the crew members hope to demonstrate the potential of solar power in transport and how it might be used for shipping. They also will be making a feature film of the voyage to promote the important role that solar plays in the mix of energy generation.

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The PlanetSolar catamaran will have 470 sq m of solar cells on deck to power it around the world next year.

GreenLight

Solar dishes popping up in US deserts

Next-generation solar dishes called SunCatchers are popping up like desert cactus flowers, with a light and structurally efficient design that can be manufactured on an automotive-type assembly line. The concentrating solar power systems by Stirling Energy Systems of Scottsdale, Ariz., have been installed at Sandia National Laboratories in Albuquerque, N.M., as part of a pilot power-generating facility. The company is gearing up for several commercial installations as well.

The project at Sandia National Labs previously had six rectilinear SunCatchers; the recent addition of four redesigned SunCatchers took the total amount of usable energy produced from 150 to 250 kW. The collector's parabolic shape uses half the number of mirrors as the rectilinear version (40 as opposed to 82). It works by reflecting the sun's energy off the mirrors onto a point, which concentrates the energy 1300 times before it enters a power conversion unit. A Stirling engine inside the unit uses that intense heat to drive a 25-kW generator.

Each 11.6-m dish of the Sun Catcher is made up of 40 mirror facets, which are manufactured on automotive-type assembly lines.

The mirror facets (including rib supports, metal substrate and mirrors) are manufactured by Tower Automotive of Livonia, Mich., which is moving into the solar industry partly because the mechanical support structure for the mirror facets is similar to that for automobile hoods. During the manufacture of a mirror facet, the rib supports and metal substrate are stamped out, just as they are when a hood is made. In conjunction with Stirling Energy Systems, Tower Automotive devised a technique for assembling the mirrors into a parabolic shape.

Tessera Solar of Houston is a sister company to Stirling Energy Systems and is responsible for the deployment and energy generation of the SunCatcher dish system. The first commercial plant utilizing the technology is under construction in Peoria, Ariz., where 60 SunCatchers will provide 1.5 MW of power to the grid. Tessera Solar also has plans for projects in California and Texas, which will bring the number of SunCatchers growing in US deserts to more than 60,000 by the end of 2014.

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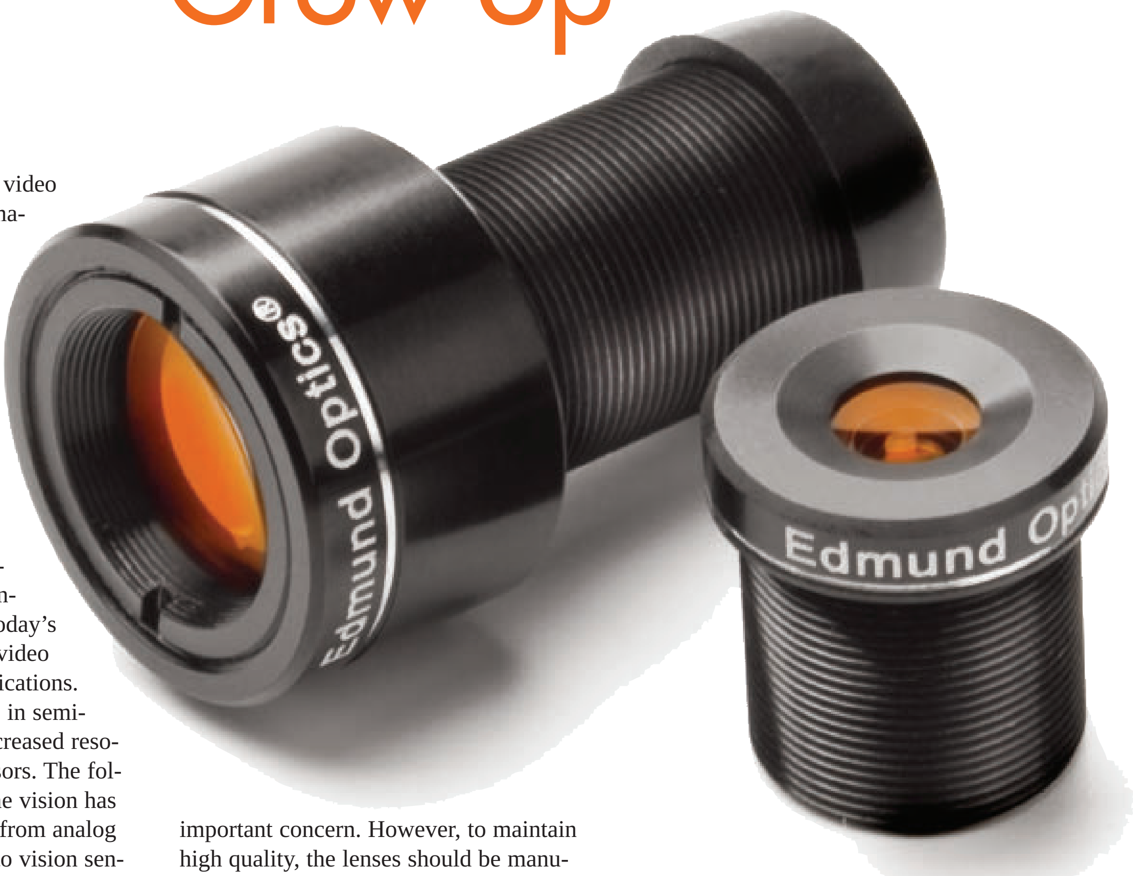
Micro Video Lenses Grow Up

BY OLIVER BARZ
EDMUND OPTICS



Micro video lenses provide all the performance of traditional C-mount lenses in a highly compact form.

A few years ago, micro video lenses were used in machine vision almost exclusively for limited-space and low-resolution applications. But the ongoing reductions in size and cost of optical sensors, along with increases in pixel count, are allowing the creation of higher-resolution compact video systems. At the same time, new optical designs are yielding micro video lenses with increased resolution to match today's sensors, rendering the micro video lens ready to tackle new applications.

The technological progress in semiconductors has resulted in increased resolution and lower cost for sensors. The following digitization of machine vision has moved many system designs from analog cameras and frame grabbers to vision sensors and intelligent cameras. While the electronics have changed a lot, the optics have remained basically the same. Most of the video lenses developed for machine vision use a C-mount and are designed for a sensor size of ½ to ⅔ in. covering an image circle of 8 or 11 mm, respectively. With high-resolution CCD and CMOS sensors now available in sizes around ⅓ in. or less, an opportunity has opened for optical manufacturers such as Edmund Optics to reduce the size of the lenses accordingly, creating "micro" video lenses.

The typical micro video lens is approximately 15 to 25 mm long and has an outer diameter of 14 to 18 mm (shown at top of page). The mount is usually an M12 × 0.5 thread, more commonly known as an S-mount. This compact size provides an advantage over traditional C-mount lens and camera systems not only for smaller assembly dimensions, but also for reduced costs.

Because micro video lenses are frequently used in large quantities, cost is an important concern. However, to maintain high quality, the lenses should be manufactured with an all-glass-and-metal design – no plastics. Cost reduction must come from elsewhere.

Naturally, the decreased lens dimensions result in lower glass costs. Micro video lens designs reduce costs further by abandoning expensive mechanical parts. For instance, micro video lenses can avoid use of a helical mount for focusing and instead use the mounting thread to adjust position. Another cost reduction design step is to make the aperture not of iris leaves but with an aperture spacer of the proper diameter located between the lens elements.

Lens selection

The cost reductions have allowed manufacturers to offer a variety of micro video lens design styles from stock to address various resolution and working distance requirements. For instance, basic infinite conjugate imaging lenses, with roots in security applications, are suitable for standard-resolution cameras with a working distance of 100 mm to infinity. Such lenses are available to cover focal lengths from 1.7 to 50 mm, enabling angular horizontal fields of view between 6.8° and 134°. For more demanding requirements, high-resolution infinite conjugate micro video lenses also are available for megapixel sensors.

For vision applications that require close-in operation, finite conjugate imaging lenses are available with a typical working distance of 150 to 250 mm. These lenses can be used also with aperture modification if the depth of field demand does not match the aperture at around *f*/2. The highest performing among these finite conjugate lenses cover sensor resolutions of up to 200 line pairs per millimeter and are used for a wide range of close-focus applications that require accurate images. Focal lengths between 5 and 25 mm are available, and the lenses act as a base for a

variety of modifications, including aperture adjustments and filter changes.

If the working distance of an application is shorter than the listed working distance for a stock lens with the desired focal length, all is not lost. Developers have found that they can use a micro video lens at a working distance of only a few centimeters with little loss of performance.

Micro video lenses are also available in a sealed optical assembly for use in harsh environments beyond typical lab and factory floor installations. Two coating options make these lenses suitable for either visible or near-infrared imaging applications.

When choosing a micro video lens, a good point to start from is the sensor size and resolution. For a sensor with more than one megapixel, a high-resolution lens is best. If the sensor is bigger than the specified 1/3 in., a short focal length will result in some vignetting. However, some users have reported a good experience with using an 8-mm lens with up to a 1/2-in. sensor.

Figure 1. A new GigE camera from Baumer utilizes a novel barrel designed together with Edmund Optics. Courtesy of Baumer Optronic GmbH.

Figure 2. Custom micro video lenses are used in the Leuze LSIS 412 vision sensor. Courtesy of Leuze electronic GmbH + Co. KG.

The next parameter to investigate is the (angular) field of view. In many vision systems, this is a more useful specification than focal length because it takes into account areas of the image that may be distorted, whereas focal length determinations deal only with the undistorted image center. Most of the images taken by vision sensors are never displayed, so distortion is not as important as it is for human-viewed images. Making a selection based on field of view, easily calculated from working distance, sensor size and object size, thus leads to a more suitable choice.

Creating custom lenses

If no stock lenses are available for a given application, the optical manufacturer may be able to help with a modification of a standard product or with a custom design. For instance, a sewer inspection system needed a small camera with a short working distance. To avoid the expensive option of refocusing a stock camera, the customer asked Edmund Optics to increase the lenses' depth of focus. This was easily done by changing the aperture spacer to *f*/5. The method of increasing depth of focus by decreasing aperture size is used also for applications where the Z-position of objects might change. Checks of optical performance using design software have shown that versions down to *f*/16 are practical.

Another typical modification that developers require is the addition of a filter. This can be handled in two ways. One is to insert a small glass filter into the housing. The other is to coat one of the lens elements with a filter layer. Typical filter requests include infrared-cut or daylight-cut filters, which confine the camera to using the visible or near-infrared spectrum only. Including this filter in the lens system can result in cost savings, as no separate filter is needed inside the camera.

Barrel changes are another modification option. If a standard housing does not fit a given camera, the manufacturer can readily modify the barrel to incorporate a different threading. Such modifications can even become standard. This month at the Vision 2009 conference in Stuttgart, Germany, for instance, Edmund Optics and Baumer Optronic GmbH announced a new camera/lens interface standard without threading. Reduced mounting tolerances help enhance the lens's optical performance, and integrated focusing capability will enable the lenses to be incorporated into preadjusted cameras. In the first use of this new interface standard, the lens mount of Baumer's new GigE camera will mate to the new barrel design from Edmund Optics (Figure 1).

For most modifications, however, the changes will be proprietary to the customer. The process begins with the manufacturer and customer first discussing the desired specifications. A typical custom design will consist of three to six lens elements and will depend on the target price, the optical performance (modulation transfer function, distortion, relative illumination) and mechanical constraints such as mounting style, sensor size and working distance. The manufacturer's optical designers are often able to make helpful design suggestions to optimize cost and performance. They can also develop virtual performance tests to evaluate the design options.

Once the modifications are specified, prototypes must be made to prove the concept. The manufacturing series can then start with just 50 to 100 pieces. Most modifications can be very cost-effective, and the volume price of modified micro video lenses can be comparable to the standard product.

Some customers like to develop the micro video lens themselves to simulate the whole device. In that case, the manufacturer double-checks the design for optical quality and producibility and discusses options to optimize the cost and performance. For example, in recent years Leuze electronic GmbH has developed several designs for its products. Two of the latest are used in the company's LSIS 412 vision sensor (Figure 2).

Applications abound

Custom or stock micro video lenses represent a new wave of opportunities for imaging system designs, allowing them to serve in applications where the classic camera/objective lens combination is too expensive and bulky. Typically, these new applications call for a highly compact configuration that uses a micro video lens together with a more-or-less specialized vision sensor. In many cases, the vision sensor even has the lens built in, as with Leuze's LSIS 412. The result is an imaging system that can fit almost anywhere.

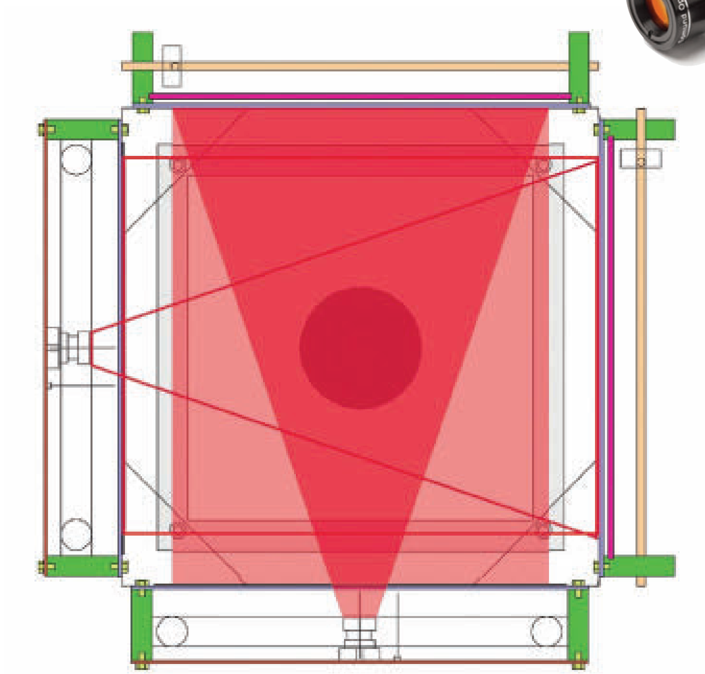


Figure 3. This electronic shot-scoring system from Knestel Elektronik uses two compact imaging systems to capture images of a bullet in flight for accurate evaluation of score value. Courtesy of Knestel Elektronik GmbH.

With a wide-angle (>90° horizontal) micro video lens, for example, it is possible to place a vision sensor in one corner of a rectangular space and monitor whether something passes through that space. This can be used to replace safety light curtains in workshops, with the system shutting down the machinery if the danger zone is entered.

The OpticScore electronic shot evaluation system from Knestel Elektronik GmbH uses two high-speed sensors with micro video lenses to capture images of a bullet in flight (Figure 3). Operating at 40,000 fps, the system can capture several images of the bullet as it passes through the light curtain. This yields an accurate and reliable measurement of shot value and position – an improvement over existing electronic scoring systems.

The BMOS 5000 keyboard from Desko GmbH uses a custom micro video lens as part of a built-in multidocument reader (Figure 4). This keyboard is used in security and passenger service stations at airports and incorporates an optoelectronic reader module no larger than a matchbox. The module handles magnetic cards and provides optical reading of travel documents such as ID cards and passports that conform to the International Civil Aviation Organization.

Other applications for micro video lenses are in produce-detecting scales in supermarkets, passport readers at customs stations, lottery scanners and automated contour measurement devices in manufacturing. Some 3-D measurement systems calculate height from the deformation of a laser line – a good opportunity to use a micro video lens to keep the housing compact. In nearly all these cases, the key to success is the availability of compact imaging solutions for large-quantity production at a favorable price.

Figure 4. The Desko BMOS 5000 keyboard incorporates an optical document reader that a micro video lens helps keep smaller than a matchbox. Courtesy of Desko GmbH.

With the advent of micro video lenses, these imaging systems are now available. Offering compact size, high resolution and low cost, micro video lenses are making imaging systems more affordable and easier to use in tight quarters. And, with the help of the lens manufacturers, even unique system requirements can be met without sacrificing cost or performance.

Meet the author

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Megawatt Laser Power at Sea

BY AMANDA FRANCOEUR
NEWS EDITOR

A solitary US naval warship is at sea when a fleet of ships surrounds it armed with hypervelocity cruise missiles and electromagnetic rail guns. Although it may be outnumbered, the warship has something the other ships don't – an ultraprecise, ultrafast, megawatt-class laser system with a selectable wavelength for optimum performance in any maritime condition.

This future weaponized laser system is part of an extensive program designed to enhance free-electron lasers (FELs) into 100-kW and megawatt-class power systems for lethal and low-collateral-damage sea and air attacks.

The plan is "to design, develop, fabricate, integrate and test a complete 10-kW-class FEL prototype device that can be used to demonstrate scalability of the necessary FEL physics and engineering for an eventual megawatt-class FEL device," said Sarwat Chappell, direct energy program officer at the Arlington, Va.-based Office of Naval Research, which advances innovative science and technology capabilities for the Navy and Marine Corps.

"The speed-of-light engagement characteristic and the ability to select the wavelength to maximize laser transmission through the marine atmosphere of the FEL weapons systems give the US Navy the unique ability to adjust for defense against targets in any maritime environment throughout the world," she added.

Two companies are competing to develop the laser, The Boeing Co.'s Directed Energy Systems Div. in West Hills, Calif., and Raytheon Co.'s Integrated Defense Systems Div. in Tewksbury, Mass. Each has been awarded a 12-month, $6.9 million contract from the Office of Naval Research. The project is estimated to reach $163 million to fully complete a 100-kW demonstration prototype.

Above: A naval warship outfitted with a megawatt-class laser system uniquely uses countersurveillance and situational awareness to target multiple opponents at once. Its point defense capability also supplies high-resolution imaging and beam direction for precision aiming. Courtesy of Raytheon Co.

Ready …

Free-electron lasers work by injecting a number of electrons into a linear accelerator, where they are amplified to very high energy levels. Directed through a sequence of powerful electromagnetic fields, the electrons emit energy, creating an intense laser beam. "The FEL is the only all-electric laser that is capable of producing megawatt-and-above powers," said Gary Fitzmire, vice president and program director of Boeing's Directed Energy Systems.

To enhance energy, two variables of the system must be changed. The first includes increasing the number of times an electron group is injected into the accelerator, and the second, increasing the number of electrons.

Unlike other lasers that use chemicals to fuel the system, the laser will run off a ship's power, eliminating the need for explosive or toxic materials onboard. And because the FEL has unlimited magazine capacity, it will eliminate the need for storing missiles while lessening the concern for having enough artillery to keep up with maritime warfare.

"FEL has, over the past decade [and] with continuing support from the [Office of Naval Research], the promise of being able to reach the power levels required to make this a defensive weapon system without some of the drawbacks that some of the other technologies have," said John Cochran, senior engineering fellow and program manager of Raytheon.

Aim ...

The idea behind advancing the laser is to have selectable wavelengths for use at sea. "One of the key benefits of the free-electron laser is that it is tunable in both its power levels and its wavelengths," Cochran said. Energy sources are absorbed by elements in the atmosphere, such as heat and humidity, he added.

To facilitate a successful and powerful laser beam that propagates through the atmosphere and that will not become absorbed, various wavelengths must be available – depending on environmental conditions – on a day-to-day basis. In addition, adjusting the power allows for fully destroying a target or for merely disabling it.

The laser also provides a point-defense capability that uses high-resolution imaging and a beam director to pinpoint a specific spot on a target quickly and accurately. "The combination of these two effects allows the system to destroy the target in the minimum time," said Edward W. Pogue, Boeing's FEL program manager.

Countersurveillance and situational awareness provide the FEL with the capability of engaging in multiple target attacks, thus reducing mobility tactics that opponents may use to avoid a strike. Incoming missiles can dodge kinetic receptors, but they won't be able to avoid the laser beam because the speed of light performance identifies and destroys the target before it can reposition to a new course, Pogue added.

A linear accelerator of a free-electron laser is shown. To operate the system, clusters of electrons are injected into the device and stripped from their atoms, resulting in very high energy levels. From there, they are directed through a series of powerful electromagnetic fields, forcing the release of energy in the form of photons. Engineers will be able to adjust the wavelength to successfully propagate through any atmospheric condition by increasing the amount of clusters of electrons injected into the accelerator or the amount of electrons in each cluster. Courtesy of the US Navy.

Upgrade!

Boeing and Raytheon are both in the preliminary stages of augmenting the laser system, which will require three phases. The first, 1A, will involve a year of constructing an introductory design proposal for the 100-kW prototype FEL system, while the second phase, 1B, will be to create a detailed design. The third, phase 2, will be the fabrication, integration and testing of the FEL prototype.

The Office of Naval Research will choose which company – if not both – is best suited to carry out the megawatt-class system project based entirely on its preliminary plan. "Upon successful completion of phase 1A, selected performers will participate in future phases, leading to development and demonstration of the 100-kW prototype," the Navy's Chappell said.

FELs are not a new technology for military weapons applications. "Many research FELs have been built to-date worldwide, albeit none near MW class average power levels," Chappell said.

Nevertheless, upgrading the laser to 100 kW and ultimately scaling up to megawatt-class power will change military defense tactics for the advancement of injectors, beam control, accelerators, amplifier and oscillator designs, and other FEL weaponry, while providing directed energy systems for a future all-electric naval ship for maritime defense.

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Finding peak performance under the cover of darkness

BY LYNN SAVAGE
FEATURES EDITOR

The pilot shifts his gaze from the instrument panel back through the lenses of his night-vision goggles. The moon is just a sliver, and a hazy sky puts a soft focus on the starlight, so the goggles alone make the mission possible, despite the pilot's years of experience . . .

Whether in a helicopter or fixed-wing aircraft, or whether hunting for insurgents in Afghanistan or lost children on a mountain slope near Denver, pilots of all stripes are putting in more hours than ever after the sun sets. Night-vision goggles, or NVGs, have been making such missions – and many more – possible for years, but where is the technology heading?

The heart of an NVG system is an electro-optical image intensifier. Akin to a photomultiplier tube, the image intensifier takes in whatever light is available – even in what appears to the eye as complete darkness – and converts the incoming photons into electrons. These electrons are rapidly replicated and sent to a display – often, the eyepieces in a set of goggles mounted onto the aviator's helmet but, sometimes, onto a separate screen.

Military operations around the world have embraced night-vision technology wholeheartedly. Recently, the Australian Defence Force, through its chief contracting firm Australian Aerospace, began an upgrade program that will refit 46 Tiger helicopters with TopOwl helmet-mounted night-vision systems. TopOwl systems are produced by Thales Group, which has sold them to military contractors in more than a dozen countries, including the US and Spain.

TopOwl is geared for use by helicopter pilots, but the company also makes TopSight, a similar system for fixed-wing aviators.

In addition, the UK's Ministry of Defence has placed an order for a dozen Q-Sight systems, helmet-mounted displays made by BAE Systems. Complementary to NVGs, the Q-Sight displays are flexible adjuncts that enable use of image intensification, thermal (near-IR) vision and overlaid tactical information via specialized symbols that light up on the display surface. The technology takes advantage of holographic waveguides that transmit light from various sources to the main screen, which is mounted onto the pilot's helmet.

"Everyone wants the latest, greatest technology," said Mike Atwood of ASU (Aviation Specialties Unlimited) Inc., a night-vision technology company in Boise, Idaho. But "the [technologies] we have now will be around for a long time."

Military and security end users have nearly maxed out the technological limits of NVGs. The standard field of view of the devices is a rock-solid 40°; any larger, and they get prohibitively expensive.

"There are a small number of large-field-of-view systems used in the military because they're the only ones who can afford them," Atwood said. "Most would take panoramic systems if they could, but getting them at an affordable price won't come about for years, if ever."

A wider vista

Panoramic systems – providing 100° or more of coverage – would give pilots more vista to view but also would enable them to keep their eyes forward and avoid swiveling their heads to scan a scene.

Other factors that directly affect aviators are the size and weight of NVG systems. Helmet-mounted packages have shrunk somewhat over the past 20 years, but they still are bulky and weighty enough for fliers who occasionally hit speeds that ramp up the g forces. Extra weight equals extra strain on head and neck muscles, plus there is an increased danger from the equipment in the event of a crash.

Although NVGs and other night-vision systems have had a robust life in the armed services, growth in the market is coming from civilian aviation; specifically, search-and-rescue missions, emergency medical services, police and fire use, aerial insecticide applications, transportation to oil rigs and other dark, dangerous areas, and more. As more military pilots with night-flying experience leave the service for civilian life, a growing number of aviators are looking to fill niches where they can put those skills to good use.

What has kept the market from flooding with night-flying pilots and their NVGs isn't the technology itself – advances have kept up with the industry. Instead, the hurdle has been getting regulations and guidance in place on how civilian pilots should be trained in the practice of night-vision systems.

According to ASU's Atwood, federal regulations were drafted as far back as 2000 but only recently enacted as part of Title 14, CFR Chapter 1, Part 61. Now that firm guidelines are in place for training and operating aircraft with NVGs and the like, a virtual explosion of civilian pilots – albeit, highly specialized ones – are expected to adapt to night flying.

"Night-vision systems are not the panacea for night flying – it can still be too dark for them to operate properly," Atwood said. "But they are very good at what they do."

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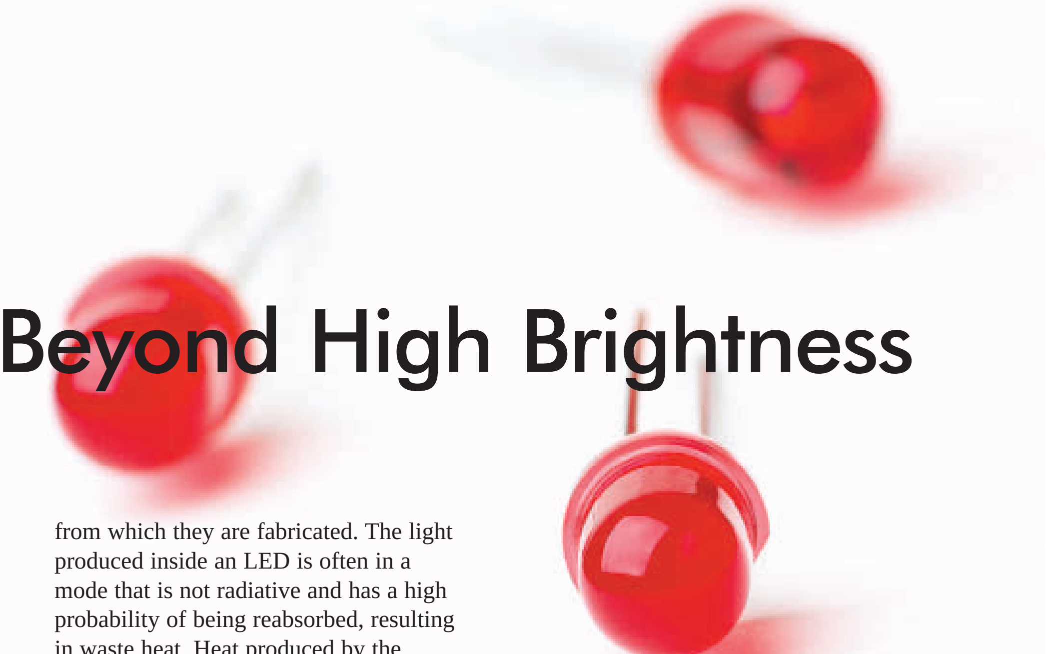
Night-vision goggles and related technology are becoming ubiquitous in the military, but what about the civilian markets? Courtesy of BAE Systems.



LEDs: Beyond High Brightness

BY RICK ZARR
NATIONAL SEMICONDUCTOR CORP.

The US Department of Energy's Energy Information Administration (EIA) reported in 2007 that the US had used roughly 526 billion kilowatt-hours of electricity for lighting (both commercial and residential). In 2008, the EIA reported that a typical American nuclear power plant produced roughly 12.4 billion kilowatt-hours.

Simple math shows that the lighting needs of the US alone require roughly the equivalent of more than 42 nuclear power plants. As the global population has continued to grow, the lighting industry has pursued new light sources with higher efficiencies to reduce the energy consumed.

LEDs have long been the panacea of the lighting world, promising replacements for various incandescent, fluorescent and gas discharge sources that reduce energy consumption and keep harmful chemicals out of landfills. However, it has long been known that, even though the efficacy of LEDs approaches or exceeds that of high-efficiency sources such as high-intensity discharge lighting, the implementation, drive electronics and overall brightness fall short.

LEDs have suffered from the way light is produced independent of the material from which they are fabricated. The light produced inside an LED is often in a mode that is not radiative and has a high probability of being reabsorbed, resulting in waste heat. Heat produced by the Stokes shift in phosphor-based white LEDs creates additional efficiency losses. Several innovative methods can improve both the radiative recombination rate and the extraction of photons to increase the brightness and efficiency of LEDs.

A leap in brightness

One method, pioneered by Luminus Devices Inc., is an implementation of a photonic lattice to provide waveguides for photons trapped in the substrate. Photonic crystals also occur naturally in nature and can be seen in materials such as opal. The ability of closely spaced structures to provide paths for emission greatly improves the intensity of the light produced. With this and other improvements, such as the use of quantum wells and optical cavities, LED brightness has blown through the roof. These devices are finding their way into all kinds of high-brightness applications, such as video projectors, LCD backlights and others, but the future application is for general lighting.

In any lighting application, there are issues with the life span of the source. It either dies a sudden death, as with a filament failure in an incandescent bulb, or it slowly degrades with time due to the aging of the material. LEDs also suffer from aging, which is directly affected by the junction temperature of the device. If a fixture is engineered to provide a certain luminance, over time this luminance will degrade below some useful limit. The life span will typically end at some number relevant to the application. For instance, a streetlamp application may be useful well down to 50 percent of the original luminance, but a medical endoscope light source may not.

Managing loss of luminance

The end-of-life point where the luminance falls below a useful level is highly temperature-dependent (see Figure 1). Say the curve in Figure 1 represents a light source for designing a practical, general-purpose lighting solution. If the source must last at least 50,000 hours before its light output is only 50 percent, the junction temperature must never exceed 100 °C. This is very difficult without active cooling. Compounding the problem is the lack of radiative emission of waste heat. Incandescent bulbs will radiate a large amount of heat in the infrared, but LEDs need to conduct heat away. Additionally, if the junction temperature even momentarily exceeds the maximum allowed temperature provided by the manufacturer, permanent damage will occur, dramatically affecting the life span of the emitter.

If the LED cannot be modified to handle extreme junction temperatures without degrading, two factors must be considered when designing the lighting system or en-

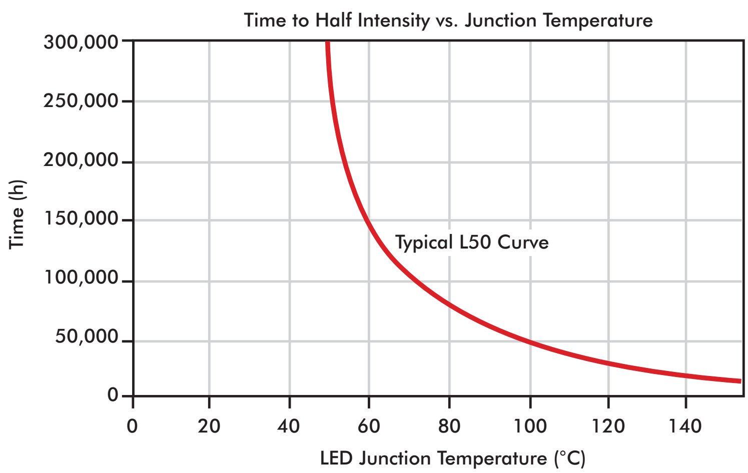


Figure 1. Temperature Effect on LED Luminance

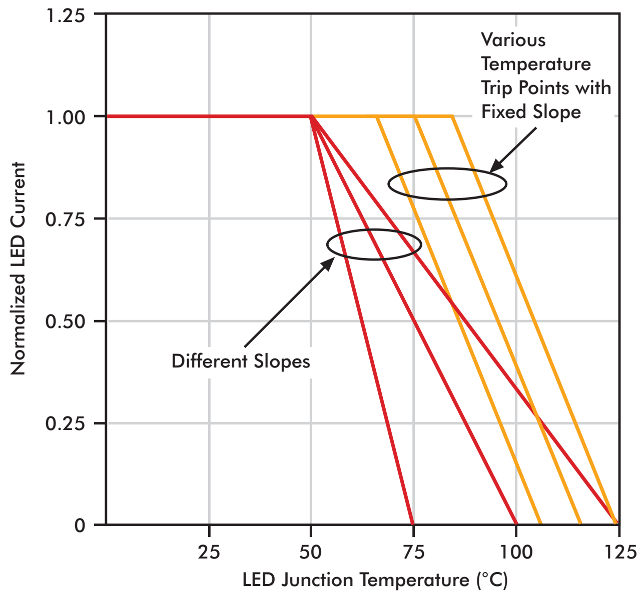


Figure 2. Examples of Thermal Fold-back Curves

gine: thermal management and LED driver awareness. Both of these apply not only to general lighting applications but also to specialty uses. The easiest solution is passive thermal management using a heat sink along with enough air flow to remove the waste heat. A company called Nuventix Inc. has developed an active cooling solution with no rotating components that is based on entrainment caused by high-speed air jets. The way it works is similar to how a cyclist is swept up and pulled along in the wake of a tractor-trailer; ambient air in the Nuventix cooler is pulled along in a similar fashion, providing highly efficient cooling. This technology has been applied to industry standard lighting configurations such as MR16, PAR20 and PAR25.

The other part of the solution is active thermal management via the LED driver. Traditionally, LED drivers have been simple constant current sources that monitor and control only the current flowing into one or more LEDs. In general, this is sufficient to drive the LED and maintain brightness over varying input voltage levels. However, with advances in brightness and changes in configuration to provide even brighter sources, LEDs have evolved into light engines complete with thermal control demands.

To prevent damage and premature end of life, thermal control is required and can be implemented in various ways. Figure 2 shows two different fold-back curves that limit the LED current as the temperature increases. As long as the junction temperature remains below a preset point, normal current regulation is the primary control loop. However, once the set point is exceeded, a secondary control loop engages to limit the current. The temperature at which the fold-back occurs and the rate at which the drive current is reduced will both vary depending upon the application or the LED manufacturer's recommendations.

State-of-the-art LED drivers, such as the National Semiconductor LM3424, have the thermal fold-back feature built in, allowing the designer to select the set point and gain (which selects the slope) of the system. This greatly simplifies high-power LED supplies for general lighting or specialty applications, such as emergency signage, where LED failures caused by aging or high temperatures can be catastrophic.

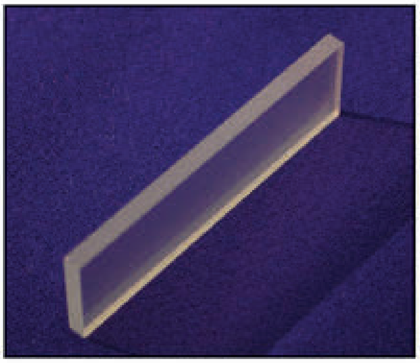
Making the switch

With new technology come new issues, and LEDs are no exception. As the efficacy and overall intensity of LEDs continue to increase, more lighting applications will move away from conventional sources and adopt these new lighting systems. New cooling and driver technologies are making thermal management much easier to implement and, in terms of life span, LEDs provide the potential for never requiring replacement – something an incandescent bulb would be hard-pressed to achieve.

Meet the author

Rick Zarr is a technologist for PowerWise Products at National Semiconductor in Florida, and he writes an energy-efficiency blog at www.national.com/energyzarr; e-mail: energyzarr@national.com.

Diffusers and custom optics



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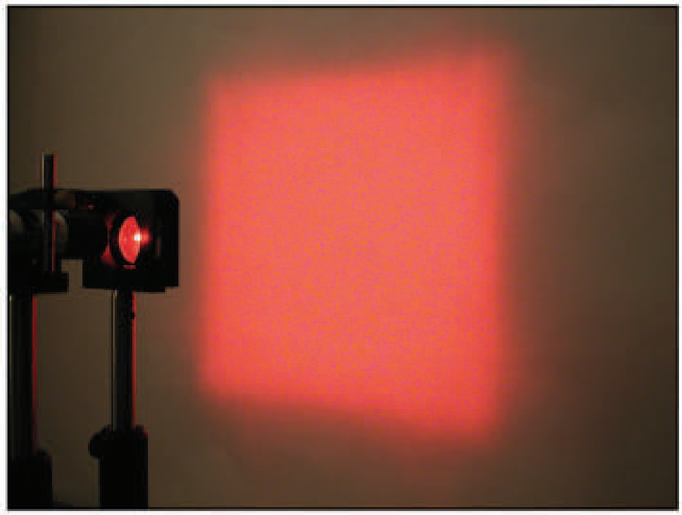

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For Lidar,
Many Happy Returns

BY HANK HOGAN,
CONTRIBUTING EDITOR

For light detection and ranging (lidar) scanners, the returns are in – and they're good. Innovations have made lidar scanners, which emit laser pulses and capture the returning light to determine distance to an object or characteristics of air, smaller and lighter in weight than ever. Their resolution has improved, as has their ability to capture more returns per pulse.

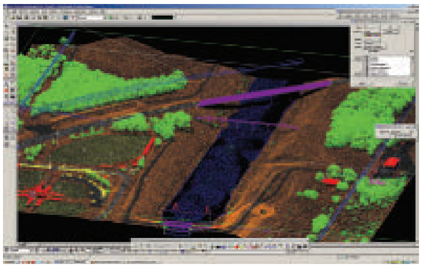
Lighter scanners are a good thing, said Nicholas Ferguson, business planning and development manager at Network Mapping Ltd. in Chobham, UK. "The weight of lidar scanners has significantly decreased. This allows helicopter systems to take more fuel onboard – and the on-task survey time is therefore longer."

Network Mapping's primary business involves the electricity transmission industry, with customers in both the US and Europe. Using lidar scanners and photographic equipment, the company surveys sites before and after power lines go in, employing either a helicopter or a fixed-wing aircraft. The data is used for routing and designing new lines, accurately recording existing lines and tower locations, and spotting infringing vegetation.

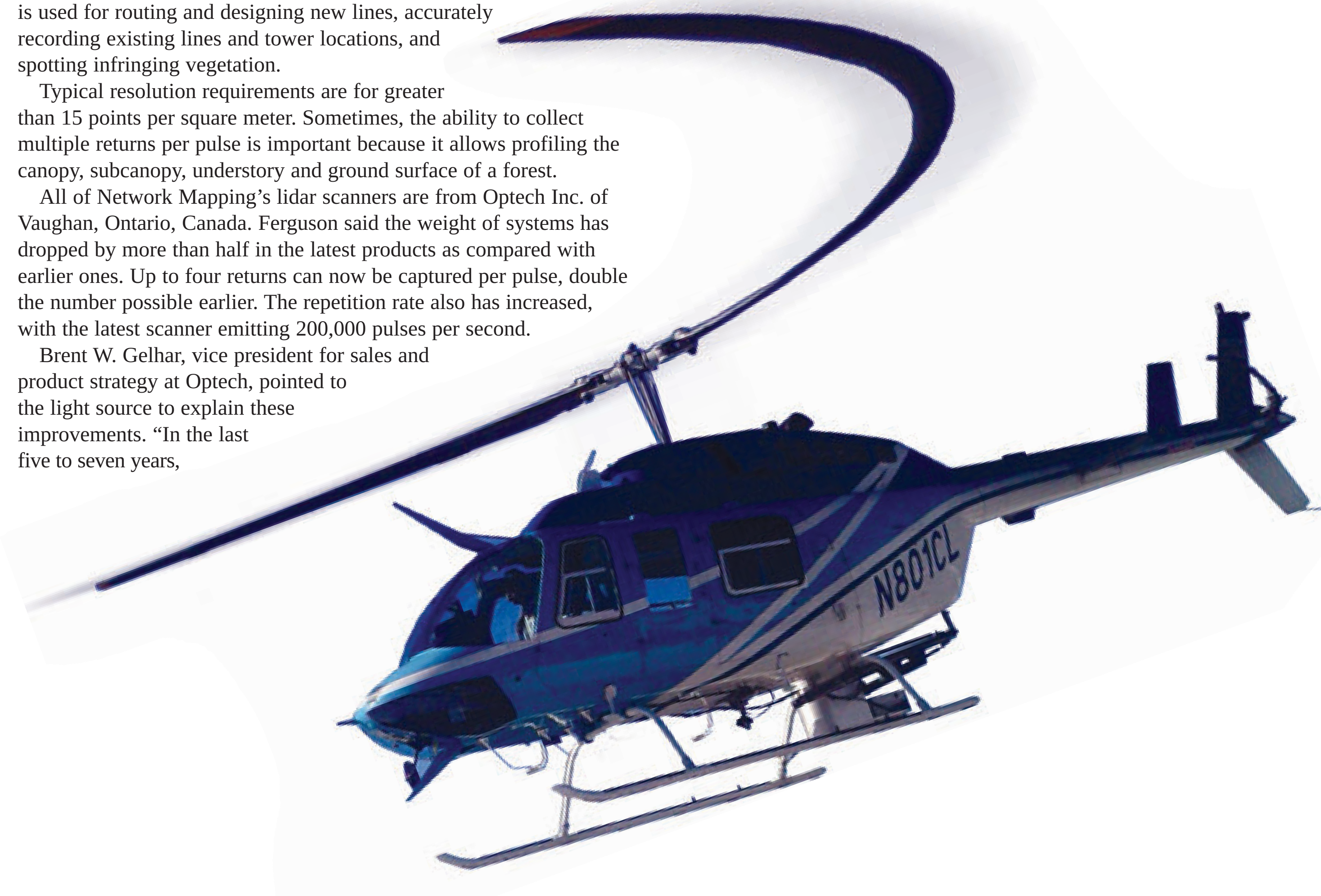
Typical resolution requirements are for greater than 15 points per square meter. Sometimes, the ability to collect multiple returns per pulse is important because it allows profiling the canopy, subcanopy, understory and ground surface of a forest.

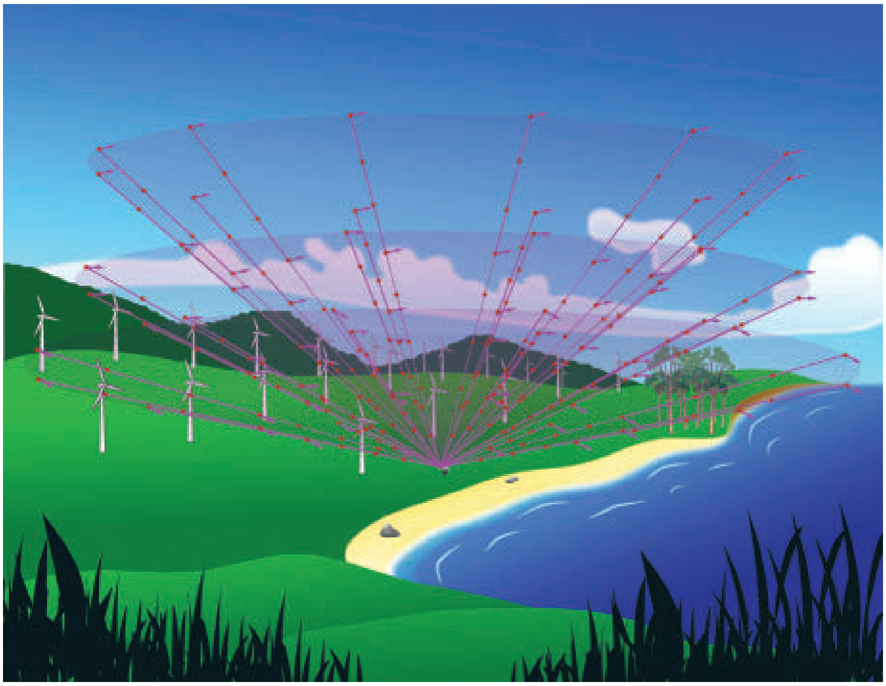
All of Network Mapping's lidar scanners are from Optech Inc. of Vaughan, Ontario, Canada. Ferguson said the weight of systems has dropped by more than half in the latest products as compared with earlier ones. Up to four returns can now be captured per pulse, double the number possible earlier. The repetition rate also has increased, with the latest scanner emitting 200,000 pulses per second.

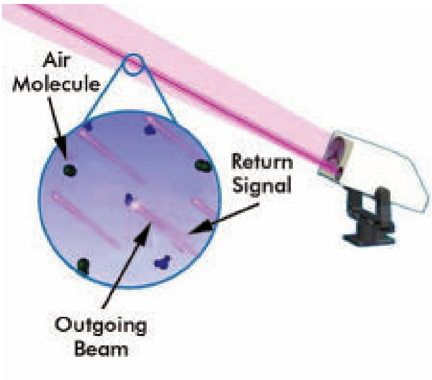
Brent W. Gelhar, vice president for sales and product strategy at Optech, pointed to the light source to explain these improvements. "In the last five to seven years,



Mounted on a helicopter or plane and flown over terrain, a lidar scanner produces a high-resolution 3-D point cloud of what is below. The data then can be classified into objects, with the information used to lay out power lines or to see where vegetation needs trimming. Courtesy of Network Mapping.







Because UV light interacts directly with air molecules (above), a direct-detection lidar scanner can provide simultaneous measurement of wind speed, direction, temperature and density over a large portion of a wind farm, potentially allowing operators to maximize energy production by matching blade configuration to changing conditions (left). Courtesy of OptoAtmospherics and Michigan Aerospace Corp.

there's been a revolution in what's available in lasers."

Diode-pumped solid-state lasers, for example, have matured, yielding systems with better reliability and less heat waste. The latter is significant because less heat means the system can be smaller and lighter. Advances in fiber lasers also have been important.

A few years ago, Optech launched a vehicle-based mobile mapping system – its Lynx product line. Being on the ground instead of in the air allows for higher resolution. It also makes for less expensive surveys because a truck or van costs much less than an airplane to purchase and operate.

Gelhar noted that the point density of scanners is increasing, leading to denser data on the ground. This trend will drive a merging of existing imaging technologies, such as cameras and hyperspectral imagers, with the 3-D time-of-flight measurements from lidar.

The result could be a new type of imager, he said. "By being able to merge this – and we're already doing it with some of our systems by integrating these cameras with lidar systems – you're basically going to true 3-D imaging."

Catching a breeze

Most lidar systems operate in the infrared for improved eye safety and to maximize range. However, those wavelengths minimize interaction with some atmospheric constituents, which is why Michigan Aerospace Corp. of Ann Arbor uses 355- and 266-nm lasers.

"The primary advantage is being able to take measurements directly from air molecules," said Peter Tchoryk Jr., the company's CEO.

Near-IR lidar systems detect scatter from airborne aerosols. However, these are absent when clear air is present, which is the case for large parts of the ocean, after a heavy rainfall or at higher altitudes. By operating at shorter wavelengths, lidar does not need aerosols to be present to determine wind velocity, air temperature or density. The first comes from the Doppler shift of the return, while the other two derive from the return's width and intensity.

These measurements could be useful for getting the most energy out of the wind. Operators need to know where to situate wind turbines, so site surveys are important. To reduce the mechanical load and optimize energy production, they have to adjust turbine blades in response to gusts, shear and changing wind direction. Their need for more accurate short-term forecasts has been identified as one of the major problems for wind energy, Tchoryk said.

He added that the company's products also could be used to spot clear air turbulence. Better techniques than those currently available to spot the problem are being researched.

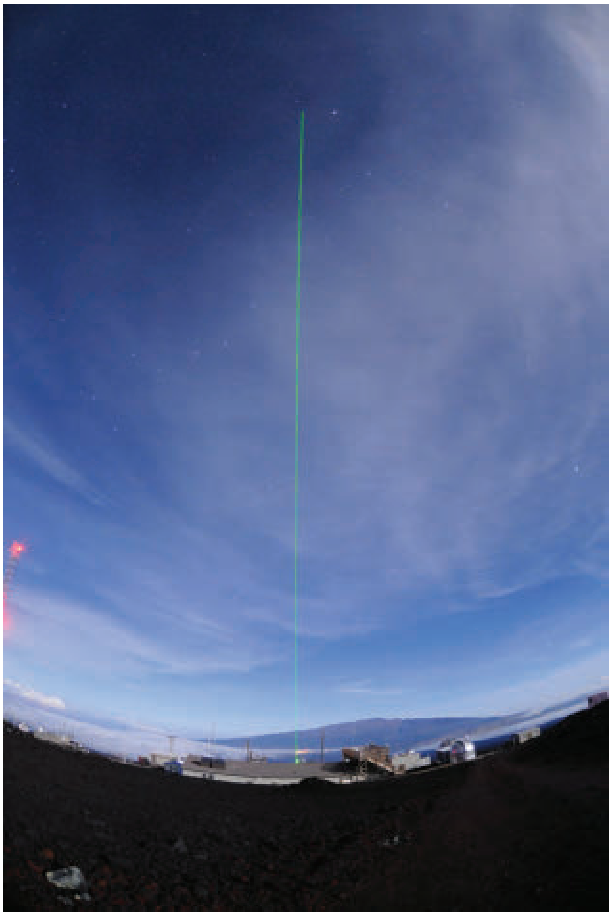
Advances in lasers have helped Michigan Aerospace build better products. However, Tchoryk said, a laser with more power in the ultraviolet and with a narrow linewidth, single-longitudinal mode would be beneficial.

One of the company's lidar systems can be found on Mauna Loa Mountain on the Big Island of Hawaii. There, the National Oceanic and Atmospheric Administration runs an atmospheric observatory. John E. Barnes, the observatory's director, said the site's three lidar systems, one of which is from Michigan Aerospace, provide data on such things as particulates, wind speed, air density, water vapor, ozone levels and temperature. A variety of wavelengths and techniques are used.

One scheme being developed for particulate measurements is dubbed "clidar," or camera lidar. In it, a laser beam is fired vertically upward while a scientific-grade CCD camera equipped with a wide-angle lens snaps a picture from ~100 m away. The image of the beam traversing the air is then evaluated pixel by pixel. This simple approach has some advantages over other techniques, Barnes said. "The clidar measures all the way to the ground, where it's got great resolution."

The bottom of the world

For a final look at where lidar technology may be headed, consider a commercial product under development and a research



A wide-angle lens and a scientific-grade CCD enable camera lidar, which, unlike standard lidar, can measure particulates with high resolution near the ground. Courtesy of John E. Barnes, NOAA, and Joseph Shaw, Montana State University.

project. The former leverages telecommunications gear, while the latter hopes to help the environment.

Mark Neal, an optical engineer with ITT Space Systems Div. in Fort Wayne, Ind., noted that telecommunication lasers are mass-produced, highly reliable and long-lived. Thus, they are well suited for a lidar scanner designed to be flown in a plane, a sometimes harsh environment where electrical efficiency, compactness, ruggedness, reliability and longevity are important.

These conditions inspired telecom components to form the basis for the Multi-Functional Fiber Laser Lidar developed by ITT in a technology incubator program funded by NASA. The development group demonstrated the lidar scanner over urban terrain and various types of countryside. They did this using a near-IR beam. However, any part of the spectrum for which telecom lasers and detectors exist could be used, Neal said.

Lastly, a research program under way in Antarctica shows that it is not all about lasers when it comes to needed lidar advances. There the government-funded Australian Antarctic Division uses a custom-built lidar system to measure atmospheric aerosols. The data collected is being used to refine ozone depletion and climate models, said senior research scientist Andrew Klekociuk.

The scientists recently deployed a new laser, a line-narrowed Nd:YAG from Continuum Inc. of Santa Clara, Calif. This source will offer better shot-to-shot stability than the original and will assist in improving measurements of backscatter, depolarization and incoherent Doppler backscatter.

Ideally, the group would like to get a complete backscatter spectrum in real time, as opposed to the tens of minutes now needed. Achieving that, however, won't depend upon a better laser. Instead, it will require a detector that can take thousands of contiguous exposures at high resolution and sensitivity in microseconds, Klekociuk noted.

"The ultimate device for our application would be an ultrafast electron-multiplying CCD," he said.

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Optics in Space

Free-space optical communications and the final frontier

The NASA Jet Propulsion Laboratory is developing free-space optical communications systems for data transmission between Earth and Mars, for example. Shown here is an artist concept demonstrating high-data-rate trunk-line links from the planet's orbit to the ground, from surface to orbit, and direct to the Earth from the surface.

BY GARY BOAS
CONTRIBUTING EDITOR

The origins of free-space optical communications can be traced back to the late 19th century, with the introduction of Alexander Graham Bell's "photophone" and the optical telegraph. Both of these technologies went the way of the daguerreotype, but the idea of communications systems based on light traveling freely through space survived. The invention of the laser nearly 50 years ago offered renewed possibility, and today the technology is helping to advance a number of communications applications.

Free-space optics holds a number of advantages for such applications. First, it offers data rates comparable to those afforded by fiber optics, typically with considerably lower deployment costs. The point-to-point transmission and narrow beam make it difficult to intercept the signal. Also, operators do not need to obtain licenses for free-space optics communications systems – as with radio and microwave systems, for example.

A range of applications, therefore, could benefit from use of free-space optical communications systems, including LAN-to-LAN connections on campuses or in dense urban areas.

And then there are space applications, such as transmission of data between remote spacecraft and stations on or near Earth. Planetary probes such as the Messenger spacecraft, which recently completed a flyby of Mercury, generate countless photos and other images, and sending the image data back to Earth presents a tremendous challenge.

Until recently, engineers designing space-bound communications systems have had to rely on radio links operating in the X or Ka band. Data links using free-space optics can offer significantly increased transmission capacity, however – from hundreds of kilobits to several megabits per second, and sometimes even higher. Currently, they are considering optical data links primarily for the downlink because the volume of data transmitted is much greater there than with the uplink.

The next generation of space communication

The NASA Jet Propulsion Laboratory (JPL) in Pasadena, Calif., devotes considerable time and energy developing laser communication technology for data transmission between Earth and space assets at planetary distances. One of the investigators' primary efforts in this area, said Hamid Hemmati, supervisor of the optical communications group at the laboratory, is a laser-based system for a possible Mars mission – a "trunk line from Mars," as he called it.

The researchers are developing a system offering a high data rate – 0.5 Gb per second from the shortest distance to Mars; the data rate decreases as the distance increases. This represents a factor of 10 improvement in data rate over existing systems, Hemmati said, with the same mass and power consumption. In some cases, it might even offer a factor of 50 or so improvement.

He noted, however, that it may be some time before the system actually is used on a Mars mission, and then only as "another tool in the toolbox"; the laser-based system will not replace radio links. "At least two or three demonstrations are needed before a spacecraft manager will feel comfortable making a laser-based system the primary telecommunications system," he said. "We haven't yet completed one."

Unique challenges

The optical communications group is working on a variety of technology programs geared toward deep-space applications. Such applications present a number of challenges, however.

Not the least of these are mass and power consumption. With near-Earth communications systems, solar cells provide a relative abundance of power. Spacecraft receive less sunlight, however, as they go deeper into space, "so you have to use thermonuclear generators beyond Mars," Hemmati said, "and those things are limited in power." For this reason, and because of the low mass requirements of deep space probes, it is necessary to make the communications systems as efficient as possible. To this end, the group is using, for example, lightweight materials offering the required structural integrity and low thermal expansion.

Perhaps the most significant challenge the researchers face is in the area of laser beam pointing. From Mars distances, the beam must be pointed with accuracy on the order of a fraction of a microradian – roughly 1/30,000 of a degree. Spacecraft platform disturbances often exacerbated by extreme thermal fluctuations make achieving the needed accuracy a formidable challenge for which the JPL team has developed strategies that await validation from a deep-space mission.

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Picosecond Lasers
for High-Quality Industrial Micromachining

BY DIRK MÜLLER
LUMERA LASER GMBH

Just as CW and quasi-CW lasers have revolutionized the materials processing world, picosecond lasers are poised to change the world of micromachining. The use of picosecond lasers in micromachining was ushered in more than three decades ago because various millisecond and, later, nanosecond lasers had proved that pulsed lasers offer new capabilities.

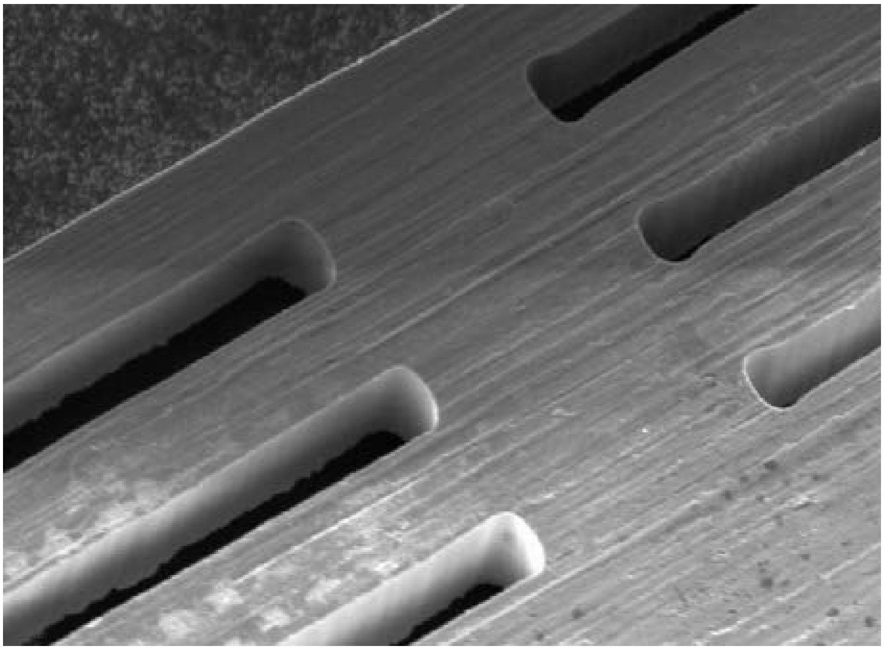
Today, laser pulses in the millisecond to nanosecond regime are being used for drilling holes in wafers, cutting thin sheet metal and scribing ceramics, and for marking automotive parts, credit cards and passports. In micromachining applications, lasers outperform mechanical tools because of their flexibility, reliability, reproducibility, ease of programming and lack of mechanical force or contamination to the part.

Until the introduction of picosecond lasers, all applications were based on the principle of very fast local heating, melting and vaporization of the target material, which later caused thermal side effects such as burrs, recrystallization and microcracks in a product.

Industrial ultrafast lasers have become available recently. Focused picosecond pulses of appropriate energy are well suited to avoid major thermal side effects and reach a new level of machining quality.

Perhaps equally significant is that picosecond pulses are material-unspecific, making them the universal machining tool because micromachining with picosecond pulses does not rely on an absorption process. Underlying the micromachining is the formation of a surface plasma cloud. The large electric field of a picosecond pulse strips the low mass electrons off the atoms, and the positively charged atoms left behind undergo a Coulomb explosion.

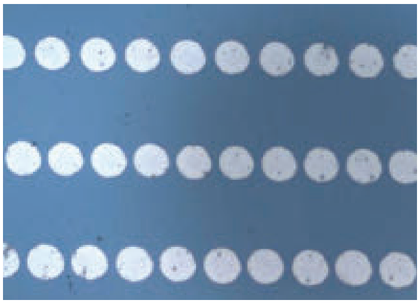
It could be argued that even shorter laser pulses in the femtosecond range would further enhance the micromachining quality. However, femtosecond lasers are significantly more complex, prone to failure and deliver less average power at a much higher price. The electric fields generated in picosecond laser pulses are sufficient to trigger this process, and going to shorter pulses only complicates the system. The high peak power of femtosecond pulses requires careful beam delivery and is prone to unwanted nonlinear effects.



These 15-μm-wide slots are in a 20-μm silver sheet. Images courtesy of Lumera Laser GmbH.

Laser pulses in the picosecond range seem to hit the sweet spot: Picosecond pulses possess excellent beam quality, deliver the right pulse energy level and can be produced in a reliable, industrial package. They reach megahertz repetition rates with more than 50 W of average power, enabling economic industrial scale throughput. If the energy density is slightly above the ablation threshold (~1 J/cm^2), most materials will show an ablation of a 10- to 100-nm-thick material layer. The ablation threshold varies only slightly with the type of material (0.1 to 2 J/cm^2) and is mostly independent of wavelength, pulse length or other conditions.

Most micromachining applications are interested in sculpting a surface structure; i.e., the “cold” micro removal of material to scribe a trench, cut a shape, drill a hole, reveal a material layer or isolate an area.



Shown is the removal of a 70-nm SiN layer on silicon, with up to 1 million dots per second. Dot diameter is 50 μm.

Mechanical drilling/milling and electron discharge machining are overstretched in reliability and cost when creating structures <50 μm. A high-quality laser beam with an M^2 <1.5 can be conveniently focused to a 5- to 50-μm spot size, enabling machine structures of similar size. A typical focal spot diameter of 25 μm will require ~10 μJ of pulse energy to satisfy the 1-J/cm^2 ablation threshold criteria.

Higher pulse energy densities will not necessarily work better or faster: The ablated plasma cloud gets denser and can no longer dissociate from the surface. Even worse, it may thermally alter the material and destroy the "cold" quality. An ideal industrial picosecond laser source for "cold" micromachining should produce pulse energies in the range of 10 to 50 µJ at a repetition rate of ~1 MHz. At even higher repetition rates, a shading effect from the plasma cloud of the prior pulse eventually reduces the efficiency.

Recently, it has been observed that several picosecond pulses with nanosecond-scale separation (burst mode) not only will improve the ablation rate substantially, but also the micromachining quality; e.g., the surface roughness of blind holes.

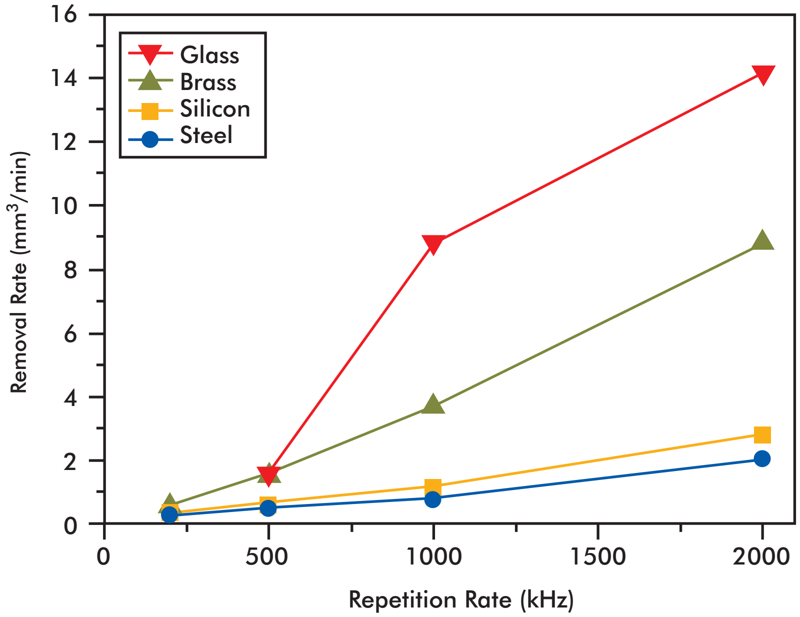
Experiments with 50-W picosecond lasers operating in burst mode have achieved ablation rates of ±60 mm^3/min. Applications with low aspect ratio (depth/diameter) yield in glass up to 20 to 60 mm^3/min; in stainless steel, 10 mm^3/min; in silicon, 30 mm^3/min; and in organics and biomaterials, up to 10 mm^3/min.

The cost per photon has dropped by a factor of 10 within the past four years, making the picosecond laser a very economical choice and one capable of competing with many other machining choices on a cost-per-part basis. Although the initial investment for a picosecond laser of adequate power and beam quality is higher than that for a nanosecond one, the total cost of ownership is only about $0.29/min. Within a minute, 20 mm^3 or more of any hard or difficult-to-machine material, such as cubic boron nitride or diamond, sapphire, glass or ceramics, can be removed.

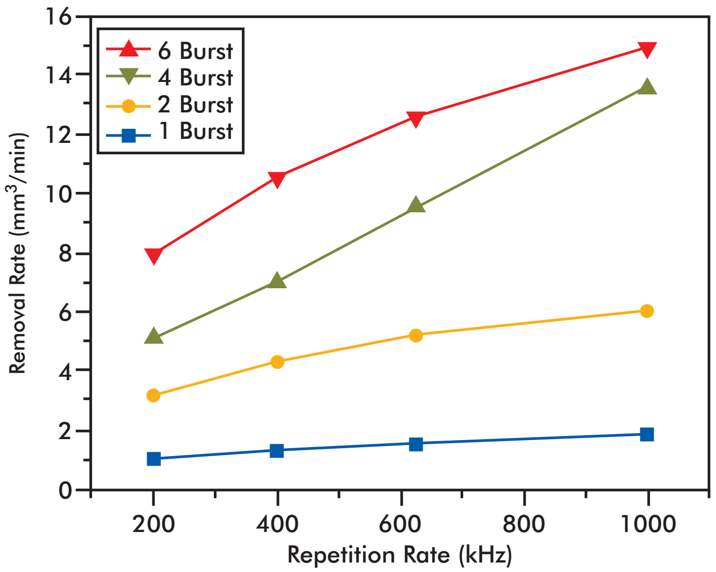
An ever-growing number of interesting applications are emerging, where removal of thin, small volumes creates high value in the product: the semiconductor industry (low k materials); photovoltaic industry (especially thin-film technology); display technology (transparent conductive oxide, organic LEDs); micromolds on demand; and precise apertures and electrode structures, large microstructured surfaces for the printing industry, or embossing of rolls or medical implants.

Even large marine vessels are candidates for micromachining. Micron-size features offer antifouling protection and reduce friction. Further, injection nozzles for high-compression cylinders as well as cutting and drilling of thin glass materials are emerging as important high-volume applications. To cater to large-scale industrial applications, picosecond lasers are required to demonstrate more than one year of mean time to failure and <1 h of time to repair. The newest generation of industrial picosecond lasers already demonstrates such performance.

Analysts agree that the market for industrial picosecond lasers will grow tenfold within the next three to four years. Power levels of 500 W will be reached, costs will be reduced and throughput will be increased. Reliability and cost of ownership will be the most decisive metric for any large-scale industrial use.



Removal rates increase with repetition rate.



Removal rate substantially increases with burst mode operation.

Meet the author

Dirk Müller is director of business development at Lumera Laser GmbH in Kaiserslautern, Germany. He can be contacted via e-mail at mueller@lumera-laser.de

The UK Fights Back

In tough economic times, government continues to support innovation in optics.

BY GARY BOAS
CONTRIBUTING EDITOR

The UK economy has had a tough slog in the past year and a half. At the end of September, the government reported that the gross domestic product shrank by 0.6% in the April to June period, marking five consecutive quarters of contraction. The 5.7% drop in that time doubles that seen during the recession of the early 1990s, and even approaches the 6.4% contraction witnessed in 1980-81.

There are signs of improvement. The government predicts growth in the July to September period, and possibly even an end to the recession by Christmas. Still, one official told the BBC in September, the next 18 months are bound to be difficult. Even when the recession technically comes to a close, "it's not going to feel very different from three months ago."

No sector of the economy has been spared during this upheaval. Optics and photonics companies – some of the larger ones, especially – have suffered considerably. Importantly, however, the government has continued to encourage innovation in this area, both through existing programs and new ones designed to address the challenges currently faced within the industry.

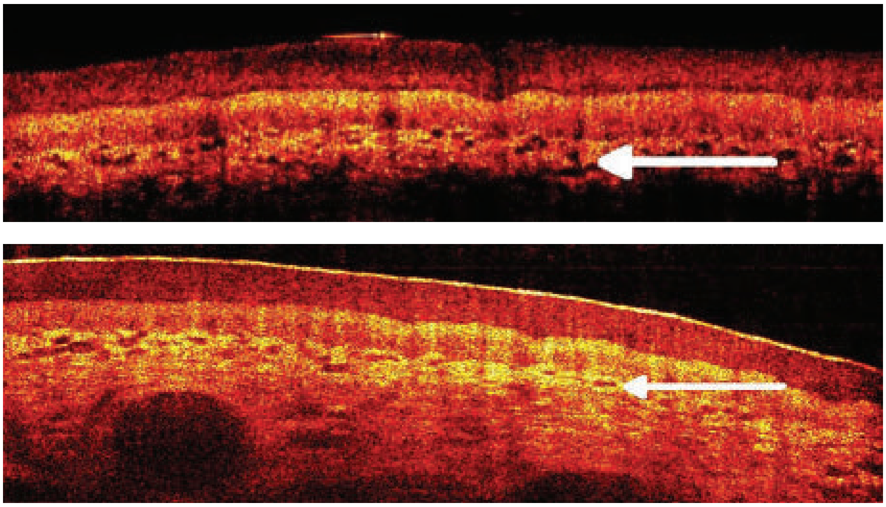
Innovation initiatives

In 2004, the UK government established the Technology Strategy Board, an advisory committee composed mainly of industrial business leaders. Initially charged with guiding the government's technology strategy, the board was given a broader role to play as part of a 2007 change in government organization. It now oversees a range of programs – including Knowledge Transfer Partnerships, Knowledge Transfer Networks, and Collaborative Research and Development – and sponsors a number of micro-/nanotechnology centers.

The board's mission, according to its Web site, is "to promote and support research into the development and exploitation of science, technology and new ideas for the benefit of business, in order to increase sustainable economic growth and improve the quality of life." To this end, it has identified priority areas representing major societal challenges – environmental sustainability and health care, for example – as well as key technology areas to help address those challenges. One of the six technology areas is electronics, photonics and electrical systems.

Recognizing the importance of knowledge and technology transfer from academic research centers to industry, the board has created several programs to encourage and facilitate such transfer, including disbursement of grants funding collaborations between academic labs and companies. These efforts are similar to the Small Business Innovation Research program in the US, said Jon Holmes, chief executive officer of Michelson Diagnostics Ltd. in Orpington, UK, although they are much more targeted than the latter program.

In 2007, Michelson Diagnostics was awarded £325,000 from the Technology Strategy Board to further develop an optical coherence tomography (OCT) system for cancer diagnosis and treatment, by supporting collaboration among Michelson Diagnostics, Cardiff University and Gloucestershire Hospitals NHS Foundation Trust. The two-year project focused on development of an in vivo imaging probe that uses OCT to produce high-resolution subsurface images of cancerous tissue – operating at a 1-µm wavelength, in contrast with the longer 1.3-µm wavelength typically used for imaging skin tissue.



A grant from the Technology Strategy Board enabled UK company Michelson Diagnostics Ltd. to partner with academic researchers and other companies to develop an OCT probe operating at 1 μm rather than at the conventional 1.3 μm. Although the differences are subtle, the images obtained at 1 μm (top) provide improved contrast and resolution over those obtained at 1.3 μm (bottom) and could offer advantages for particular pathologies.

Holmes noted that, as the project draws to a close in late 2009, the researchers have determined that OCT images of the skin obtained at 1 μm do not have a clear advantage over those captured at the more conventional 1.3 μm. Still, the grant provided a funded project through which the company could attract and work with leading academic and commercial specialists.

“The relationships we formed with these partners have flowered into further projects, contracts and opportunities of much greater total value than the original grant sum,” he said.

The Technology Strategy Board continues to fund important innovation projects. In fact, Holmes said, the overall amount of funding has increased in the past several years, on the order of hundreds of millions of pounds. He added, however, that this growth is not likely tied to the recession but rather to an expansion of the board’s offerings.

Government introduces VC fund of funds

Other efforts are more directly tied to the difficulties that optics and other technology companies are facing. In late June of this year, the UK government announced plans for a new venture capital (VC) fund of funds, for which it would be the cornerstone investor. Dubbed the UK Innovation Fund, it will include an initial £150 million (US $248 million) put up by the government. The hope is that this will attract further investment by pension funds and the private sector, reaching £1 billion within 10 years.

The announcement was well received by the UK private equity and venture capital industry, according to a June 29 article in *The Wall Street Journal*, as well as by the country’s biotechnology industry, which has taken a drubbing since early 2008 as investors have sought less risky investments.

The government earlier had announced plans to create a £750 million strategic investment fund to assist cash-strapped high-tech companies, but the British Venture Capital Association and a collection of biotechnology and IT (information technology) trade groups requested that the strategic investment fund be turned into an innovation fund – recommending, in particular, the “fund of funds” model eventually adopted. This model would be most effective, they stated in a letter to the secretary of state for business, enterprise and regulatory reform, in helping early-stage companies survive the economic downturn.

Many of these companies, including biotechnology companies working with optics, have tremendous potential for growth. But after receiving initial funds – oftentimes from the venture capital industry, thus demonstrating their investment prospects – they are struggling to obtain “follow on” funding.

A portion of the £150 million dedicated to the UK Innovation Fund will come from the strategic investment fund.

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Getting VC Funding: Improving Your Odds

BY MILTON CHANG
INCUBIC MANAGEMENT LLC

There is no shortage of good advice on how to get venture capitalists (VCs) to invest in your start-up company. Out of curiosity, I Googled "get VC funding" and found almost 2 million links. One top site is an informative short video by Paul Holland, a general partner at Foundation Capital in Menlo Park, Calif. He said the firm sees 1000 business plans a year, most of which come from people they know or have worked with. His company uses market size, technology and people to winnow down the number to about 10 new investments yearly.

Given that, on average, only one in four companies funded by venture capitalists succeeds, fewer than three in a thousand get to a happy ending. Instead of accepting this discouraging statistic, let us find ways for you as a first-time entrepreneur to improve your odds of getting VC funding or backing from other sources.

Potential investors have one-track minds, and it is only logical that you give them what they are looking for: a high return in a given time period. As professional investors, VCs focus on big opportunities, to avoid spreading themselves too thin managing a number of small investments. They are already swamped by money that has poured in from institutional investors in recent years. I am by no means implying that raising money from them is easy; deep-pocketed investors may have short arms.

Investors are too sophisticated to be sold by hand-waving sales pitches. You have to do extensive homework to verify the market, resolve all the technology risks and put together an experienced team. Willingness to make investors a good deal will enhance your likelihood of getting their attention. The fact that Holland neglected to mention random entrepreneurs knocking on his door could mean that a proper introduction by respected people might increase the chances of your proposal succeeding.

You want to target the appropriate VCs – those who would invest in your business space and in the amount you need, who have a good reputation and the right chemistry to develop personal rapport and a professional relationship. Do not shop your business plan to VCs who will never invest in your space; you will waste time and create the impression that no one is interested in your proposal.

Here's how Iris Medical (now Iridex, NASDAQ) did it.

The founders – Ted Boutacoff, Eduardo Arias and Dave Buzawa – came to me for seed capital. Years later, I learned that they had been unsuccessful for many months in acquiring this because investors were not convinced that their technology was viable. Their proposition was to use diode lasers to make a compact ophthalmic system, replacing argon-ion lasers. The objective was about 1/10 the size and 25 percent of the cost, and required no water cooling or laser tube replace-

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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)

7

Signature ____________ Date ____________

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ments. Investors were concerned about the efficacy of the wavelength and about whether semiconductor laser companies could deliver reliable devices. I made the decision to invest quickly because this is a technical area I know; I had just left Newport Corp. and was itching to get involved.

With the capital, the founders had an artist make a few detailed graphic renditions of the product and set up a lab demonstration in Ted's garage. Using a diode laser, they made a small hole on carbon paper, which produced a noticeable popping sound. This gave investors a positive impression that the system would work. And because the founders had experience in the ophthalmology business, investors were happy because they had all three ingredients they were looking for: market size data based on argon laser systems sales figures, technology that they believed would work and people who came from this industry. Once the company had acquired a reputable VC specializing in medical devices as its lead investor, other investors followed suit.

How does a technologist with an innovative idea satisfy a VC's needs? The long gestation period for commercializing innovations already creates the hurdle of a low return. Not only that, but photonics is now a relatively mature industry. Technical advances can make incremental improvements to existing photonic products instead of providing the critical mass to start a stand-alone company. Big opportunities are likely to come from applying photonics to other fields, such as biotech, enabling us to join start-up companies.

Before seeking venture funding, most entrepreneurs in our industry gather the necessary pieces by getting government research grants to develop the technology either in academia or in small business innovation research companies. Sometimes embryonic companies are put together using funds from patient and savvy angel investors, not unlike what occurred at Iris Medical. The other approach is to start small and build over time, as Newport and New Focus did. You begin with a modest objective to relax the requirements, learn to manage the business and seize opportunities to become a substantial business.

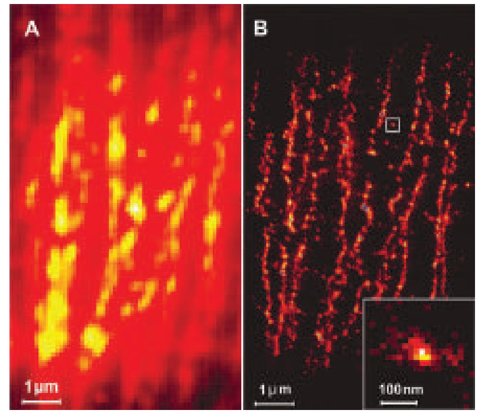
Don't forget that you can also create value without starting a company – by carrying your project forward to a stage where its potential value can be recognized, and then licensing the technology or in some way partnering with existing companies.

I had a phone conversation recently with a newly minted PhD who wanted to start a company to pursue a technology concept that, according to him, would "really shake up the optical industry." It didn't take long to see that he believes he has the tiger by the tail but no clue how to turn his idea into products. We mutually concluded that he would do well to stay on as a postdoc in the university to complete the technology development and in the meantime learn something about business to prepare for entrepreneurship.

His last question was, "What is the one thing you look for in an entrepreneur?" My unequivocal reply was someone objective, intellectual and capable of making realistic choices.

Meet the author

Milton Chang, who is semiretired, spends time mentoring entrepreneurs. He has been an investor in the photonics industry and was CEO and president of Newport Corp. and New Focus Inc. prior to forming Incubic Management, a venture capital and management consulting firm. He is a fellow of the IEEE, LIA and OSA, and was past president of LIA and LEOS; e-mail: miltonchang@incubic.com



Choosing the best protection

It's essential for entrepreneurs and small businesses to consider their options carefully when selecting a protection plan that is ideal for their asset or innovation, as well as their budget, according to Stephen Schanz, a teaching associate professor in the department of management innovation and entrepreneurship at North Carolina State University in Raleigh.

Schanz published a paper in the September 2009 edition of *Entrepreneurial Business Law Journal* that breaks down protection plans into three categories: patents, copyrights and trade secrets, emphasizing each one's advantages and disadvantages. Schanz forewarns companies and inventors about weighing the pros and cons in relation to stability against competition, expenditures and security, including how much protection the asset will need.

"All businesses are not created equal," he said. "Each of them has a different inventory of protected intellectual property."

Keep your options open

To promote an invention and safeguard its manufacture and sale in the public domain, many businesses and entrepreneurs seek patent protection. A utility patent, for example, protects revenue over a span of 20 years. Many processes, products and business methods are also deemed patentable, and obtaining the patent rights gives the holder full protection under the law.

Yet, according to Schanz, some people feel that a patent guarantees a profitable contract. They see it as though "anything that is patentable will be an automatic success," which is not true. A business must evaluate its product based on whether it is a good and marketable idea and on whether it will generate revenue. "It doesn't make a whole lot of sense to go through the time and effort to patent the idea if no one wants the product," he added.

Therefore, in addition to being patentable, an idea has to be viable, because a patent is extremely expensive. Hiring a lawyer, filing an application and paying maintenance fees can significantly cut into profits, so it is important to assess expenditures when determining a patent's worth. It is also imperative for companies to consider legal costs that may stem from re-examination of the claims or infringement disputes.

Furthermore, a 20-year patent protection plan begins on the application filing date. This is another disadvantage in that it can take two to three years before a patent gains final approval, resulting in the patentee losing that time in the period of exclusivity. Moreover, as Schanz stated in his paper, pharmaceutical companies that patent drugs could be subject to even less exclusivity time because of the time required for agencies to grant approval.

A protection outlet similar to a patent is a copyright, which protects original expression of authorship. This includes software, visual art, dramatic productions and published works. The copyright holder is entitled to reproduce, sell, publicly exhibit or perform, or digitally broadcast recordings of the work throughout the creator's lifetime, and the protection remains in place 70 years beyond.

Third parties who engage in willful infringement run the risk of criminal charges to include fines not exceeding $500,000 and/or up to five years in jail for the first offense, while subsequent violations will incur a $1 million fine and/or 10 years in jail. However, a copyright doesn't always protect against a third party developing the same concept. It is hard to prove that the third party had access to the defendant's ideas and that the two works are similar to a considerable degree. As a result, the copyright holder could lose credibility and be surpassed by his opponent in the race to commercial success.

Those who do not want costly expenditures can choose the trade secret alternative, which requires no application or government approval. This third type of protection plan, which falls under state rather than federal law, involves withholding from the public domain information that is essential to a business's success. A unique method, formula or discovery can belong to a business indefinitely and is maintained by confidentiality. Of course, security measures may be needed to keep the information private because anyone who discovers a trade secret fairly can compete openly.

Sticking to his standard

Schanz weighed his own options when choosing a protection plan for a legal medical software program he had developed. The program was based on a database of regulated occupations and involved identifying categories of information. "This software program did not house expressions [as required by a copyright], but functionality," he said. And with a trade secret, "the only problem is if [a company] got the secret, there [would be] no consequence for reverse engineering." So Schanz chose what was best for him and the product: "For functionality, you should always consider a patent."

Amanda D. Francoeur
amanda.francoeur@laurin.com

Energy-Efficient Modular Lighting Platform Patented

The US Patent and Trademark Office has awarded Orion Energy Systems Inc. of Manitowoc, Wis., a patent for its modular energy-efficient lighting platform called Compact Modular, which the company says can help companies reduce their energy, installation and maintenance costs, along with their carbon footprint. The plug-and-play device does not require hard wiring and can be integrated with other energy-saving devices. The platform is guaranteed to reduce light-related energy costs by typically 50 percent while increasing light levels by 50 percent.

Camtek Receives Permanent Injunction

The US District Court of Minneapolis has issued a permanent injunction against Camtek Ltd. of Israel. The developer of automated optical inspection systems for semiconductor manufacturing companies can no longer sell its Falcon line of inspection tools in the US. The tools relate to US Patent No. 6,826,298, which is owned by Rudolph Technologies Inc. of Flanders, N.J., and covers optical inspection of semiconductors using strobing illumination. The court awarded Rudolph, a designer and manufacturer of high-performance process control metrology systems, post-trial interest on lost profits.

Cognex Wins Patent Case for 2-D Symbology System

Cognex Corp. of Natick, Mass., a developer of machine vision sensors and systems, has announced that the US District Court ruled in its favor over Acacia Research Corp. of Newport Beach, Calif., and its subsidiary VData LLC, along with Veritec Inc. of Golden Valley, Minn., and its subsidiary VCode Holdings LLC. The lawsuit filed by Cognex claimed that US Patent No. 5,612,524 for capturing and reading 2-D symbology codes is invalid and unenforceable due to unjust conduct by the defendants while obtaining the patent.

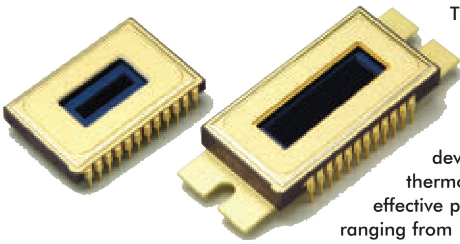
License Agreement Will Enhance Chip Security

Cryptography Research Inc. of San Francisco, specializing in security matters such as tamper resistance, content protection, network security and financial services, has announced its license agreement with EM Microelectronic of Marin, Switzerland. The Swiss semiconductor manufacturer will use the American company's patents to increase the security of its smart card chips against differential power analysis and additional attacks. The flash-based chips are used in applications such as banking and electronic identification.

Laser Line Generators

StockerYale Inc. has released the Lasiris Powerline laser line generators for industrial machine vision and scientific applications. The thermoelectrically cooled instruments output 2 W at 810 nm and 500 mW at 670 nm, and they operate from −20 to 55 °C. They feature overvoltage, reverse polarity, overheating and electrostatic discharge protection, and all models can be operated in continuous-wave or external modulation mode. The beam can be modulated by an external signal through a DB-9 connector on the back panel. The lasers can be user-adjusted to produce a focused line at any projection distance, and the line can be collimated so that its thickness remains constant.

StockerYale
lasers@stockeryale.com



CCD Area Image Sensors

The S10140/S10141 is a series of back-thinned fast Fourier transform CCD image sensors from Hamamatsu Corp. Designed for spectrophotometry and low-light-level detection from 200 to 1100 nm in scientific applications, the devices are available in noncooled and thermoelectrically cooled versions. They have an effective pixel size of 12 × 12 μm, with image areas ranging from 1024 × 122 pixels to 2048 × 506. Back-thinning produces high quantum efficiency with maximum sensitivity at 660 nm. Readout noise is 4 e⁻ rms. Thermal efficiency results from the hermetic seal and from cooling only the chip. No moisture or condensation builds up within the sensor package. The binning function improves the signal-to-noise ratio and the signal processing speed.

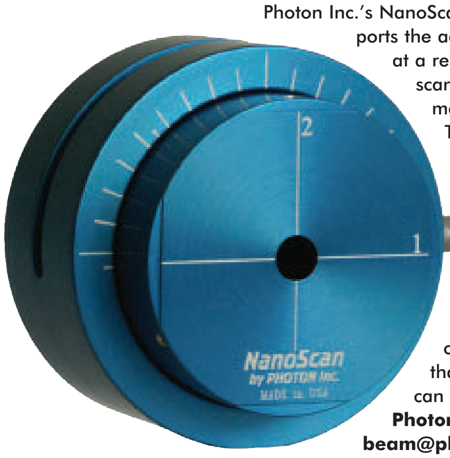
Hamamatsu
usa@hamamatsu.com

Gigabit Ethernet Cameras

Baumer Ltd.'s TXG Gigabit Ethernet cameras have four independent input/output ports located adjacent to the trigger and flash connection. The ports have customizable pulse width modulated signals, and they enable direct connection between the camera and the illumination module, eliminating PC control over lighting. The pulse width modulation controller can be programmed to set the duty cycle and the frequency of the modulated signal. Each port provides a 100-mA current. Resolution ranges from VGA to 5 megapixels, and operating rates are up to 90 fps. The internal sequencer technology enables the camera to take pictures with various settings for gain and exposure.

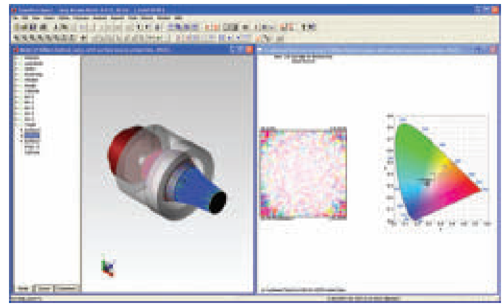
Baumer
sales.us@baumergroup.com

Pulsed Frequency Measurement



Photon Inc.'s NanoScan beam profiler now measures and reports the actual frequency of pulsed lasers operating at a repetition rate of 1 kHz or higher. It uses the scanning slit beam profiling technique to measure beam size, position and profile. The pulsed measurement option is available on all models, including those with a silicon detector for operation from 350 to 1000 nm, a germanium detector for 700 to 1800 nm, and a pyroelectric detector for 190 nm to 20 μm at beam powers of up to 1 kW. The system measures continuous-wave beams down to 4 μm and up to 20 mm and includes a power measurement window so that beam size, position, profile and power can be generated in a single measurement.

Photon
beam@photon-inc.com



Optomechanical Design Software

TracePro 6.0 is the newest version of Lambda Research Corp.'s optomechanical design software. It is x64-capable, enabling it to simulate larger systems using larger ray traces over spectral bands to investigate uniformity, solar and color issues with higher fidelity. It is recommended for Windows x64, Vista and System 7 operating systems. New analysis capabilities include an interactive CIE plot showing color gamut, enhanced RepTile prism geometry and solid concentrator constructors designed for simulating solid compound parabolic concentrators for solar applications. The property dialog boxes have been redesigned in a quick entry style and are alphabetical and simpler.

Lambda Research
sales@lambdares.com

1-W White LEDs

For backlighting LCD panels, Osram Opto Semiconductors Inc. has introduced two white versions of the 1-W Oslon LX LEDs. Measuring 3 × 3 × 1.6 mm, they are side-injected into lightguides with a thickness of 2 to 4 mm, enabling the displays to be made with ultrathin profiles. Typical light output is 75 or 90 lm at 350 mA, enough to provide uniform backlighting for computer monitors and up to 65-in.-diagonal TVs. The integrated polynomial lens with a beam angle of 125° produces 80% injection efficiency into the lightguide. The multiwhite version covers 100% of the sRGB color space, with typical light output of 75 lm. The ultrawhite version covers 80%, with typical light output of 90 lm.

Osram Opto Semiconductors
support@osram-os.com

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Green Laser

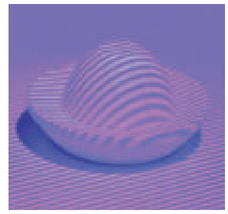
Coherent Inc. has introduced the Avia 532-23, a Q-switched, frequency-doubled, diode-pumped solid-state pulsed green laser that offers 23 W of average power at 532 nm. With repetition rates of up to 300 kHz, it is suitable for use in applications such as P2 and P3 patterning of thin-film solar cells, micromachining of microsecure digital card packages, microelectronics package singulation and silicon via drilling. PermAlign solder-bonding technology enables drift-free mounting of all the resonator optics and the aluminum-free active-area pump laser diodes. PulseEQ delivers constant pulse energy over time, and ThermEQ ensures uniform pulse energy when the laser is operating in burst mode.
Coherent
tech.sales@coherent.com

Two-Bar Module

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

Molding Technology

An advanced molding technology used by Docter Optics GmbH enables large-scale production of optical glass components with complex geometries. All sides of a prototype optical component can be measured immediately after molding at greater than 1 million points with 1-μm resolution. The measurement methods are based on stripe projection technology and on dedicated software that permits recursive comparison of actual contours and projected light patterns to determine the best optical design. The system uses this comparison to generate the data required for modification of the mold.



Docter Optics
sales@docteroptics.com

Laser Beam Combiners

Edmund Optics has unveiled new dichroic laser beam combiners that efficiently combine or separate multiple laser beams at a 45° angle of incidence. The polarization-insensitive devices feature low loss, reflection >98% and transmission >95%. Available at six cutoff wavelengths, they are suitable for combining or separating lasers between 375 and 785 nm. Made from low-autofluorescence substrates, they have a hard ion-beam-sputtered coating and are suitable for a variety of multilaser fluorescence imaging and measurement applications, including laser microscopy and flow cytometry.

Edmund Optics
medmund@edmundoptics.com

Vibration Isolators

Newport Corp. has added the S-2000-TC to its S-2000 Stabilizer series pneumatic vibration isolators, which are compatible with tie bars and casters. The instrument has a 2000-lb load capacity, supports large-area subfloors and is suitable for isolating optical tables, large inspection equipment and heavy machinery. The individual legs can be bolted together to improve mobility and system rigidity. Heights range from 16 to 28 in., and all models are equipped with precision pneumatic re-leveling valves and float-height indicators. SafeLock mounting clips secure the isolators to the bottom of the company's optical tables. Vertical resonant frequency is 1 Hz, and vertical isolation efficiency is 90% at 10 Hz. Horizontal isolation starts at 2.5 Hz and reaches 95% efficiency at 10 Hz.

Newport
warren.booth@newport.com

Piezo Controller

PI (Physik Instrumente) LP has added four open- and closed-loop models in benchtop and OEM module versions to its E-616 multichannel controller line for piezo-based steering and stabilization mirror platforms. The closed-loop units have two servo controllers, sensor circuit channels and three integrated amplifiers that provide up to 10 W of peak power. The 25-pin sub-D piezo and sensor connector is on the front, with offset trim pots and LEDs for power and overflow. A 32-pin rear

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I certify that the above statements made by me are correct and complete.

Thomas F. Laurin
President

connector enables commanding and reading of the sensor and amplifier monitor outputs. Internal coordinate transformation simplifies control of parallel kinematics designs.
PI
photonics@pi-usa.us

Temperature Controllers

Wavelength Electronics has upgraded its HTC series precision temperature controllers to offer better temperature stability and reduced internal voltage drop. Immune to ambient crossover, the devices provide short-term off-ambient stability of 0.0009 °C and long term of 0.0015 °C. On-ambient stability of 0.002 °C can be achieved with thermistors. The controllers provide up to 3 A of heating or cooling current for medical, defense, communications and manufacturing applications. The linear proportional integral control loop offers maximum stability, while the bipolar current source provides higher efficiency. They maintain precision temperature regulation via an adjustable sensor bias current and error amplifier circuit. External components configure limit current, temperature set point, proportional gain, integrator time constant and sensor bias current.
Wavelength Electronics
sales@teamwavelength.com

AC/DC Power Supply

The XAIS3531 released by Wall Industries Inc. is a 308-W AC/DC power supply with a 207- to 294-VAC input voltage range and a 28-VDC output. Housed in a 127 × 88.9 × 50.8-mm aluminum case, it can be used in lighting for parking lots, roadways, tunnels, warehouses, walkways, billboards and garages. Features include active-power factor correction, fixed switching frequency, an operating temperature from −40 to 75 °C, 3000-VAC input/output isolation, conformal coating, and short circuit and overcurrent protection. It is ISO 9001-compliant and UL 1029-approved.
Wall Industries
rberube@wallindustries.com

Laser Measurement Systems

The LMS100 and LMS111 series laser measurement system sensors have been unveiled by Sick Inc. The former is designed for indoor profiling applications, the latter is a noncontact sensor for outdoor anticollision environments, and both have filtering technology to eliminate false trips in measurement applications. The compact sensors have adjustable mounting configurations and are IP 67-rated and able to withstand wet weather conditions. Using the free configuration tool, a user can configure the sensors with up to 10 detected fields, multiple input/outputs and Boolean logic.

Sick
info@sick.com

Positioning Robots

Cartesian T-style positioning robots have been introduced by Aerotech Ltd. The Cartesius positioning systems have a single-axis base and an open payload work area to accommodate applications such as pick and place, assembly, automated test and dispensing stations. Available in XY, XZ and XYZ configurations with travel up to 1.5 × 0.5 × 0.3 m and three-axis load up to 25 kg, the systems include full-chain cable management with motor and encoder connectors fitted for fast and trouble-free integration into user applications. There are numerous options for travel, load and speed performance up to 1.4 m/s. Nearly 30 linear stages are available in standard and heavy-duty versions that combine in left- and right-hand-mounted Cartesius systems.

Aerotech
sales@aerotech.com

Infrared Thermometer

Extech Instruments has announced the 42570, a dual-laser infrared thermometer that features 100-ms response time and displays highest, lowest, average, maximum and minimum values. Adjustable emissivity increases measurement accuracy for various surfaces, and an alarm alerts the user when the temperature exceeds the programmed and adjustable high/low set point. Ideal measuring distance is indicated when the two laser points converge to a single target spot. Distance to target ratio is 50:1. A lock function is available for continuous readings and data transfer to a PC via the included USB cable and software. A white backlight multifunction LCD with a bar graph provides easy viewing of the Type K temperature probe, which features thermocouple input ranges from −50 to 1370 °C.

Extech Instruments
sales@extech.com

Laser Mount

ILX Lightwave Corp. has released the LDM-4872, a quantum cascade laser mount with case temperature control. A thermoelectric module and a water-cooled cold plate provide an active temperature control range of −30 to 30 °C, with heat loads up to 10 W. The device enables the laser to be operated under vacuum, and it supports C-Block, Alpes ST and NS chip-on-carrier packages as well as customers' own laser packages. An optional XYZ stage offers multiple mid-infrared lens options and provides precise adjustment. Precision differential adjustment screws for the X- and Y-axes provide 25-μm-per-revolution fine adjustment, and the knurled lens cartridge has 64 threads per inch for precise Z-adjustment.

ILX Lightwave
sales@ilxlightwave.com

Vibration Isolation

A portable benchtop vibration isolation system introduced by Kinetic Systems Inc. has a self-contained design that allows it to be repositioned on the benchtop, even with a load and in float. The EL_pF (ergonomic low-profile format) platform features a load capacity of 100 or 300 lb, stands 3 in. tall, uses a 0.41 × 0.48-m tabletop and weighs 40 lb. Ergonomic features include gauges tilted upward for easier viewing and recessed handles for carrying. Designed for use in laboratories and Class 100 cleanrooms, it supports atomic force microscopes, microhardness testers, analytical balances, profilometers and audio equipment. Self-leveling and active-air isolation provide 1.75-Hz vertical and 2.0-Hz horizontal natural frequencies, and typical isolation efficiencies of 95% vertical and 92% horizontal at 10 Hz.

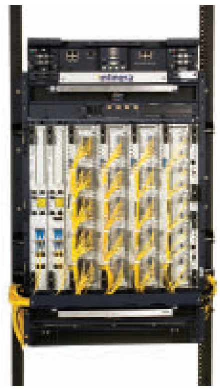
Kinetic Systems
sales@kineticsystems.com

Mobile Control Unit

The Master4Light mobile control unit from Majantys is for driving and measuring the optical properties of LEDs. Measuring 48 × 36 × 20 cm, it integrates an adjustable current source generator for driving the LEDs and two thermocouple inputs to probe their temperature in real time. Current may be continuous or pulsed, with various amplitudes and frequencies. A spectrophotometer connected to an 80-mm-diameter integrated sphere measures the optical parameters. The LED is set on top of the sphere port, which is connected to a power output. The control unit connects to an external 9-VDC adapter and a remote PC via a USB port. The software provides access to the measured spectrum and to parameters such as color coordinates, dominant wavelength, correlated temperature and color rendering index.

Majantys
contact@majantys.com

Submarine System



To introduce photonic integration to undersea networks, Infinera has adapted its DTN dense wavelength division multiplexing system to accommodate the submarine market. Used as submarine line terminating equipment, the system is deployed at cable head end sites, enabling undersea service providers to upgrade existing submarine networks and double bandwidth capacity. Benefits include cutting deployment times by up to 83% and improving space utilization by up to 95%, according to the company. Features include up to 100 Gb/s of photonic integrated circuit-based multiwavelength capacity in a single circuit pack, capacity of up to 160 wavelengths on a fiber, and high-gain forward error correction that ensures end-to-end system operation at a guaranteed bit error rate $<10^{-15}$ across the network. Semiconductor optical amplifiers have been added to provide transoceanic optical reach.

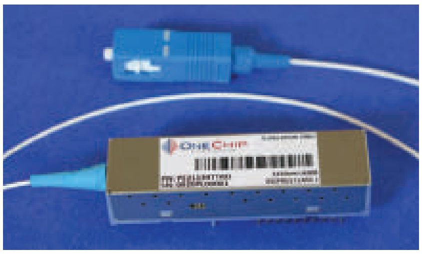
Infinera
jbaeck@infinera.com

IR and Broadband Optics

IR and broadband optics from Meller Optics Inc. can be made from sapphire and spinel for harsh environments, from germanium for detector and sensor applications, from zinc selenide and -sulfide for laser and forward-looking infrared applications, from calcium- and magnesium fluoride for nonhygroscopic front surface applications, and from silicon for mirrors and reflectors. A variety of

antireflection, partial- and total reflective coatings are available, all conforming to MIL-PRF-13830. They are available in planoconvex, -concave and meniscus configurations with λ/4 and λ/10 surfaces and finishes to 10-5 scratch-dig. They can be produced with outer diameters from ¼ to 6 in., or diagonal with tolerances to ±0.005 in. and thickness to ±0.002.
Meller Optics
sales@melleroptics.com

Transceivers



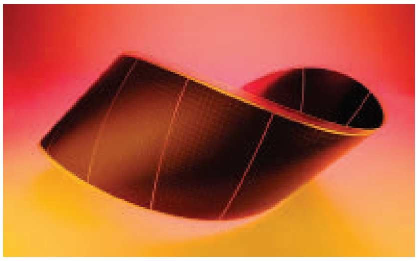
OneChip Photonics has introduced a family of monolithic photonic integrated circuit-based Ethernet passive optical network transceivers for optical line terminals (OLTs) and optical network units that are deployed at service provider central offices and at customer premises, respectively. The transceivers help system providers and carriers deploy fiber-to-the-premises less expensively and meet demand for high-bandwidth voice, data and video services. The OLT devices provide a 1.25- or 2.5-Gb/s downstream and a 1.25- or 2.5-Gb/s upstream data link in a single fiber, using a 1490-nm optical wavelength continuous-mode transmitter and a 1310-nm optical wavelength burst-mode receiver. All of the functions required for an optical transceiver are integrated onto a single indium phosphide-based chip.
OneChip Photonics
sales@onechipphotonics.com

Electric Actuators

The SCN5 series 24-V integrated electric linear actuators manufactured by Dyadic Systems Co. Ltd. are compact mechatronic cylinders that feature a motor, encoder, drive and actuator in one package. They are available in stroke lengths to 300 mm with 100-N maximum thrust, and they comprise an extruded aluminum body with 303 stainless steel for the shaft and rod tip. The actuators can be operated via 24-VDC signals and can be connected

in networks of up to 16 axes. Many moves can be set up, each with individual values for position, speed and acceleration.
Dyadic Systems
sales@servo2go.com

Metallization Paste



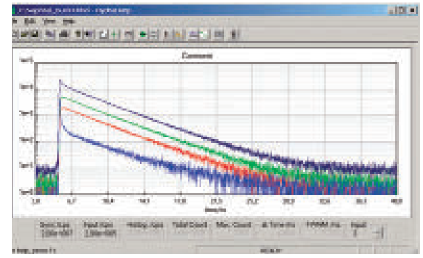
DuPont Microcircuit Materials has announced its Solamet PV412 photovoltaic (PV) metallization paste, a silver-based polymer conductive material developed to provide good front-side conductivity for copper indium gallium selenide and other thin-film PV technologies. It can be used on devices where a transparent conductive oxide is employed, and it is suitable for use with a-Si on flexible substrates, on HIT (heterojunction with intrinsic thin layers) PV cells and on any PV application that requires a low-temperature curing conductor. Features include fine-line printing down to 80-µm resolution, long screen residence time for robust printer operation, low contact and grid line resistance, high adhesion to indium tin oxide and compatibility with most transparent conductive oxides.
DuPont
contactmcm@usa.dupont.com

Solar Cell Testing

Atlas Material Testing Technology offers services to evaluate the performance, durability and reliability of solar cells and modules at its ISO 17025-accredited laboratory. There are testing programs for full-scale photovoltaic (PV) arrays, building-integrated PV systems, complete modules and individual PV cells. The company has developed the XenoCal solar sensor for UV preconditioning of PV modules. It measures irradiance (W/m²) or radiant exposure (kWh/m²). Depending upon which IEC standard is selected from the menu, values in two wavelength bands are displayed. The watertight sensor can operate in harsh environments and is supplied in a case with a lithium battery, a connecting cable and an RS-232 interface. Processing software can be downloaded free from the company's Web site.
Atlas Material Testing Technology
info@atlas-mts.com

Software

PicoQuant GmbH has introduced version 1.2 software for use with its HydraHarp 400 time-correlated single-photon-counting system. The program provides a real-time correlator for fluorescence correlation spectroscopy (FCS) that



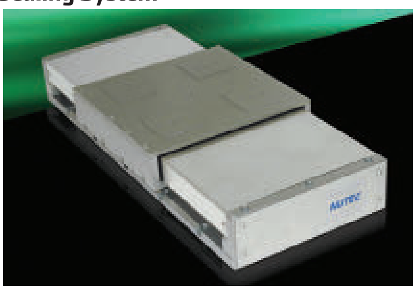
calculates two autocorrelations and the cross correlation between two photon streams simultaneously. The new release supports Windows 7 and the latest HydraHarp hardware, with up to eight timing input channels. Each channel produces 1-ps resolution at a processing rate of 12.5 million counts per second per channel. All channels operate independently but with a common crystal time base. A time-tagged data collection mode provides a stream of individual timing events to the host computer that can be processed and analyzed for photon burst detection, coincidence correlation or for combined measurement of fluorescence lifetime and FCS.
PicoQuant
info@picoquant.com

Power Meter

Model 3023 is a fiber optic power meter manufactured by GAO Fiber Optics Inc. to measure absolute optical power and relative fiber loss. The testing instrument is suitable for use in the installation of single-mode optical cable networks and for debugging and maintenance of telecommunications networks, CATV networks and local ones. Compact and lightweight, it has a large-character LCD screen and consumes little power. It operates from 780 to 1700 nm, with input value ranging from −43 to 27 dBm. It can operate continuously for up to 20 h.

GAO Fiber Optics
sales@gaofiberoptics.com

Sealing System



CLS, a sealing system manufactured by Nutec Components Inc., protects the company's stages in applications in contaminated environments, resulting in a motion platform with greater long-term reliability and higher efficiency. The patented design includes a concealed linear seal under the three-sided stainless steel top cover to keep out solid debris, airborne particles and fluids. Travel ranges from 100 to 1200 mm,

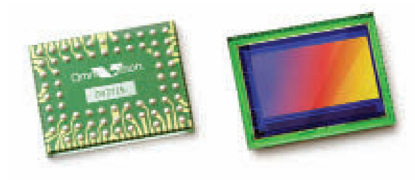
load capacities are up to 500 kg, and speed is up to 2 m/s. Features include various accuracy grades, linear encoders to 50-nm resolution, an all ground-up metric design, high-force linear brushless servomotor drives, ball screw drives with in-line or fold-back brushless servomotors, and X-Y table assembly from 3- to 60-arcsec orthogonality.
Nutec
info@nutecomp.com

Laser Control Module

The Stinger Raster Engine laser control module unveiled by New Age Imagers LLC enables laser manufacturers to use Harlequin raster image processing (RIP) software to control a laser engraver. It is suitable for use in computer-to-plate and portrait engraving applications. The system comprises a control module and an RIP interface with input/output ports to control all peripherals. An engineering development kit is available for purchase. The engine is designed to move the large raster image data sets directly, yielding precise pixel placement on the media.
New Age Imagers
jcampbell@newageimagers.com

CMOS Image Sensor

The OV2710 high-definition CMOS image sensor has been unveiled by OmniVision Technologies Inc. It is designed to deliver high-end video conferencing and recording for digital video



camcorders, mobile phones, notebooks, netbooks and PC cameras. The ⅓-in. sensor has a 1920 × 1080-pixel array that uses a 3-μm OmniPixel3-HS pixel to deliver dark current of 6 mV/s and a peak dynamic range of 69 dB. It runs at a rate of 30 fps and can operate in low-light conditions below 15 lx. It supports multiple platform architectures and controllers with both parallel and mobile industry processor interfaces.
OmniVision Technologies
security_market@ovt.com

Laser Retrofitting Services

To help customers replace older CO_2 and YAG production lasers with energy-efficient fiber ones, IPG Photonics Corp. is offering retrofit services. By replacing their older lasers for applications such as cutting, welding and cladding, manufacturers can use their existing motion systems or transfer lines while they obtain newer laser technology. The company has a calculator on its Web site that determines potential electrical energy savings realized from using a fiber laser. Customers who switch will benefit from lower maintenance, no diodes to replace and decreased downtime. Engineers familiar with systems integration, including beam delivery, application development, controllers, robots, software and safety, will provide the service.
IPG Photonics
sales.us@ipgphotonics.com

Laser Modules

A series of laser modules for the micromachining, optoelectric and industrial laser industries has been released by Quantum Composers Inc. The modules include high-speed shutters, energy attenuators, motorized slit apertures, filter wheels and motorized lens tubes. The shutters complete an open/close cycle in <40 ms and can be used by customers who need to pick off individual pulses of lasers firing at 25 Hz or slower. The motorized energy attenuators can be used to adjust the output energy of multiple or individual wavelengths from 0 to 100% attenuation, with residual energy of blocked wavelengths at 0.25% or less. The slit apertures provide a square beam that controls the X- and Y-axes and theta rotation.
Quantum Composers
apalm@quantumcomposers.com

HAPPENINGS

DECEMBER

Introduction to Optomechanical Design (Dec. 1-2) St. Asaph, UK. Contact Sonja Hardy, OpTIC Technium, +44 1745 535 140; sonja.hardy@optictechnium.com; www.optictechnium.com.

PowerMEMS 2009 (Dec. 1-4) Washington. Contact Preferred Meeting Management Inc., +1 (619) 232-9499; info@powermems.org; www.powermems.org.

Sixth Annual Printed Electronics & Photovoltaics USA Conference and Trade Show (Dec. 2-3) San Jose, Calif. Contact Chris Clare, +44 1223 813 703; c.clare@idtechex.com; www.idtechex.com.

Fourth Rio de la Plata Workshop on Laser Dynamics and Nonlinear Photonics (Dec. 8-11) Piriapolis, Uruguay. Contact Cristina Masoller, cristina.masoller@upc.edu; or Igal Brener, ibrener@sandia.gov.

JANUARY

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

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

Photonics Japan (Jan. 20-22) Tokyo. Includes Internepcon Japan; Electrotest Japan; IC Packaging Technology Expo; International Electronic Components Trade Show; Printed Wiring Boards Expo; Material Japan 2010; International Automotive Electronics Technology Expo; and EV Japan 2010. Contact Hajime Suzuki, Reed Exhi-

PAPERS

SPIE Astronomical Telescopes and Instrumentation (June 27-July 7) San Diego
Deadline: abstracts, December 14
Organizers of this conference invite abstracts in the areas of telescopes and systems, including airborne and ground-based instrumentation, optical and IR interferometry, adaptive optics systems, observatory operations and systems engineering. The event also will address detectors and advanced software and control. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

Optical Data Storage (May 24-26) Boulder, Colorado
Deadline: abstracts, January 11
Submissions are encouraged for this topical meeting on holographic, multidimensional, near-field, super-resolution, hybrid recording and other optical data storage technologies. Other topics to be considered include nanophotonics, biophotonics, plasmonics, testing and characterization, and coding and signal processing. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

OSA Optics & Photonics Congresses (June 21-24) Karlsruhe, Germany
Deadline: abstracts, January 20, noon EST (17:00 GMT)
The Optical Society of America is accepting submissions for its two collocated congresses, Renewable Energy and Advanced Photonics, which will encompass the meetings Optical Nanostructures for Photovoltaics (PV); Solid-State and Organic Lighting (SOLED); Access Networks and In-House Communications (ANIC); Bragg Gratings, Photosensitivity and Poling in Glass Waveguides (BGPP); Nonlinear Photonics (NP); Optical Sensors; and Signal Processing in Photonic Communications (SPPCom). Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org.

bitions Japan Ltd., +81 3 3349 8502; photonics@reedexpo.co.jp; www.photonicsjapan.jp.

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

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

Applications of Lasers for Sensing and Free-Space Communications: Topical Meeting and Tabletop Exhibit (Jan. 31-Feb. 4) San Diego. Contact Optical Society of America, +1 (202) 223-8130; info@osa.org; www.osa.org.

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

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

FEBRUARY

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

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

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

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

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

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

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

MARCH

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

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

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

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

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Sandfish lizards do the locomotion

Physicists, biologists, mathematicians and engineers have formulas to characterize movement over hard ground, but they still have much to learn about locomotion over more fluid surfaces, such as sand or mud. To find out more, physicists at Georgia Institute of Technology in Atlanta have studied various animals that “swim” in sand, such as the aptly named sandfish lizard (*Scincus scincus*), a species of skink.

“We would like to understand how biological organisms interact with media with complex physics to gain understanding of this part of biology,” said Daniel I. Goldman. He was the lead researcher of a study published in the July 17, 2009, issue of *Science* that explored how sandfish lizards propel themselves forward while moving beneath the sand’s surface.

Shown at left is an x-ray image of a sandfish lizard moving beneath the surface of granular media. When moving beneath the sand, the sandfish lizard propels itself forward in a snakelike fashion.

Researchers (from left) Ryan D. Maladen, Daniel I. Goldman, Yang Ding and Chen Li surround the high-speed x-ray imaging system they used to study the dynamics of motion over fluid substances. A container with glass beads resembling sand is in the foreground, and an x-ray source and visible light camera are seen at top. An x-ray camera, below, is not shown. Georgia Tech photos by Gary Meek.

The experimental apparatus consisted of a transparent container measuring 21.5 × 18 cm filled with spherical glass beads – approximating sand – 10 cm deep. Tiny holes on the bottom allowed air to be blown in, thus varying the beads’ volume fraction, or density. The clear box was positioned between an x-ray source and a high-speed visible light video camera above and a high-speed x-ray video camera below. Both cameras operate at 250 fps.

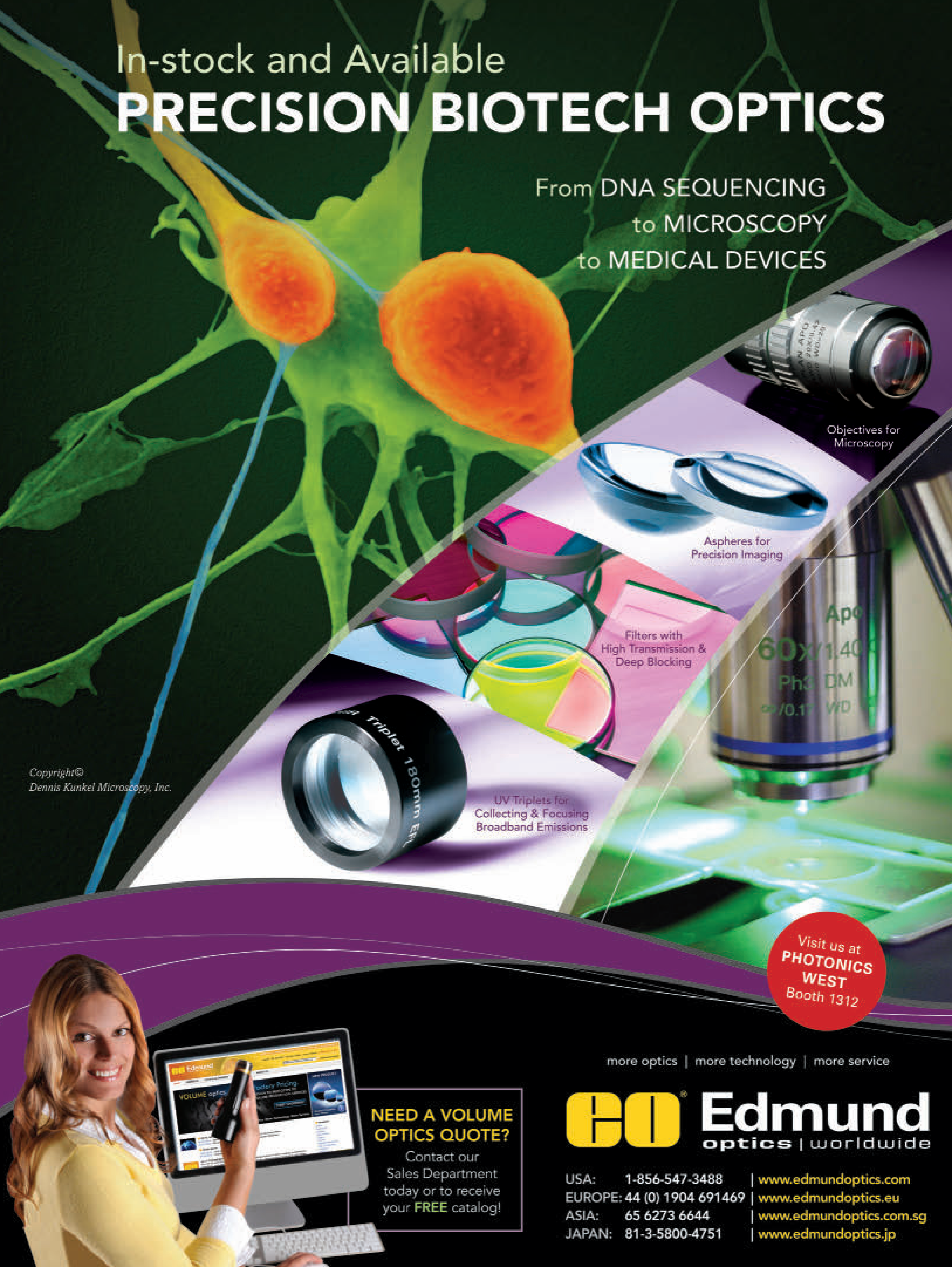
After the sandfish was released from an adjacent holding pen, it dived into the container, guided to a particular location by a Plexiglas barrier. By using synchronized x-ray and visible light videos, the researchers studied the parameters of the sandfish’s movement. Natural markers visible to x-rays, as well as opaque markers attached to the back and limbs, enabled the investigators to identify the animal’s midline and to track it with Matlab software. The weight of the markers, 0.04 g, was much less than the sandfish’s average weight of 16 g.

Contrary to a previous study of the sandfish lizard using nuclear magnetic resonance, published in 2008, this investigation found that sandfish do not use their limbs for locomotion beneath the sand. Instead, they use their entire body to propel themselves forward in a snakelike motion.

Regarding the discrepancy, Goldman speculates that container size might be the key. “In our x-ray studies, we have observed that, when the container size is just a little larger than the animal, or the animal is close to a solid surface, it will use its limbs.” The team was a bit surprised to find that the volume fraction does not determine the sandfish’s travel speed.

Goldman is uncertain why the high-speed x-ray method was not used before, but because of the temporal and spatial resolution of the device and the relatively low cost, his team will continue using the technique. Results of the study may specifically benefit the researchers’ goal to build a robot that can move over and within sand, mud or rubble.

Margaret W. Bushee
margaret.bushee@laurin.com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