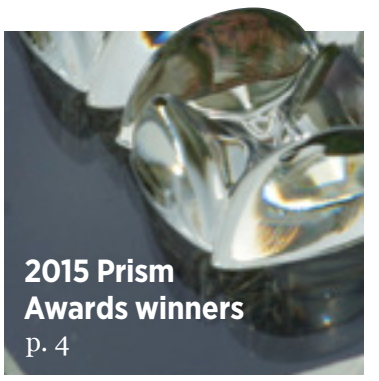
THURSDAY EDITION

THURSDAY, FEBRUARY 12, 2015

SPIE. PHOTONICS WEST | optics.org

PHOTONICS WEST. SHOW DAILY



NASA's Donald Cornwell, Jr. at Wednesday's LASE plenary. Credit: Adam Resnick

TODAY'S NEWS

Optical communications reaches for the stars

Advances in space-based optical communication, ultrafast lasers, and 3D printing highlighted Wednesday's LASE plenary session, echoing a theme seen throughout this year's Photonics West: technologies that have long been in the research stage finally finding their footing in real-world applications.

The first talk, presented by Donald Cornwell, Jr., head of NASA's Space Communications and Navigation Program, focused on NASA's optical communications program — notably, the 2013 Lunar Laser Communication Demonstration (LLCD), the first two-way, high-rate (622 Mbps) laser communication from the moon. During the demonstration, an error-free data rate of 20 Mbps was transmitted from Earth to the LADEE (Lunar Atmosphere and Dust Environment Explorer) spacecraft and back to Earth at 622 Mbps, about 400,000 km at rates up to 4,800 times faster than the fastest RF uplink to a spacecraft.

NASA achieved this using commercially available 1550-nm erbium-based technology, with frequencies 100,000 times higher and wavelengths 100,000 times shorter than via radio to impart more data on the beam, he said. "We can narrow the beams, and diffraction is less of a problem. So we can deliver more concentrated energy at a distance."

Technology breakthroughs for the project came from NASA, MIT's Lincoln Laboratory, and the European Space Agency. They included an optical module with an inertial reference system that measured and com-

continued on page 03

DON'T MISS THESE EVENTS TODAY

INDUSTRY EVENTS

Photonics West Exhibition (10 AM-4 PM)

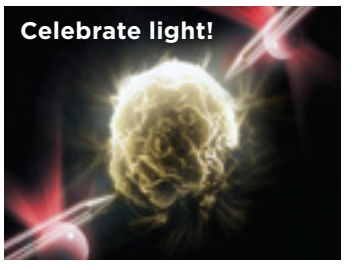
Prism Awards for Photonics Innovation winners at exhibition

SPIE photonics industry update (9:15-9:45 AM, Room 134)

Commercialization and Prototype Showcase (10 AM-12 PM, Demo Area 2 in Hall D North)

See the technical program and exhibition guide for more details on daily events. Conference registration may be required. Industry events are open to all registration categories.

IN THIS ISSUE



Pick up your free book at the International Year of Light booth, North Lower Lobby. Credit: Mervyn Miles

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‘A giant of a friend’

Calling him “a giant of a friend,” SPIE CEO Eugene Arthurs shared his memories of Charles Townes Wednesday in a special tribute to the laser pioneer during the LASE plenary session.

Townes, who shared a Nobel Prize in 1964 for the development of the maser and laser, passed away 27 January at the age of 99.

“My career, my life were indelibly influenced by this genius,” said Arthurs, who started his career as a laser physicist. “He really was a remarkable person to know. His vision, his openness to everything, his interest in all areas of science was quite inspiring. ”

One of the many impressive things about Townes was his love of his students, Arthurs noted. “Nobel laureates can be hard to pin down sometimes, but if he was asked to speak to students, he was immediately there. He loved doing that, loved giving them advice.”

In addition to winning the Nobel Prize, Townes also won the Templeton award, which is given to an individual who encourages and honors those who advance knowledge in spiritual matters, Arthurs noted.

“It is a $1.5 million award — bigger than the Nobel prize — and anyone who had the honor to know Charles would not be surprised to know that he gave away all of the money — to Furman University (his alma mater), to a homeless shelter in Berkeley, and to a church,” he said.

Arthurs said that what struck him most about Townes was his joie de vivre, his generosity, and his boundless curiosity.

“Although it is usual to give a moment of silence to pay tribute to such a person, I don’t think he would want that,” Arthurs said.

“He would want us to celebrate, not to mourn. He would want us to get the message: Enjoy exploration. It’s fun!”

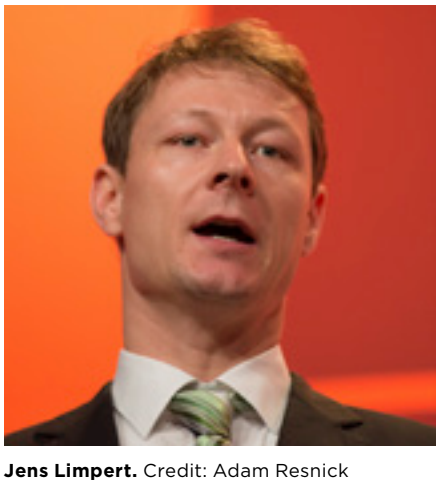
Charles Townes at a laser anniversary celebration, 2010.

LASE continued from page 01

pensated for microvibrations caused by the spacecraft that could have affected the ability of the beam to hit its target.

Guido Hennig of Daetwyler Graphics, who moderated the LASE plenary session along with Yongfeng Lu of the University of Nebraska-Lincoln, said the free space laser optical communication of NASA’s LADEE program “is an excellent, record-breaking laser application that requires precise beam steering and beam control as well as ultrafast signal processing, including data management and error handling.”

The positive results from that demonstration enabled NASA to expand its laser optical communication program for future deep space missions, including a laser communications relay demonstration (LCRD) from geo-synchronous orbit in 2018. That mission would involve a low-Earth-orbit laser communications



Jens Limpert. Credit: Adam Resnick

terminal on the International Space Station that will relay data through the LCRD in 2019. NASA also wants to develop a deep-space optical terminal for the next Mars rover by 2020.

“Why does NASA care about free space laser communications?” Cornwell said. “We’ve been using radio for the last 60 years. Why isn’t that good enough right now? Because we need more and more bandwidth to bring back more data from the instruments we send out into space,” Cornwell said. “We are leaving 90 percent or more of our data on the surface of Mars or the orbit of Mars, and I think we are missing moments of serendipity because we’re not bringing enough data back.”

Ultrafast lasers advances

Today’s femtosecond and picosecond lasers with average power values ranging from a few watts up to kW are commercially available with adjustable pulse energy, high beam quality, and pulse rep rates up to several MHz. In addition, diverse pulse repetition schemes from single pulse to burst modes can be applied to optimize the ablation rate and the resulting surface properties of the workpieces.

“The big challenge is to scale up the beam delivery systems for efficient high throughput,” Hennig said. “This means developing concepts and components for ultrafast scanning, modulation, and beam delivery optics.”

Toward this end, the second LASE plenary talk, by Jens Limpert, head of the laser development group at Friedrich-Schiller-University Jena, focused on a unique approach to increasing the peak powers of ultrafast lasers: combining ultrafast laser pulses to enable Joule-class high repetition rate femtosecond lasers, which could lead to new applications in science, industry, and medicine.

“The coherent combining of multiple ultrashort pulse lasers is a very ambitious research project designed to achieve extremely high pulse peak power in the petawatt range with near megawatt average power,” Hennig said. “This will enable new experiments in high-field energy physics.”

Laser plasma particle acceleration requires very demanding laser parameters to enable efficient generation of electrons, Limpert noted. Current target parameters

Xiaoyan Zeng. Credit: Adam Resnick

for the laser source include 32 J, <300 fs, 15 kHz, 480 kW, and >20% efficiency.

“Such parameters are beyond the powers of any known laser architecture today,” Limpert said.

In an attempt to achieve these parameters, his group has been experimenting with fiber-chirped pulse amplification (CPA) to scale up the power of the ultrashort laser pulses and demonstrated up to 5.7 mJ pulse energy, 200 fs pulse duration, 22 GW peak power, greater than 500W average power, and 90% combining efficiency. Another approach combines spatially and temporally separated amplification with chirped pulse amplification — a process known as divided pulse amplification (DPA); using this setup, Limpert’s group was able to extract 65W average power at 10 kHz rep rate.

“I believe coherent combination will enable the next generation of ultrafast laser sources,” Limpert concluded.

3D manufacturing trends

The final talk of the LASE plenary session was a review of laser 3D printing of metallic components and its industrial applications, given by Xiaoyan Zeng of Wuhan National Laboratory for Optoelectronics. He discussed two typical methods of laser 3D printing for metallic components that can yield high performance, net shape, short cycle, and almost 100 percent density. They are laser melting deposition (LMD) with power feeding and selective laser melting (SLM) with powder bedding. Zeng’s talk focused on the current status of LMD and SLM for manufacturing metal components and technical breakthroughs of these methods in China.

For example, over 18 years of LMD R&D at Beihang University, “several breakthroughs have been made,” Zeng said, including improvements in thermal distortion and cracking and quality control and the development of industrial-scale LMD equipment featuring 5-10 kW lasers and online process monitoring systems.

And Zeng’s group at Wuhan has developed SLM equipment for metals that allow them to print multiple complex components with good mechanical performance, including jet nozzles, grid filters, and blade wheels. These systems use four fiber laser beams to scan an area, saving time and enhancing precision, he added.

“I believe fiber lasers are the best choice at the moment,” he said.

KATHY KINCADE

Scan to follow Photonics West news online.

Optics, scanners, and lasers win Prism Awards

Scanners for bacteria detection, 3D-printed optics and tunable supercontinuum lasers were among the innovations to land a Prism Award at last night's gala event celebrating the best new technologies in the field.

Industry giants and startups alike were recognized, as Intel, Raytheon and Corning shared the limelight with Netherlands start-up LUXeXcel, the UK's Fianium and Tescan Orsay from the Czech Republic, among others.

For additive manufacturing, an expert panel picked out LUXeXcel's Printoptical technology as the winner. It is an on-demand, additive process for simple, low-cost and scalable manufacturing of optical components.

US-based BacterioScan won in the biomedical instrumentation category for its laser microbial growth monitor, which offers a low-cost way of measuring bacteria in fluids at concentrations below the limit of detection of other state-of-the-art technologies. It is claimed to detect changes in urinary tract infections within 90 minutes, with more than 90 percent sensitivity.

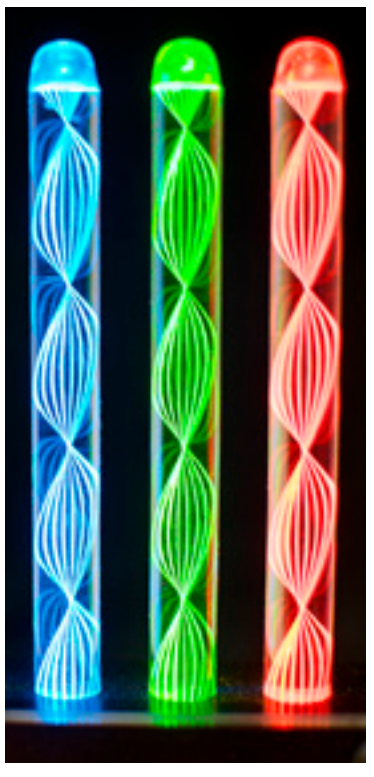
Fiber laser giant IPG Photonics won in the industrial laser category for its green quasi-CW singlemode source, while Fianium, the UK firm spun out of Southampton's Optoelectronics Research Centre back in 2003, also took home an award. Its WhiteLase SC400-20 widely tunable source, which emits out to 2400nm, won best scientific laser.

Elsewhere, Japan's Hamamatsu won in the detectors and sensors category. Its fingertip-sized micro-spectrometer comprises a grating chip and CMOS image sensor that face each other across an air gap. Hermetically sealed for robustness, it can be connected to handheld mobile devices for use in point-of-care diagnostic applications and color testing.

Among the household names to pick up Prisms was Raytheon, for its lightweight Seek Thermal Camera, while the optics and optical components category went to a collaboration between industry giants Intel and Corning, along with US Conec. Their "MXC" parallel optical connector, designed for next-generation data centers, is based on advanced composite, precision-molded plastics. Supporting up to 64 fibers, IT managers using the MXC will be able to install cables carrying an astonishing 1.6Tbps of data.

Another exhibitor, Inrad Optics, won out in materials and coatings for its stilbene scintillation crystals for neutron detection, while in metrology instrumentation German firm WITec and partner Tescan Orsay from the Czech Republic won for their "RISE" microscopy platform. It combines scanning electron kit with Raman spectroscopy to provide chemical imaging in a single unit, with molecular depth profiling capability.

MIKE HATCHER



Agilent's metrology-focused spin-off Keysight Technologies showed a range of monolithic laser combiners designed to support fluorescence, confocal, and super-resolution microscopy research at Photonics West booth 222. A fixed mounting system guarantees that the optics in every combiner are permanently aligned for the product lifetime.

Credit: Matthew Peach.

US photonics "energized"

With the three finalists competing to create the $220 million Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) now known, the historic turn for US optics and photonics is generating excitement in the community.

Bob Breault, a pioneer of Optics Valley in Tucson, Arizona, said, "It's been the most significant six months ever for the US optics industry. Photonics is being energized."

Within the past ten days, a trio of teams co-ordinated out of New York, central Florida and southern California have emerged as the finalists in the race to host the Department of Defense (DoD)-funded IP-IMI scheme.

The teams are expected to submit detailed proposals by March 31. Each announced a scattered network of partners that would create several distant hubs.

At Photonics West Michael Lebby, a University of Southern California (USC) consultant, was recruiting industry partners, saying that USC had a big advantage from the success of its 30-year-old "shared mask" semiconductor foundry model, known as MOSIS.

But he told *Show Daily* that all IP-IMI teams agreed that no matter the competition, this program is critical. "It's timely, and will position the US as a global leader in integrated photonics," he said.

In terms of the USC bid, Lebby said: "The new foundry will be based on integrated photonics services, building on the experience and success from MOSIS." John Damoulakis from the USC bid team said the California hubs would focus on data and high-speed communication centers.

On the Photonics West exhibit floor, the University of Central Florida (UCF) opened a busy booth to promote its own proposal, to be called "PRISM." Some 250 companies had stopped by for information by Wednesday afternoon along with two or three more universities interested in becoming partners, said James Pearson, executive director of the Florida Photonics Cluster. He added: "We are leading and we are going to win this."

UCF showed off plans for a nearby 100,000 square foot manufacturing research facility focusing on sensors, due to open in spring 2016 at a 20-acre site in Osceola County. Its hub plan includes Georgia Tech, University of Alabama-Huntsville, Clemson and the University of Illinois.

Under the giant "New York" banner sailing above the Moscone show floor, reps gave out information on about 100 optics and photonics companies like Kodak, Corning, Jenoptik, Bausch and Lomb, and Xerox. Although there was no formal IP-IMI booth, a support letter for the New York bid team said that its plan will have committed funds to share costs in excess of 4:1 for five years. Terms call for the $110 million in federal funds to be at least matched from other sources over that period, and each of the three finalists is said to have already obtained commitments well above that goal.

FORD BURKHART

The Corelight fiber laser engine at the heart of JDSU and Amada's new range of multi-kilowatt systems. Credit: Matthew Peach.

Fiber power reflects growing tech shift

Fiber lasers and direct-diode sources continue to eat into the long-held market share of CO_2 laser systems for metal cutting. According to industry analyst Strategies Unlimited, the market for kilowatt-scale fiber lasers will swell to $780 million in 2017.

That trend is more evident than ever at this year's Photonics West 2015, and it isn't just about IPG Photonics. JDSU used the show to introduce five new turnkey fiber laser and direct-diode laser systems aimed at machine tool companies, designed and developed with key collaborative partner Amada. Those systems use JDSU's Corelight fiber laser and direct-diode laser engines, with products slated for market release this summer.

The Corelight range comprises the firm's "AJ" 2 kW, 4 kW, and 6 kW fiber systems, complemented by JDSU's "ExC" 2 kW and 4 kW direct-diode lasers.

Elsewhere, II-VI SUWTECH is showing its new high-power, fiber-coupled diode pump module, which offers scalability for various power levels up to 300 W with different emitter and fiber configurations (105 micron and 200 micron fiber cores). With more emitters integrated, this high-brightness pump, based on single diodes, will enable fiber laser customers to generate higher pump power levels using fewer modules — and therefore more cost-effective designs.

Towards the lower end of the power spectrum, Canada's MPB Communications has extended its suite of visible-range sources, reaching wavelengths not previously available. Its portfolio now includes continuous-wave (CW) models from 488 nm to 775 nm with outputs up to 5W, alongside near-infrared models from 1028 nm to 1550 nm offering up to 100 W output. The model the company is highlighting as its latest achievement is a 750nm, 500 mW CW source.

MATTHEW PEACH

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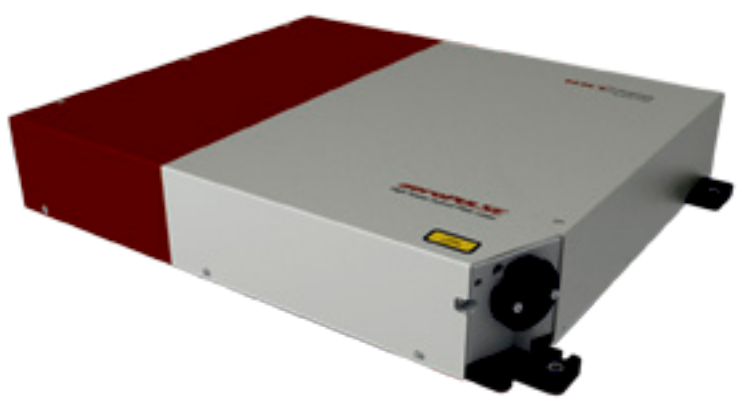

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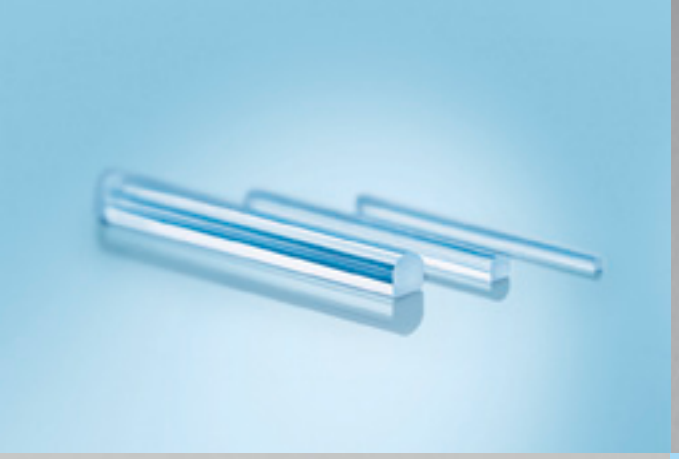

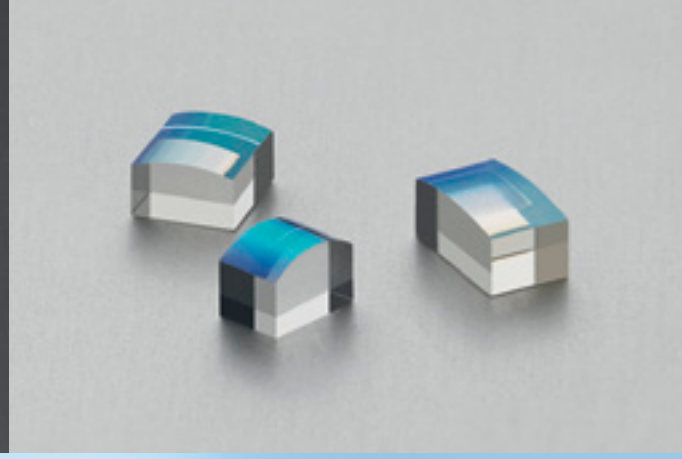
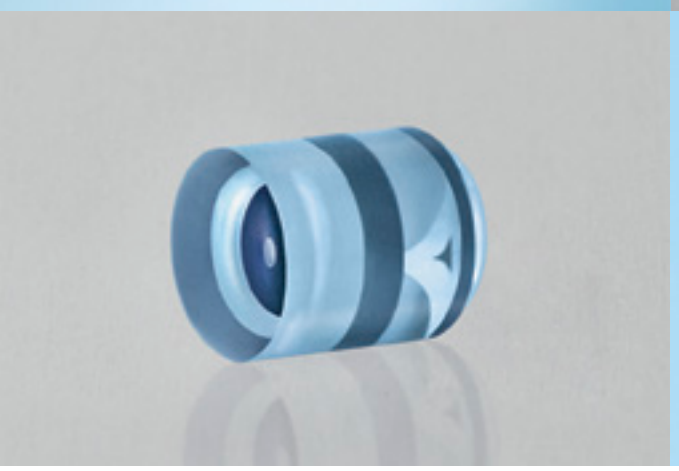


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Pictures of light: the winners

Celebrating the winning entries to the SPIE International Year of Light Photo Contest.

Light-emitting diodes (LEDs) figure prominently in the SPIE International Year of Light Photo Contest, with the top three winning photographs showing LEDs on automobiles on a bridge in Shanghai, solar-powered study lights in India, and a paddle in the Pacific Northwest waters of the United States.

SPIE Professional, the Society's quarterly member magazine, sponsored the contest to celebrate the International Year of Light and Light-based Technologies, providing prize money of $4,500.

Amateur and professional photographers from all over the world submitted nearly 800 photographs of lasers, solar panels, rainbows, the Milky Way, and everyday settings where light and light-based technologies play a central role.

SPIE CEO Eugene Arthurs says he was "impressed by the quality, variety, and large number of submissions."

The winning entry came from Paul Reiffer, a professional photographer originally from the UK but currently based in Asia. His 2013 New Year's Eve photo is a 35-second exposure of the three-layered, elevated ramp to the Nanpu Bridge in Shanghai — and the brilliant display of colorful LED lights from the traffic and the bridge itself.

In second place was a photo taken by amateur photographer Susanta Mukherjee from Bengal in India. In March 2014 he was in the village of Sundarban, India, when a non-governmental organization (NGO) called ARCHI invited him to photograph a group of children receiving solar-powered LED study lights from One Child One Light, another NGO helping rural residents without access to electricity.

Paul Reiffer's 35-second exposure of the Nanpu Bridge in Shanghai and the cars driving over it won first prize in the SPIE International Year of Light Photo Contest. Credit: Paul Reiffer/SPIE.

Children receiving solar-powered LED study lights from One Child One Light. Susanta Mukherjee's entry was awarded second place. Credit: Susanta Mukherjee.

LEDs attached to the paddle "paint" the still water with red and green light, in Ian Bell's remarkable photo. It was voted into third place. Credit: Ian Bell.

And in third place was an image captured by Ian Bell, a photography and business major at Montana State University in the US. He also used a long exposure to show an athlete on a stand-up paddle board. The LEDs attached to the paddle "paint" the still water with red and green light.

Judges for the photo contest included SPIE Student Chapter leaders, art students, and an executive panel that selected the top three from a group of 35 finalists. The remaining 32 images are eligible for the People's Choice Award. For more information, visit: http://spie.org/IYLphoto.

KATHY SHEEHAN

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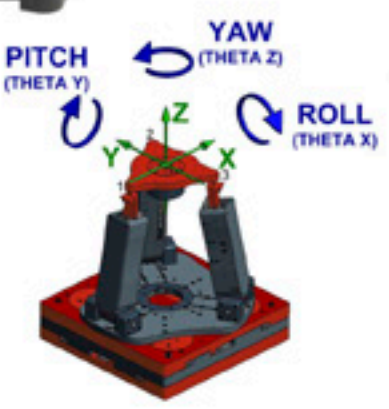

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The European challenge: turning R&D into jobs

Wolfgang Boch believes that the European Commission's commitment to the photonics industry is paying off, and sees the Juncker agenda, with the creation of a connected digital single market among its top priorities, boosting jobs and growth.

Prior to joining the European Commission (EC) in 1989, Wolfgang Boch earned his master's degree in electrical engineering from the University of Karlsruhe and worked as an R&D project leader in the German aerospace and avionics industry**.** In Brussels, he has held several management positions related to Information and Communication Technologies (ICT), under the European Union's various Framework Programmes for research and innovation.

Before taking over leadership of the photonics unit previously managed by Thomas Skordas, he was, from 2007 to 2013, responsible for "Future and Emerging Technologies (FET) — Proactive Initiatives," as well as heading up the unit responsible for the selection and launch of the high-profile "FET Flagship" research initiatives on graphene and the human brain.

He told *Show Daily*: "One of the key characteristics of these large-scale FET Flagships is that they are science-driven, but bring in industrial partners at an early stage so as to increase the opportunities for early deployment of new innovative products and solutions. Now, as head of the photonics unit, I am closing the circle by moving back into a field that is strongly industry-dominated, its activities much more focused on developments driven by concrete business opportunities and the creation of new products and markets."

With the significant investment in photonics via a new public-private partnership (PPP) initiative, part of Europe's seven-year Horizon 2020 innovation effort, Boch says that there is a reinvigorated drive supporting the photonics community. The EC has committed €700 million to meet the PPP objectives, with the private sector pledging four times that amount to make a total investment of €3.5 billion.

Wolfgang Boch, Head of Photonics Unit at the European Commission. Credit: EC.

New funding instruments

The purpose of the PPP is to use photonics to create economic growth and jobs in Europe, and to create innovative solutions for some key societal challenges. "Horizon 2020 places a lot of emphasis on innovation, which means that research and development actions need to be complemented by innovation actions which target activities closer to the market and higher Technology Readiness Levels (TRLs)," says Boch. "Our toolkit of funding instruments has been extended to support these innovation activities."

> "I would contend that whole digital sector — including photonics — has gained additional weight under the new Juncker Commission."

For innovation actions, the EC is demanding that industry partners put more substantiated business cases forward when applying for funding — to establish the market opportunities and the path to commercialization of new products and services. Only where the mission is clear will it support those activities with appropriate funding.

But as part of Horizon 2020 the EC has also devised new funding instruments to accelerate innovation. Historically, one intrinsic feature of its funding regime was that an EU-funded research action required the involvement of at least three different partners from three different countries.

To some extent that is still the case, but under Horizon 2020 in order to help increase the number of high-potential SMEs involved and simultaneously cut the level of bureaucracy, there is a new instrument. This allows an individual company from just one country to bid for European funding on its own. In the first SME calls, launched in 2014, of the 155 successful bids from companies across all industries, Boch says that more than 10 percent were in the photonics sector.

First impressions

So, one year into the job, what is Boch's impression of European photonics?

continued on page 11

Wolfgang Boch

continued from page 09

"The photonics industry is currently in a good state," he says. "But it does need special attention and further support. This is not a contradiction. It is about investing public money in a vibrant and vital sector, which has a high potential for creating growth and jobs."

He feels that a good level of coordination and network of companies and organizations has been established, helping new business ecosystems form across the contintent. "This enables coordinated working together on jointly agreed research projects in ways that are more efficient and more effective," he said. "This is good for all the [players] in this sector, which has been previously rather fragmented, from SMEs to large industry and from universities to research organizations. Photonics21 has played a key role in this and now the photonics PPP will bring this collaboration of the public and private sector to the next level."

In Europe, the photonics sector is considered to be agile and successful at discovering new opportunities across a vast range of applications and markets. A good example is with laser-based manufacturing. Europe has about half of the global market, but this area still requires continuous development to keep pace with the new concepts of highly networked manufacturing processes and ever-increasing digitization.

Boch also sees major opportunities in the medical sector: "Other strong European photonics areas are in optical communications and in biophotonics," he said. "Exploiting biophotonics offers huge opportunities, for example in terms of early detection of diseases such as cancer or performing blood sample analysis with lab-on-chip solutions at the patient's bedside with instant results. So there are still major market opportunities ahead of us."

But as Europe gets its act together on the benefits of collaboration and builds on its wealth of academic and commercial resources, there is the ever-present competition from Asia and the Americas.

> "The European Commission cannot afford to fund research when it does not have concrete applications or business opportunity in mind."

Considering the more coordinated approach emerging in the US over the last few years, Boch says: "It appears that competition is increasing on all fronts and the speed of innovation is further increasing. The US is putting millions of dollars into the creation of more than ten different new facilities for manufacturing, which will strongly benefit photonics-related areas. We are also seeing increasing competition from south-east Asia and China. Consider the LED lighting market: it's clear that this technology addresses a global market and I think that all European players are aware that we need to continuously remain competitive, strive to protect our position and strengthen collaborations."

New Commission

Led by Jean-Claude Juncker, the new European Commission has been in office since November 2014. Its investment plan includes building on a close partnership between the EC and the European Investment Bank.

Under that new regime there are now two full-time commissioners looking after the possibilities relating to the photonics sector. They are Günther Oettinger, who has overall responsibility for Digital Economy & Society, and Andrus Ansip, commissioner for the Digital Single Market and also EC Vice President. So how is the new organization likely to impact photonics?

"Among the new people at the helm of the Commission, there is a strong commitment to create fresh investments in Europe, to remove regulatory bottlenecks, to enable Europe to emerge stronger with focused investments in new innovation infrastructure projects," Boch says. "These initiatives will not only help a faster rollout of broadband communication networks, but will also benefit development of key enabling technologies such as photonics, advanced manufacturing or nano-micro-electonics, to accelerate innovation and create stronger innovation hubs in Europe. In summary, I would contend that whole digital sector — including photonics — has gained additional weight under the new Juncker Commission."

Political pressure: create jobs

Arguably, the needs of European industry and the required focus on re-industrialization through key enabling technologies such as photonics is something now better understood by politicians. Boch also believes that the International Year of Light presents a fantastic opportunity to create a greater awareness and appreciation of photonics technology to both politicians and the wider public. "It is not by chance that the European Commission is a strong supporter of the International Year of Light," he said. "Expressed in relatively simple terms, photonics is driving innovation in the 21st century [just] as electronics drove innovation in the 20th century."

However, it would be incorrect to characterize the photonics sector as a complete bed of roses: there is always room for improvement, and during his first year in the job Boch has identified a few recommendations:

"One of the observations I have made is that while photonics SMEs invariably understand their technologies well, there is still some serious homework to do. They still need to invest more time and effort into understanding both their competitors and the marketplace, in other words to prepare themselves better to attract investors to engage in their business.

"The message I would have for academics and researchers in photonics is that the European Commission cannot afford to fund research when it does not have concrete applications or business opportunity in mind. We are facing more than ever the political pressure that there needs to be a more effective link between public investments in R&D and the jobs it may help to create."

Having managed programs both in industry and science, he acknowledges the benefits of "blue sky" research but that kind of research is not in the focus of the actions funded by the EC in the ICT and photonics area. "Our photonics actions are very much focused on and driven by meeting industrial needs and societal challenges. I am very positive about the photonics sector in Europe and optimistic that these challenges can be met."

MATTHEW PEACH

First-time exhibitors at this year's shows

Photodetectors made inside a mountain, 3D-printed optics and a tunable mid-infrared laser specialist debut at Photonics West this year.

Every year the BiOS Expo and main Photonics West exhibitions showcase a growing number of companies, institutions and cluster groups offering new and innovative photonics expertise. Here is a selection of the new exhibitors aiming to make an impact in San Francisco this week, and a run-down of those that you may have missed at the weekend's BiOS Expo.

Main exhibit

CAMBRIDGE CMOS SENSORS (UK)

Launched in 2008 following research conducted at the University of Cambridge's Department of Engineering, Cambridge CMOS Sensors (CCS) is focused on the development of environmental sensors to monitor hazardous gases and other volatile organic compounds (VOCs).

Last year, Cambridge CMOS Sensors won the UK National Microelectronics Institute Innovation Award. Credit: NMI.

With sensors seen as the fastest-growing area of innovation in portable consumer electronics, CCS last year launched its "CCS800" product family, described as the world's smallest and lowest-power gas sensors. A new round of venture funding followed swiftly.

The company's tiny sensors are said to extend the application range of the technology to new platforms, bringing them within the range of smart phones, tablets and wearable devices. CCS is also collaborating with the Taiwanese MEMS packaging specialist ASE on consumer-focused gas sensors capable of detecting alcohol, carbon monoxide and formaldehyde. The technology could be used in the future to turn smart phones into alcohol "breathalyzers," or to determine the amount of fat being burned during exercise by monitoring ketone levels in human breath.

BOOTH: 4837

CLASS 5 PHOTONICS (GERMANY): HIGH-POWER FEMTOSECOND LASERS

A spin-off from the Deutsches Elektronen-Synchrotron (DESY) and Helmholtz Institute Jena in Germany, Class 5 Photonics is developing high-power femtosecond laser systems based on optical parametric chirped-pulse amplification (OPCPA) — the pulse-compression technique employed by many of the world's most powerful laser systems.

The Hamburg firm, which previously won a start-up prize organised by the OptecNet Deutschland network, says that it can provide OPCPA system designs, upgrade modules and make individual custom amplifiers to fit experimental or industrial needs. Offered pulse energies range from 1 microjoule to 1 millijoule, along with pulse durations of less than 15 femtoseconds and average power levels of up to 100 Watts.

Class 5 has already provided a conceptual design for the high repetition rate OPCPA laser to be housed by the Extreme Light Infrastructure's attosecond source in Hungary, and is also developing a new pulse diagnostic tool for use with OPCPA systems that combines a line autocorrelator, an M-squared measurement setup and a beam-profiling CCD camera.

Its range of lasers are named after different types of stars, with the "white dwarf alpha" series set to provide pulse energies of 1-5 microjoules and a maximum average output power of 20 Watts. The "white dwarf gamma" line-up will provide much higher outputs of up to 300 microjoules and 40 Watts average power.

The "supernova" and "red giant" series, using up to three OPCPA stages, are designed for pulse energies of up to 1 millijoule, and average powers of up to 100 Watts.

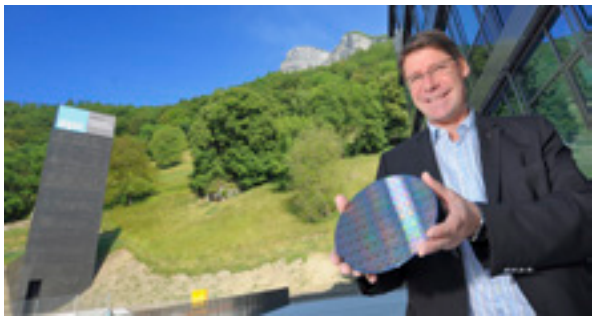
BOOTH: 4601

ESPROS PHOTONICS (SWITZERLAND): FAB INSIDE A MOUNTAIN

Almost certainly the only Photonics West exhibitor to have constructed a production facility inside a mountain, ESPROS Photonics sounds like it lives up to the expectations of Swiss precision manufacturing.

The company cites "perfect mechanical isolation" from the outside world as the reason for what is perhaps the ultimate high-end manufacturing location, saying that it guarantees a vibration-free cocoon. "A constant climate and total radiation shielding allows us to control operation of the facilities inside in an efficient and cost-effective way," it says. The Swiss Alp in question is the Gonzen — 6000 feet high at its summit and close to the border with Liechtenstein, overlooking the Rhine Valley at Sargans.

ESPROS makes optical detectors using a well-established 150 nm CMOS process featuring 1.8V and 5V devices. "This process is adapted to incorporate the necessary new devices for optical detectors, while keeping the impact on the available devices as low as possible," states ESPROS, adding that specific adaptations to the implants also enable backside illumination.



ESPROS Photonics CEO and president Beat de Coi with one of the company's wafers, in front of the firm's Alpine headquarters. Credit: ESPROS Photonics.

"At the core of the modification is the seamless incorporation of a CCD module in the CMOS process flow without any compromise on the reference device parameters," it claims.

Its featured products at the show include a QVGA 3D time-of-flight imager, and the combined CCD/CMOS epc901 line imager.

BOOTH: 5543

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First-time exhibitors

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FEMTOPRINT (SWITZERLAND): LASER-PRODUCED WAVEGUIDES

Short-listed for a Prism Award this year, Femtoprint's technology consists of a table-top 3D laser printer, used to produce glass microsystems with nanoscale features. The ultrafast, femtosecond-pulsed source is able to fuse silica and other transparent substrates, by locally modifying the refractive index of the material. It means that features like 3D optical waveguides can be produced without the need for a photomasked process.

"This simple process opens interesting new opportunities for a wide range of users to create their own micro-systems rapidly and without the need for expensive infrastructure," says the firm, which is based in Muzzano, close to Lake Lugano.

A broad variety of microsystems with feature sizes down to the nanoscale can be produced, it adds. These patterns can be used to form integrated optics components or be 'developed' by chemical etching to form 3D structures like fluidic channels.

Patterns with features smaller than the laser wavelength can be formed, while thanks to the low energies needed to pattern glass, the laser system is only the size of a shoebox.

Featured product: The FEMTOPRINT printer: a table-top 3D femtolaser platform for the production of 3D microdevices.

BOOTH: 4208

FREEDOM PHOTONICS (US): HIGH-PERFORMANCE PICS

Now based in Santa Barbara, California, following a recent move, Freedom Photonics says that its photonic integrated circuits (PICs) are aimed at applications across a diverse range of defense and commercial markets. Offering both core technology and fully custom PIC design, the company was set up by co-founder and general manager Leif Johansson — a graduate of University College London who has since migrated west with stints at both UCSB and Agility Communications.

Featured products at this year's event include widely tunable lasers, PICs for sensing, and devices designed for free-space optical communications.

BOOTH: 4219

LIGHTFAB (GERMANY): 3D-PRINTED OPTICS

Co-founded by Martin Hermans, Jürgen Ortmann and Jens Gottmann, LightFab is a new spin-off to emerge from RWTH Aachen University — and based at the Fraunhofer Institute for Laser Technology in the same German city.

They say: "We produce micro structured glass components as well as the micro scanner to fabricate the components by laser light — the 'LightFab'." In practice, that means selective laser-induced etching (SLE) of transparent materials, exploiting the capabilities of high-power ultrafast lasers for a range of photonics applications.

Featured products for the company's debut year include the LightFab 3D printer for making glass parts, while 3D microfluidics for medical diagnostics is seen as a key area of application.

BOOTH: 4601

MULTIPHOTON OPTICS (GERMANY): ENABLING CHIP-SCALE OPTICAL INTERCONNECTS

Another debutant company that has been short-listed for a Prism Award this year, MultiPhoton Optics (MPO) has recently completed a round of seed funding to back its own approach to optics production.

The method, initially developed by CEO Ruth Houbertz and colleagues at the Fraunhofer Institute for Silicate Research in Würzburg, is said to provide customers with a scalable, low-cost process for making optical waveguides.

While this is the first time that MPO has appeared at the Photonics West exhibition, Houbertz is no stranger to the event. Two years ago she and her team won the Green Photonics Award for optical communications thanks to their development of the two-photon technique used to make optical packages for chip-scale links.

MultiPhoton Optics CEO Ruth Houbertz. The company is one of a growing number in the area of 3D-printed optics. Credit: Fraunhofer ISC archive.

Investors in the seed financing round believe that the approach could end up being as disruptive as 3D printing has become in the wider manufacturing space — because complex assembly steps are avoided.

MPO will be showing off its "LithoProf3D" system, as well as opportunities for small-series prototyping, in San Francisco this week.

BOOTH: 4601

SPHERE ULTRAFAST PHOTONICS (PORTUGAL): PULSED FIBER LASERS

Set up by University of Santiago de Compostela graduate Rosa Romero, Sphere Ultrafast Photonics offers a new generation of products and services in the ultrafast pulsed laser regime. The company's "d-scan" product is described as an "inline, compact and high-performance device for the simultaneous measurement and compression of even the most demanding ultrafast pulses." It can be used as either a standalone system or integrated with existing optical pulse compressors, and is said to handle broadband oscillators, amplifiers, OPAs and hollow-fiber compressors. "Coupling your beam into the d-scan is easily achieved in less than one minute and a full measurement takes less than ten seconds," states the firm.

Featured Product: d-scan — measure and compress your ultrafast laser, single shot for CPA and OPCPA

BOOTH: 117

BiOS new exhibitors

The BiOS Expo took place at the weekend, with more than 220 companies exhibiting their wares at what is believed to be the world's largest biomedical optics and biophotonics exhibition. Among them were a number of first-timers — here are some that caught our eye.

CYLITE OPTICS (AUSTRALIA): HYPERPARALLEL COHERENCE TOMOGRAPHY

Cylite Optics, based out of the Monash Technology Precinct in Melbourne, Australia, launched its new imaging technology platform. Called "hyperparallel coherence tomography," the company says that it will "revolutionize" wavefront measurement for medical imaging applications.

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First-time exhibitors

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Meanwhile Trevor Anderson, Cylite's VP of R&D, covered recent developments in Monday's technical conference session on *Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XIX*.

The new technique is described as a "unique" 3D spectral imaging technology that can measure more than 1000 simultaneous A-scans over a 7.5 mm range, and at a speed of more than 50 frames per second. An important advantage of that high rate includes an insensitivity to sample movement, while multiple simultaneous surface measurements are said to greatly enhance the registration of consecutive frames and enable aggregate measurements over a very fine lateral grid.

The technology is also said to offer lower-cost implementation, thanks to the use of standard optical components such as lenslet arrays and a 2D image sensor.

So far, the system has been developed for measuring the elevation and curvature of anterior and posterior corneal surfaces in the eye, as discussed by Anderson.

INVENIO IMAGING (US): FIBER LASER RAMAN MICROSCOPE

Spun out of Sunney Xie's University of Michigan research group, Invenio Imaging's novel Raman microscope promises a new level of precision when it comes to helping surgeons see the margin of cancerous tumors. The system, said to offer a contrast and spectral fidelity comparable with the more complex coherent anti-Stokes Raman scattering (CARS) approach, allows label-free chemical imaging.

According to Invenio, wider adoption of the technique has thus far been hindered by the need for a costly and environmentally sensitive tunable ultrafast dual-wavelength source. Now, its team has worked with chemists, neurosurgeons, pathologists and others to develop an optimized, all-fiber laser system based on the optical synchronization of two picosecond power amplifiers.

Invenio says that the microscope offers shot-noise-limited sensitivity and an imaging speed of up to one frame per second.

MODULATED IMAGING (US): PATTERNED TISSUE ILLUMINATION

Founded back in 2005, within the Photonic Incubator of the Beckman Laser Institute (BLI) at UC Irvine, Modulated Imaging has been working on clinic-friendly optical instrumentation and software ever since. Its focus area is spatial frequency domain imaging (SFDI), developed in collaboration with BLI scientists, for sub-surface structured tissue imaging.

In February 2014, the company expanded off-campus to the Capistrano Business Center in San Juan Capistran to house its operations and manufacturing, and is now making its first commercial product — the Ox-Imager RS. It employs patterned illumination to obtain surface or subsurface images of optical properties of tissue over a wide field-of-view. Using it, biomedical researchers can detect, quantify and visualize spatially-resolved optical and functional parameters of biological tissue including chromophores that relate to tissue health — for example, oxy- and deoxy-hemoglobin, water and melanin.

Late 2014 saw the firm appoint Richard Oberreiter to the position of chief operating officer, with the challenge of leading the commercialization effort.

"Ox-Imager RS possesses sufficient spatio-temporal resolution to study both fast and localized events at depths of several millimeters in tissues," says the firm.

OPTOGENIX (ITALY): LIGHT DELIVERY FOR NEUROPHOTONICS

Headquartered in Lecce, deep in the heel of Italy, Optogenix develops, produces and sells equipment designed to deliver light into the brain, claiming an unparalleled versatility and minimal invasiveness that overcomes some of the key limitations of other devices currently available on the market.

The firm's probes, based on tapered optical fibers, are said to provide a unique approach for optogenetics experiments, allowing for uniform large-volume illumination and spatially addressable multi-point light delivery with extremely narrow optical fibers.

Optogenix formed as a spin-off from a research collaboration between the Center for Biomolecular Nanotechnologies at the Istituto Italiano di Tecnologia (IIT) in Lecce, and the Department of Neurobiology at the Harvard Medical School in Boston, US.

Its "Lambda-B" fibers are said to be ideal for single- and multi-wavelength illumination of large brain volumes, offering a better homogeneity in comparison to standard fibers.

In addition, side-emitting "Sigma" fibers allow illumination of localized sub-regions lateral to the fiber's axis. "In multiple-emitting-points configurations, it is possible to select the emitting window with a special optical strategy at the fiber input end, thus allowing spatially selective optogenetic modulation with a single, minimally invasive waveguide," says the firm, adding that the shape, size and position of the windows can all be customized.

OPTORES (GERMANY): OCT SOURCES

Optores is a spin-off from Lehrstuhl für BioMolekulare Optik at Ludwig Maximilians University (LMU) in Munich, Germany. Together with Professor Robert Huber, the company has coined the term "MHz-OCT," indicating an order-of-magnitude faster speed than earlier OCT sources, and is planning to bring the technology to a wider audience and enable new OCT applications in the process.

Crucial to the faster sources is a technique called Fourier domain mode locking (FDML), said to complement standard mode locking. In FDML, the spectrum, rather than the amplitude of the field, is modulated. A dynamic spectral window function (wavelength window that changes in time), rather than a temporal function with no wavelength dependence, is then applied, and the laser generates a sequence of narrowband optical frequency sweeps at either the cavity's fundamental repetition rate or a harmonic. This frequency-swept output is essentially a sequence of highly chirped, long pulses, with a fixed phase relationship between successive frequency sweeps.

Featured product: 1310nm MHz swept laser, based on FDML technology — claimed to be the fastest wavelength-swept laser in the world.

MIRSENSE (FRANCE): TUNABLE QCLS FOR SENSING

mirSense is a Paris-based start-up company which develops and produces quantum cascade laser (QCL) diodes and QCL-based advanced photonic devices such as wideband tunable sources for real-time, high sensitivity trace detection and chemical analysis of gas, liquids and solids by infrared laser absorption spectroscopy. Said to be unique, the mirSense approach only uses microelectronic solutions with no moving mechanical or optic components, resulting in compact and robust devices.

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Here you will find an effective at-a-glance guide to some of the latest products available on the market with booth numbers if available making it easy for you to check out the products for yourself.

All this information and more can be found on the optics.org website. Simply go to **www.optics.org** for all the latest product and application news.

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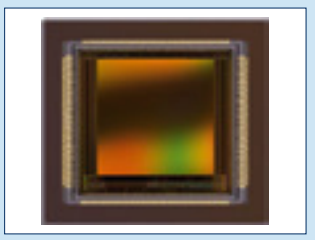

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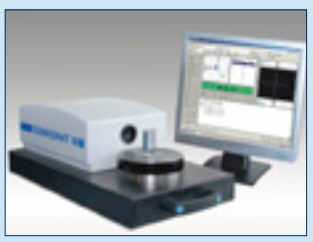

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Arden Photonics Ltd

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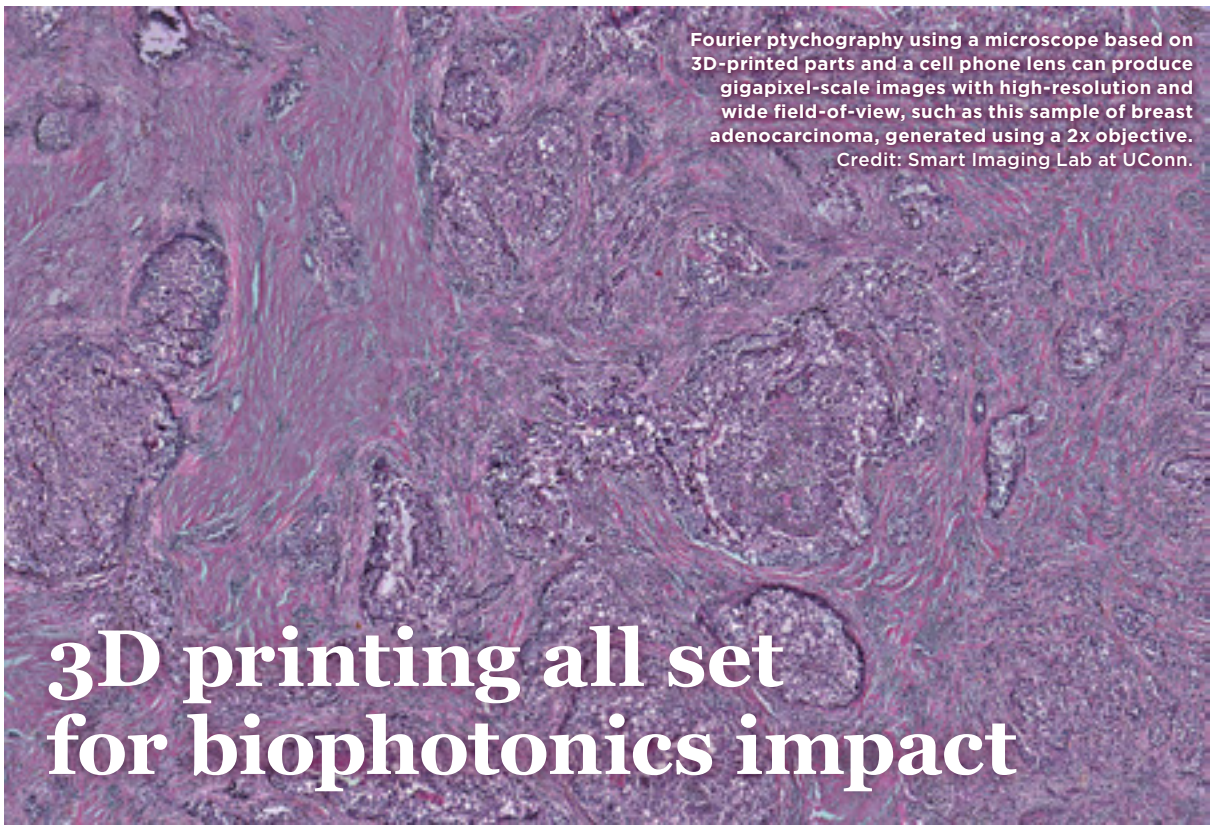

Fourier ptychography using a microscope based on 3D-printed parts and a cell phone lens can produce gigapixel-scale images with high-resolution and wide field-of-view, such as this sample of breast adenocarcinoma, generated using a 2x objective. Credit: Smart Imaging Lab at UConn.

3D printing all set for biophotonics impact

Additive manufacturing continues to make inroads across photonics, as proved by the conference strand dedicated to the topic at Photonics West. Two examples from the program prove the appeal of the technique to researchers chasing new breakthroughs in biophotonics.

Optical phantoms are key supporting players in the development of successful bioimaging technologies. Designed to mimic the optical characteristics of real biological tissues, they are an essential part of any effective testing, calibration or system comparison exercise.

Traditionally, they have comprised basic cubes and cylinders, molded from polymers having intrinsically friendly optical qualities with the judicious addition of materials such as titanium dioxide and carbon black to tailor the scattering and absorption coefficients. But 3D printing is now allowing researchers to be more ambitious, and a number of examples feature in the new Photonics West virtual conference dedicated to 3D printing applications.

"3D printing has the potential to open many doors for phantom fabrication, the most useful being the ability to make arbitrary 3D shapes and to improve the reproducibility of the results," said Gennifer Smith of Stanford University, whose work on the manufacture of bladder tissue phantoms forms part of the virtual conference, addressing their use in optical analysis techniques.

"In my group we are interested in phantoms that mimic not only the optical properties of the tissues, but also the 3D shape of the organs of interest," she commented. "In particular, we have been investigating full 3D bladder phantoms."

The critical quality in any optical phantom is a level of contrast matched to that of the relevant real tissue, but recently the advantages of phantoms able to mimic different types of diseased tissue have also become apparent — another area where the new manufacturing possibilities of 3D printing can assist.

3D organ phantoms

Smith's research group set out to mimic several different stages of bladder cancer. They used 3D printing to create models of the phantoms for subsequent molding operations, as well as small-scale phantoms on which to test new ideas.

Bladder shapes extracted from a CT scan were used to define the profile of the model, which was then produced in ABS plastic (thermoplastic acrylonitrile butadiene styrene) using an off-the-shelf Stratasys machine.

"The main advantages are that the process is repeatable, and that arbitrary shapes can be created," said Smith. "Without 3D printing it would have been very difficult to obtain the organ shape. In this case, new manufacturing techniques enabled some out-of-the-box thinking."

The next logical step is to use similar additive methods to produce the final phantom itself, and some groups are said to be working on doing so. But Smith believes that the technique may not yet be a perfect fit with the particular needs of phantom manufacture, as fine tuning the optical properties of the polymers used remains problematic.

"Most of the polymers I have seen used in 3D printing do not fit the needs of OCT phantoms," Smith noted. "Many phantoms also require a variety of different polymers within a single phantom, so the 3D printers would need to be able to accommodate this."

In addition, a 3D-printed phantom will need to present features small enough to meet the imaging resolution capabilities of OCT. Retinal phantoms, for example, would have to match the 10-micron thickness of some layers in the retina — at present a tall order for an additive system.

Even so, the technique looks set to become a significant option for developers. "I think that the benefits of directly 3D-printing phantoms will compel the discovery of a way to successfully do so," said Smith. "From my experience, I think all roads lead to it."

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3D printing

continued from page 21

Routes to cheaper and more versatile optical microscope platforms are always being sought; and 3D printing is playing its part here too. For example, one group at the University of Connecticut has developed FPscope, a high-resolution Fourier ptychographic (FP) microscope which includes 3D-printed parts in its construction and a cellphone lens in its optical system. Details of the hardware were presented during the new BiOS conference *Optics and Biophotonics in Low-Resource Settings*.

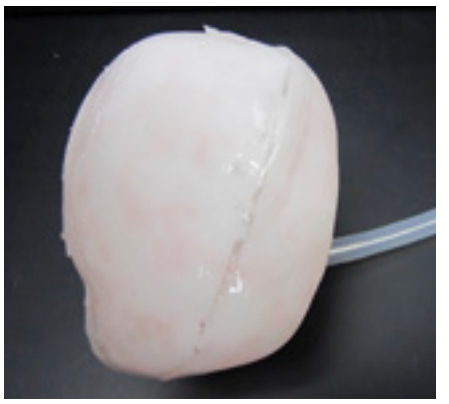
The platform could be a cost-effective solution for field-portable microscopy imaging, including healthcare applications in challenging environments. "FPscope is intended to challenge the design requirements of conventional platforms," said Connecticut's Guoan Zheng. "We aimed to use a low numerical aperture lens for high-resolution imaging, correcting for aberrations in a post-processing operation."

Fourier ptychography uses an LED array to illuminate a sample from different incident angles, stitching the images together in the Fourier domain to recover a high-resolution, large field-of-view picture. Images from a low-resolution 2x magnification objective lens can generate a gigapixel-scale result.

The team opted to use a cellphone lens in its platform, as an example of a utilitarian lens module widely available in various configurations at low cost.

"The limitations of a cell-phone lens are a low numerical aperture and a high number of aberrations, but the FP approach bypasses both aspects," noted Zheng. "The quality of lens is effectively irrelevant in the FPscope design."

Although the application of cellphone lenses in low-cost microscopy is not new, their use alongside the FP algorithm in FPscope could allow an economically attractive route to field-portable imaging



Bladder shapes extracted from a CT scan were used to define the profile of this model, which was then produced in ABS plastic using a Stratasys 3D printer. The "phantom" tissues are needed to assist with the development of new applications of optical coherence tomography. Credit: Gennifer Smith/Standford.

platforms — if the other costs involved, such as manufacture of the system's structural components, can be controlled.

This is where 3D printing steps in. The group used a MakerBot additive manufacturing system to manufacture the plastic case used to house FPscope's LED array, CCD detector and cellphone lens.

"We also designed and 3D-printed a mechanical stage, to move the sample in the XY plane and adjust the focal position," added Zheng. "It was all done with an off-the-shelf 3D printing technique."

As a result, FPscope is portable, lightweight and cost-effective. It should be well-suited to the imaging of tissue slides and blood smears, as well as tackling some familiar global health problems such as malaria diagnosis.

It may also point in a new direction for general microscopy imaging, replacing strict hardware requirements with computational processing, given that the number-crunching abilities of processors escalates regularly for mobile devices.

"In the future, we envision that FPscope can be implemented on a cell phone to perform gigapixel imaging, which will be important for digital pathology," commented Zheng.

TIM HAYES

SPIE updates industry analysis

Bottoms-up process based on real sales and employment data holds a few surprises, writes SPIE's industry and market strategist Stephen G. Anderson.

Making and selling basic photonics components and materials has grown into a healthy global business segment with suppliers located in more than 45 countries, according to SPIE's supply-side profile of the photonics components industry. Small- and medium-sized enterprises (SMEs) account for more than 70 percent of the companies involved. However, the revenue breakout shows a different picture, with a handful of corporations generating the vast majority of global photonics revenues.

Before we drill down further, some context is in order. In the 2012 US National Research Council (NRC) report *Optics and Photonics: Essential Technologies for Our Nation* the state of data collection and analysis of photonics-related R&D spending, employment, and sales in the US was described as "deplorable." The committee of eminent scientists that produced the report noted the lack of data significantly complicates analysis of photonics technology economic impact and opportunity.

In one example of the data collection problem at the government level, the North American Industry Classification System (NAICS) does not include a specific code for photonics companies. Instead, the optics and photonics industry currently uses more than 250 different NAICS codes to describe itself, rendering ineffective the system for tracking the photonics business.

The NRC Report findings came as no surprise to those familiar with the photonics business landscape. For years, SPIE and others have tried to quench the thirst of local business clusters, the investment community, and government entities for information about the photonics industry. "How fast is it growing?" or "How many jobs does it create?" are examples of questions from policy makers that have — more often than not — been left unanswered or vaguely addressed only by "rough estimates."

At SPIE, the NRC report served as a catalyst to launch a project that had been nascent for a couple of years. We believed that by combining the SPIE database on the photonics industry — the largest in the world — with data from Dun & Bradstreet, a commercial provider of company information, we could build a useful profile of the photonics industry using actual company data that would serve to fill some of the information gaps identified by the NRC report. We embarked on a multiyear mission to develop a methodology to create a continuing and updateable profile of the photonics business.

Last year at Photonics West, we unveiled the first results, with a detailed look at the core component suppliers who exhibited here in 2012. This "pilot program" started late in 2012 so was based on that year's data. We counted companies that make and ship photonic components but focused only on a known and manageable data set, showing that the 1008 component manufacturers exhibiting at Photonics West generated global sales of $84 billion and employed 335,000 individuals in 2012.

Building from company information

The lessons we learned from this original pilot program have enabled us to move forward with an expanded data set using similar but refined methodology. Simply put, our process involves five steps:

1) Identify entities that are active in photonics
2) Exclude entities that do not make and ship photonics components
3) Determine sales and employee counts
4) Pro-rate revenue and jobs for each company based on that company's photonics business only
5) Address any anomalous data; compute total sales and jobs by summing all company information

This netted an initial list of 4962 entities. After excluding distributors, publishers, educational establishments, societies and associations (step 2 above) the net result was 2748 companies that made or shipped photonics components *and* exhibited at a major photonics event somewhere in the world in 2012. Companies in the US and Germany account for about half of the total.

The SPIE photonics industry study is exceptional in that it provides a bottoms-up analysis of the photonics components business based on real sales and employment data. Of course there are the inevitable glitches in the data set such as a paucity of information about China and occasional lapses in the D&B numbers. Nonetheless, the study offers a unique lens through which to view and understand the industry landscape — and there are a few surprises!

It may be a statement of the obvious to many readers that the industry consists of mostly SMEs, but it may be less obvious that, in terms of revenues, more than 70 percent of global industry sales originate from only 70 of the 2748 companies (just 2.5 percent). Japan easily tops the revenue list by country, with 48 percent of total worldwide sales, followed by the US and Germany respectively.

This project is only a beginning. Now that we have a process, we are adding data for years since 2012 and will be able to highlight photonics component revenue and employment trends. In a parallel effort, SPIE will map this component manufacturing information into a more detailed study of all photonics-enabled markets worldwide.

Fragmented: more than 1000 component suppliers exhibit at Photonics West, but 70 percent of photonics industry revenues are generated by the 70 leading vendors. Credit: Joey Cobbs/SPIE.

Supercontinuum goes violet

Supercontinuum sources have been commercially available for several years providing high brightness laser output with tremendous spectral broadness eclipsing even that of incandescent lamps. However, the spectral area below 430 nm has been challenging and many offerings in the market have had sub-par stability, lifetime and mode quality. With many applications, such as bio-imaging, material characterization and spectroscopy, moving to shorter wavelengths, the need for stable single-mode sources in the 400nm region has increased and today NKT Photonics - the World's biggest manufacturer of supercontinuum sources - addresses that need.

With the introduction of the new violet SuperK EXTREME EXU series users now have access to diffraction limited laser sources emitting in the entire 400-2400nm wavelength range. The sources are single-mode over the entire output spectrum and features a maintenance-free lifetime of thousands of hours. The new sources can be paired with variable filters, such as the SuperK SELECT or VARIA, to create a tunable laser with a bandwidth covering the visible and near-infrared part of the optical spectrum and due to the filter quality and superior beam quality of the source, output stability is unrivaled in the industry. Both source and filter are controlled by NKT Photonics new unified software suite, CONTROL, making source and filter work as one integrated system.

The new SuperK EXTREME EXU line of supercontinuum sources are available now and is on display at NKT Photonics booth #811.

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CDA offers optical module design, prototyping and high volume assembly. These small integrated packages require often high precision alignment between light source and optics as well as proper packaging material for high reliability and maximum performance.

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CDA additionally provides the integration of microfluidic structures into compact and sensitive devices, (›lab-on-a-chip‹). Such devices

Heads-up display

are becoming increasingly important where chemical, electrical and/or optical properties need to be tested on a small scale. Tried and tested structures and options include:

- channels for separation and mixing
- hydrophobic and hydrophilic surfaces
- combining these with microoptics and printed electronics

Appropriate devices lend themselves well to high levels of parallelization, thus reducing costs, but their manufacture does require a fully integrated process chain and command of several cutting-edge microfabrication technologies.

Manufacturing services

According to Pia Harju, Business Development Manager at CDA, "The opportunities for both microoptical elements and for integrated devices are truly global. Our manufacturing services – design, prototyping, assembly and mass production – are designed to benefit our customers' global strategy."

Contact

Booth: North Hall 4318

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CDA
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Choosing a Digital Low Light Camera for Long Range Applications

The ability to observe and record images and scenery undetected are paramount to the safety of both life and infrastructure. Modern warfare techniques, whether static monitoring or mobile surveillance, rely heavily on information gathered via covert long-range surveillance methods such as hidden cameras. The imaging technology is most effective if the camera can produce high quality long range images in both daylight and nighttime conditions. Today, the need to aggregate and share information requires these long range solutions to be digital.

Detection, Recognition and Identification are critical in long range imaging, and each is dependent on proximity. Identification with high probability is a short-range function, as it needs a great level of detail and a high quality image to clearly determine if there is a threat and what it may be. Identification is most difficult under low-light conditions due to poor signal-to-noise ratio and most digital surveillance cameras use supplemental technologies to enhance low light imagery.

The two technologies most often used to supplement CMOS or CCD low light digital imaging are thermal imaging and NIR illumination. Thermal is good for detection and recognition as it relies on differences in adjacent heat signatures. However, thermal technologies do not showcase identifying details, such as cultural signage or facial features, even at short range.

NIR illumination is often used in static surveillance to augment CCD daytime imagery. This is ideal for short range imaging, but the power required to illuminate at long distances is impractical for mobile applications. It can also expose a location to danger, as any reconnaissance with NIR sensitivity can clearly identify a target.

CMOS technology has emerged as a stand-alone digital low light imaging solution. The solid state sensor is impervious to bright light damage, yet can provide superior, high resolution and low noise images from full daylight well into starlight conditions. CMOS sensors can provide high resolution and high speed imaging, without supplemental technology and without cooling.

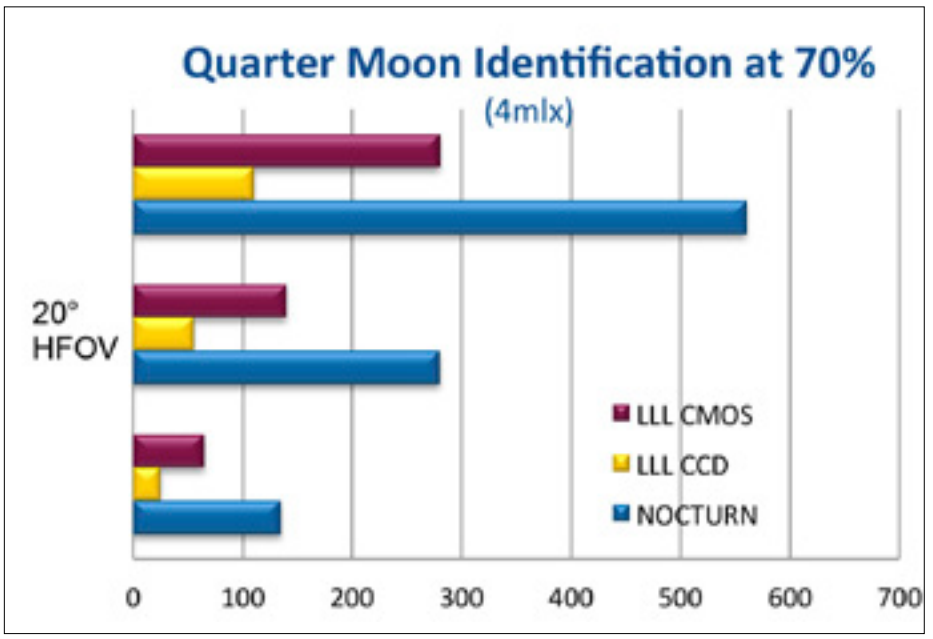

Figure 1: Nocturn camera provides significantly longer identification under quarter moon lighting conditions than competitive digital technologies and without supplemental technologies.

PHOTONIS is a global leader in low light technologies. Our expertise in night vision optics has made it possible to create a superior family of low light cameras that provide SXGA resolution (1280x1024) with large 9.7 micron pixels for efficient light collection. The Nocturn family of low-light cameras offer <4e-rms at the full 100Hz, and supports common video frame rates. Nocturn is offered in a wide range of standard connectivity options, and some models can be ordered in color for added certainty of identification in low light conditions.

See for yourself at our live demo at Booth #4314.

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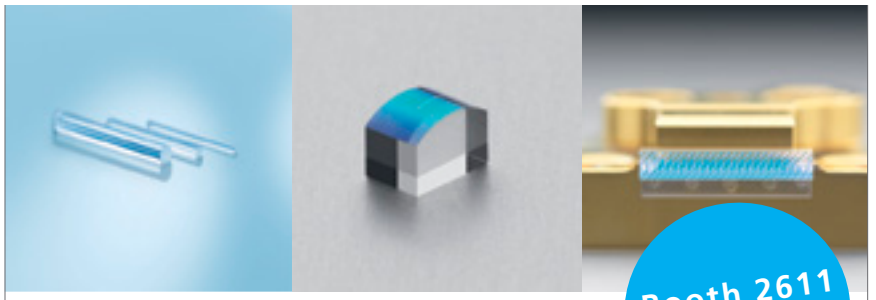

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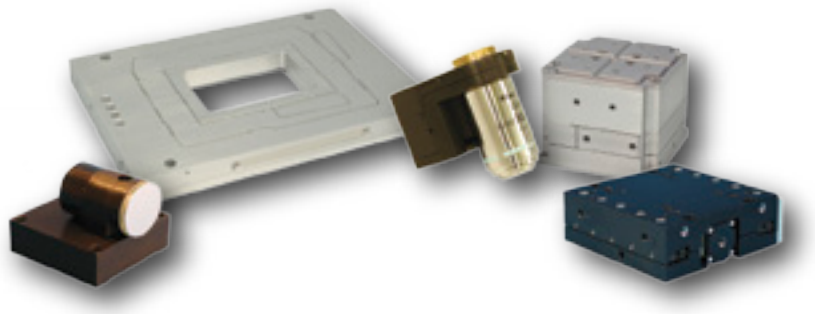

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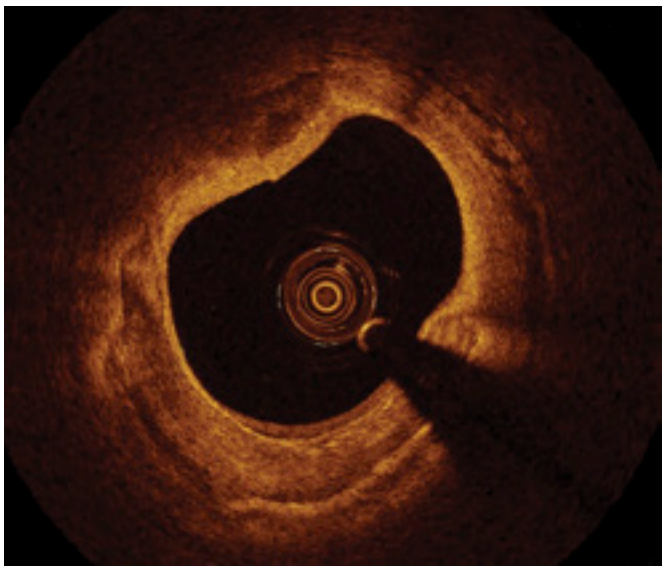
Ultra-mobile OCT breaks new frontiers

Developers continue to push OCT into novel application areas and enhance the technology, especially though the design of smaller components and platforms.

Optical coherence tomography (OCT) has more than a decade of real-world commercialization behind it, but bold new strides in the field continue to be made — many of which are under discussion this week at Photonics West.

"It's currently an exciting sector, for sure," commented Milos Todorovic, bioelectronics analyst at the consultancy firm Lux Research. "The commercial market for OCT in ophthalmology remains solid, and the technique is now advancing into other market spaces, as developers work on achieving deeper penetration depths, 3D imaging and other enhancements."



The view inside a calcified, hardened blood vessel generated by optical coherence tomography using equipment developed by medical device giant St Jude Medical. Credit: St Jude Medical.

Among the most promising applications is the use of OCT to identify and diagnose cancers, either on the skin or in the gastrointestinal (GI) tract, along with uses in cardiology. But exactly how fast it penetrates these sectors will depend on several factors.

"It always hinges on proving the utility of the technique," Todorovic said. "There can be natural resistance to techniques which are unproven in particular areas, as has historically been the case with new imaging modalities. Plus new techniques tend to be relatively expensive."

Among the developers making strong progress is NinePoint Medical, which Todorovic noted is working on OCT's potential for real-time *in vivo* biopsies, especially within the GI tract. Others are Bioptigen, examining ways to diagnose some of the neurological diseases of the eye; and Michelson Diagnostics, whose system can be used to aid skin cancer diagnosis.

Some developers are also studying potential applications in the consumer space: cosmetics developers could benefit from OCT analysis of skin chemistry, for example.

"Work is under way on both the systems and technology aspects, especially on efforts to miniaturize the platforms," said Todorovic. "Solid-state devices are likely to be a significant step in this direction, potentially enabling a reduction in the size of OCT devices by at least one order of magnitude."

But challenges remain, among them the need for robust light sources able to meet the requirements of these fresh applications. And economics is inevitably a factor; developers naturally hope to make a profit from procedures which clinicians can implement and patients can pay for. Incorporating any technology's new applications into the relevant medical reimbursement system is always a potential hurdle.

"The biggest issue is how to effectively make money; who pays for it, and how much," Todorovic commented. "Developers and vendors will need to consider how best to put appropriate reimbursement codes in place, in order to start selling into a market that can actually afford the technology. At present, different developers have taken different approaches. Some have tagged onto existing reimbursement codes for ultrasound imaging, as a fundamentally similar procedure. But that's not a viable long-term model."

A clearer view of the target markets and their requirements will also help, and ultimately make them more appealing to the larger developers.

"A sure sign will be when the really big players get involved, as they have done in the ophthalmology space," said Todorovic. "When that happens in these new OCT segments, it will indicate the true maturity of both the technology and of its applications."

Compact endoscopy

Xingde Li of Johns Hopkins University, program committee member and a technical session chair for the *OCT and Coherence Domain Optical Methods in Biomedicine* conference this week, expects compact OCT platforms such as the one developed by his group to prove their worth in translational clinical use. They should be especially valuable for deploying OCT in tightly confined operational spaces, such as the ones encountered in endoscopy suites.

In Li's view, the key development has been enhancing the resolution available from a compact platform, an achievement which in turn has hinged on three related breakthroughs.

> "Clinicians and other potential users were extremely excited about the performance of this compact platform."
>
> OCT RESEARCHER XINGDE LI FROM JOHNS HOPKINS UNIVERSITY.

"First of these is our development of a compact broadband light source and its optimal operation conditions," he commented. "The second is the ultra-high resolution endoscope, able to accommodate the broad spectrum bandwidth. And the

continued on page 28

Ultra mobile OCT continued from page 27

third is the compact spectrometer system capable of acquiring the OCT imaging data. These are the key improvements relative to conventional platforms employing femtosecond lasers, bulky scanning endoscopes or large imaging spectrometers."

The most significant challenge along the way proved to be the scanning fiber-optic endoscope; it needed to be compact, flexible, low-cost, and only one millimeter in diameter, while still matching the resolution achieved by bench-top microscope-based systems. Another stiff requirement was achieving comparable imaging performance and signal-to-noise ratio from a compact supercontinuum light source as that available using a conventional femtosecond laser.

> "Ours is a novel system architecture which takes advantage of the benefits provided by integrated optics."
>
> MEDLUMICS' CTO JOSE LUIS RUBIO.

Li's future work will focus on two main topics. One is to improve the imaging speed of his compact OCT platform, which at present is not optimal; another will be addressing the relatively high cost of the light source. But in the meantime the system has already won the approval of potential end-users.

"We have not conducted any clinical studies with the system yet, but pre-clinical imaging studies have shown tremendous promise," noted Li. "Clinicians and other potential users were extremely excited about the performance of this compact platform."

Silicon photonics brings clinical advantages

In the commercial arena, one developer making significant strides towards a miniaturized OCT platform is Spain's MedLumics, whose latest system incorporates silicon photonics.

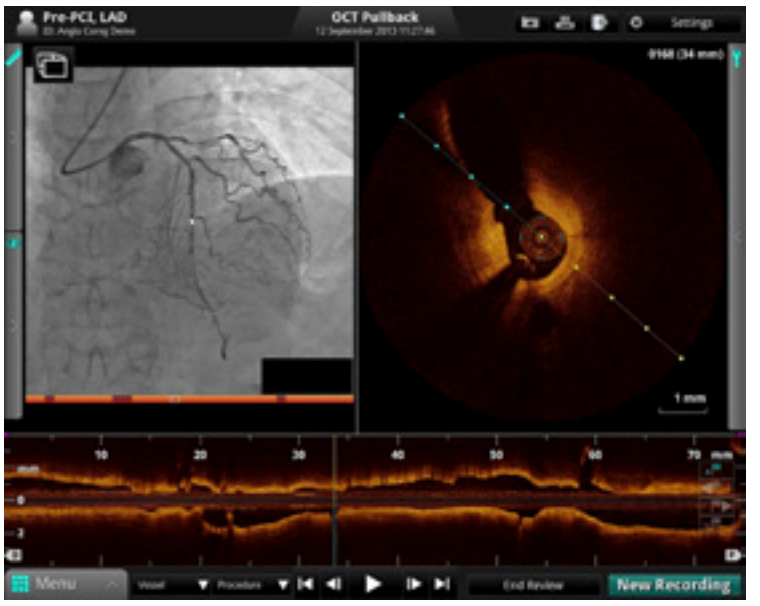
"To a great extent, the failure of the technique to match market needs can be attributed to the complexity of the required equipment," noted Jose Luis Rubio from the company, whose "ultra-mobile" technology is the subject of two presentations this week. "Bulky and costly systems translate into a limited cost-benefit relationship for the clinician, and for some applications like dermatology provide poor integration into the clinical workflow," said the CTO.

The MedLumics system relies on a fully-integrated photonic axial scanner, implemented in a 20 mm^2 silicon photonic integrated circuit. Although silicon photonics has been applied in OCT imaging before, the platform developed by MedLumics employs a novel approach.

"Previous implementations have been based on direct translation of standard spectral-domain or swept-source bulk-optics systems," noted Rubio. "Ours is a novel system architecture which takes advantage of the benefits provided by integrated optics, and which would be quite impractical to implement with bulk optics."

Use of a miniaturized OCT engine required novel engineering developments elsewhere in the platform, with many of the sub-systems such as the scanning module and control electronics being custom-designed in order to avoid compromising the system's overall compactness.

The most significant challenge was finding a means to keep optical losses under control, thus countering one of the factors that has hindered the application of silicon photonics to a technique as loss-sensitive as OCT. MedLumics claims that it has achieved the highest signal-to-noise reported so far for an OCT system making use of integrated optics, with excess losses around 20 dB lower than the previous benchmark set by an integrated silicon oxynitride design.



St Jude Medical equipment showing views of damaged coronary arteries provided by a conventional angiogram imaging (in monochrome) and optical coherence tomography (colored). Credit: St Jude Medical.

"Our platform has leveraged on the developments that integrated photonics, and especially silicon photonics, has undergone during the last decade driven by the telecommunications industry," Rubio commented. "Our path would have been longer if suitable foundries were not now available, with a level of performance and industrialization compatible with our needs."

The company's first clinical OCT system is currently pending CE-mark approval for sale in Europe, with the commercialization process set to then commence later in 2015; but positive feedback from selected European dermatology specialists has already confirmed the appeal of compact and portable OCT systems, according to Rubio. And silicon photonics offers further avenues of research to explore.

"We have a number of ways in mind to further exploit the possibilities and benefits of the silicon photonics platform, which will translate into higher performance and further reduction of the fabrication cost," he said. "These will be incorporated into the next generation of our dermatological imaging system, and also into novel products intended for other clinical areas like cardiology, where we have identified clinical indications with high potential."

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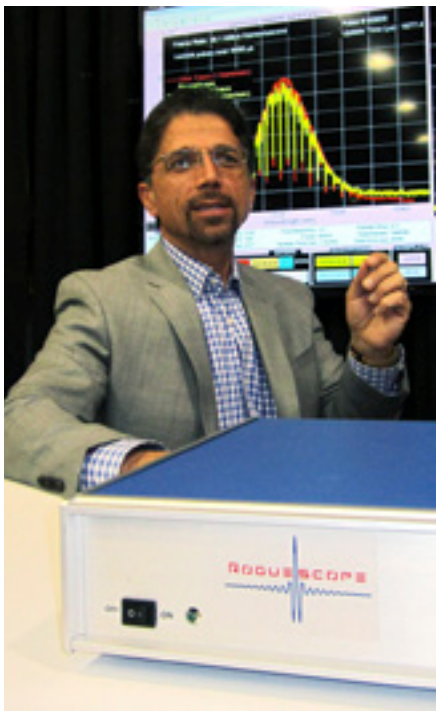


UCLA's Bahram Jalali and his "RogueScope." Credit: Ford Burkhart.

Fast-action "RogueScope" sees combustion dynamics

A super-fast spectrometer working at a million frames per second — "an unheard-of speed in spectroscopy," its inventor says — can almost write an encyclopedia about spectral behavior in one chemical reaction lasting a fraction of a second. In short, it's the world's fastest spectral camera.

The device, called the RogueScope, is the fruit of 20 years of research, most of it funded by DARPA and the National Science Foundation, by Bahram Jalali at his UCLA photonics lab. "It's like a slow motion crash camera, but working at the speed of light," he said.

The single-shot optical spectrometer is said to have applications in metrology and sensing, and also medicine.

The typical optical spectrum analyzer is good but has one key drawback, Jalali said: "It is quite slow." The limiting factor is the rotation of the grating, which he said is "inadequate for the study of transient events and the dynamics of lasers and fast chemical reactions." One example would be optimizing a combustion engine by studying rapid gas-phase chemical reactions.

A key element in the RogueScope is the time-stretch process, which maps and analyzes the spectrum in a flash.

It turns the split-second pulse into a detailed map, to capture and analyze large data sets needed to find anomalies and rare but significant events. "We know of no other system today that can show you this information," Jalali said.

FORD BURKHART

Quantel adds UV wavelengths

High-power solid-state laser specialist Quantel Laser has released new versions of its sources that feature additional wavelengths in the ultraviolet region.

First introduced in 2010, the Bozeman, Montana, company's "Big Sky Laser" product line for particle image velocimetry (PIV) applications now features a frequency-doubled 266nm output in addition to the standard PIV wavelength of 532nm. That should aid precise measurements of velocity and density fields for certain combustion experiments that are currently difficult to measure accurately, says the firm.

PIV works by taking two images very close together in time and calculating flow by observing particle movement within the velocity field, typically performed with pulsed nanosecond 532 nm lasers. "However, researchers are looking at different, more subtle effects that are best imaged via UV excitation since organic molecules in the flow have broad absorption around 266 nm and emit in the visible, allowing the use of standard PIV cameras," Quantel explains.

Product line manager Thomas Kraft said that the additional 266nm wavelength can be accessed with simple command hardware, allowing users to switch between the two lines easily.

Quantel has also added a new 193nm laser at its laser damage test facility in Bozeman. The excimer source will allow customers to verify the integrity of critical optics and coatings for deep-ultraviolet applications like semiconductor photolithography, ablation for mass spectrometry and LASIK eye surgery.

"As applications utilizing 193nm lasers expand, the importance of ensuring the reliability of the optical components is critical," says the firm. "This is especially true at 193nm, a wavelength that can rapidly damage optics."

General manager Jason Yager said: "Our customers asked us to add 193nm test capability for several reasons. First, it is a wavelength that is just tough on optics and when one damages, there is always a question as to why. Second, we know through years of experience that when we begin testing and providing that data back to our customers, their coating designs continue to improve, really helping the entire industry."

Quantel CEO Mark Enright added: "As a laser designer earlier in my career, I was a customer and saw the value that good data brings. I'm pleased that we are able to support the industry by adding this key capability."

Quantel is at booth 1907.

MIKE HATCHER

Multispectral imaging tracks AIDS treatment

Changes in Kaposi's sarcoma, the red patches of skin that appear on the cheeks of AIDS sufferers, have long depended on subjective assessments by physicians. Now a team at the US National Institute of Child Health and Human Development is using optical technology to analyze them, as a way to quantify treatment success.

Amir Gandjbakhche, chief of the institute's analytical and functional biophotonics division, says multispectral imaging can predict treatment efficacy outcomes in a few weeks, rather than waiting for as long as nine months to learn the costly treatment's effects.

"That will let them know whether a therapy is working and should be continued," he said at a new clinical applications conference.

Since treatment side effects, often for up to six months, can be harsh, and sometimes even fatal, that early quantified information offers "better prediction of outcomes during treatment that could help save treatment costs and lives."

The team uses multispectral imaging to relate observed changes in the blood concentration at the sarcoma site on the cheek to help predict treatment outcomes.

The same techniques can be applied to the AIDS-related Cushing syndrome. Gandjbakhche's approach can determine early on whether the surgery appears to have been successful.

Using a CCD camera, they can quantify levels of blood that indicate treatment efficacy. "If they took out the tumor, this lets them see if it has worked," he said. If the redness remains, that may indicate that the surgery was unsuccessful.

The team uses principal component analysis to interpret the data in a few seconds, rather than 40 minutes.

FORD BURKHART

Liquid lens targets microscopy

The new target area for liquid lens maker Varioptic is microscopy. The company is using its standard "droplet of oil in water" as a variable-focus lens to focus through biological samples.

Its Photonics West booth drew visitors to twist the knobs and vary the focus point to near or far layers of samples, simply by changing the voltage applied to the liquid lens. "The key is, you can scan through a sample without any moving parts," said Varioptic's Olivier Jacques-Sermet.

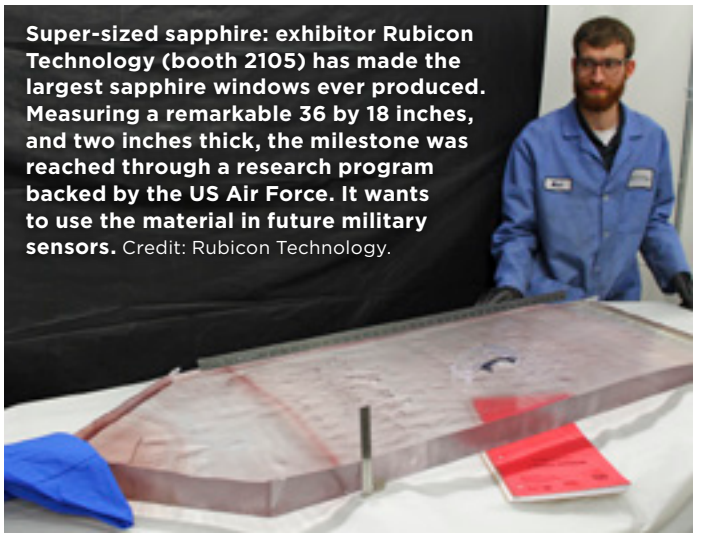
Another demo showed how to view images of the skin in a self-administered test at home, and send the images to a dermatologist showing how a skin treatment is progressing.

"We are just using the standard products in a novel way, opening new applications," Jacques-Sermet said. Later this year Varioptic, which has previously aimed the technology at consumer electronics applications, will bring to market a new lens especially for microscopy.

The technology relies on electrowetting, where voltage shifts change the shape of the interface between oil and water. The system has an autofocus feature that chooses the sharpest picture for display and readjusts automatically.

Varioptic says the lack of friction in moving parts means it can run through hundreds of millions of cycles, using only 1 mW of power.

FORD BURKHART



Super-sized sapphire: exhibitor Rubicon Technology (booth 2105) has made the largest sapphire windows ever produced. Measuring a remarkable 36 by 18 inches, and two inches thick, the milestone was reached through a research program backed by the US Air Force. It wants to use the material in future military sensors. Credit: Rubicon Technology.

Intel sees 2015 as "transitional year" for silicon photonics commercialization

After decades in the lab, silicon photonics is finally moving into the fab, where it is poised to push next-generation photonics technologies into mass markets, notably telecom/datacom, high-performance computing, and even consumer electronics in the not-too-distant future.

That prediction was heard repeatedly Tuesday during a series of presentations at Photonics West on the burgeoning market for silicon photonics — a market projected to grow from $50 million in 2017 to over $700 million by 2024, according to a July 2014 report from Yole Développement.

"All of this is being driven by mobile data connectivity and the need for higher bandwidth, which puts constraints on copper," said Mario Paniccia, director of the photonics technology lab at Intel. During his keynote address, "Silicon Photonics for a New Era of Scalable Bandwidth," Paniccia said the innovation in silicon photonics is "bringing photonics out into the mass market, and I believe 2015 will be the transitional year."

What is driving this surge in commercialization efforts? More mobile connectivity means greater need to more efficiently and effectively move data to and from the cloud. And by "the cloud," we really mean data centers — mega data centers, according to Paniccia, some a million square feet or more.

Panelists, left to right, Philippe Absil, IMEC; Peter De Dobbelaere, Luxtera; Douglas Gill, IBM; Ruth Houbertz, Multiphoton Optics; Ashok Krishnamoorthy, Oracle. Credit: Doug Cody

"Every day, we create 2.5 quintillion bytes of data," Paniccia said. "For every 400 smartphone devices, there is a server that has to be put somewhere to take that data up to the cloud and manage it. For every 100 wearable devices, we need one server. And for every 20 digital signs, there is a server."

The I/O bottleneck

There are limits, though, to how well current computing technologies can support these rapidly growing data demands, especially in terms of energy efficiency, bandwidth, and transmission speeds. Since first introduced in the 1990s, copper interconnects have become the industry standard, enabling smaller, faster microprocessors and breakthroughs in multicore-processor integration, e-DRAM, copper on-chip wiring, silicon-on-insulator technology, and high-speed silicon germanium chips. But as data rates exceed 10 Gbps for chip-to-chip, chip-to-module, rack-to-rack, and system-to-system interfaces, copper is reaching the limits of Moore's Law.

This is what makes silicon photonics, high-density photonic integrated circuits fabricated using existing CMOS process technology in a CMOS fab, so attractive. Silicon photonics devices overcome the limitations of electronic data transfers over copper by integrating photonic and electronic components — including transistors, waveguides, couplers, modulators, photodetectors, and CMOS circuits — on a silicon-based platform. The result is low-cost optical components with nearly infinite optical bandwidth, reduced power consumption, more embedded functionalities, higher density, and better reliability and scalability.

"Silicon photonics allows data rate scalability and reduces the cost of reliability," said Peter De Dobbelaere, vice president of packaging and reliability at Luxtera, which introduced its first silicon CMOS photonics products in 2008.

"Silicon photonics leverages the automated manufacturing infrastructure from the IC industry, including wafer-level processing, wafer-level test, and wafer-level assembly," he said. "And silicon photonics has already proven greater than 1 billion field operating hours (in data centers) without failure."

For today's data centers, the ability to efficiently increase bandwidth and data transfer speeds is critical. Current PCI-E data cables carry data at up to 8 Gbps, while networking cables reach 40 Gbps. In contrast, current silicon photonics-based channels can transmit data at 100 Gbps, typically four lanes transmitting 25 Gbps each. But bandwidth needs are expected to equal or surpass 1Tbps by 2018.

"A platform that can combine high-quality passive and active components in one single integration flow will power the adoption of silicon photonics circuits," said Philippe Absil, director of the 3D and optical I/O technologies department at IMEC in Belgium.

With such a platform, integrated photonics circuits can be made with single-channel data rates up to 25 Gbps and easily scaled up to 50 Gbps and even higher, Absil noted. And scalability is key.

"The market is just starting to grow, but the irony is even just nine months ago many people didn't believe 100 Gbps was possible," Paniccia said. "Today customers are already asking for 400 Gbps. They are already saying 100 Gbps is not enough."

Mario Paniccia, Intel. Credit: Doug Cody

> "I believe 2015 will be the transitional year."
>
> MARIO PANICCIA

Fabrication and packaging

Although the industry sees the data center market as critical to broad-scale adoption because it will enable volume manufacturing, other potential applications include environmental sensing and wearable medical monitoring devices.

"It's all about the wafer starts," said Doug Gill, a researcher at IBM T.J. Watson Research Center. "We are on the cusp of a revolution enabling personal well-being and environmental sensing, but from our perspective now, silicon photonics needs a wafer start application to drive adoption."

IBM, which unveiled its CMOS integrated silicon nanophotonics technology in 2010, has spent the last decade working to design its packaging to transfer the technology to a production environment.

By adding a few processing modules into a 90-nm CMOS fabrication line, a variety of silicon nanophotonics components such as wavelength division multiplexers, modulators, and detectors can be integrated side-by-side with CMOS electrical circuitry, according to Yuri Vlasov, who manages the silicon nanophotonics project at IBM. As a result, IBM's 25Gbps/channel single-chip optical communications transceivers can be cost-effectively manufactured in a conventional semiconductor foundry.

"The idea is to ride on top of billions of dollars of investment in microelectronic technology," Vlasov said in an interview prior to Photonics West. "It doesn't require any new capital to build this line, and we are using exactly the same tools we use for building the processors."

Packaging design is critical to enabling silicon photonics to be fabricated using existing microelectronics equipment. Unlike CMOS, where the design can be done separately and the package can be chosen after the fact, packaging design with silicon photonics must be considered up front. "Otherwise the integration doesn't pay off," Vlasov said.

Like IBM, IMEC is developing and fine-tuning its silicon photonics offering. IMEC's platform enables the implementation of a complete WDM architecture and the fabrication of integrated photonic circuits for telecom and datacom with single-channel data rates up to 25Gbps.

IMEC is now making this technology available to US manufacturers through a partnership with MOSIS, which has more than 30 years experience in providing multi-project wafers (MPWs) — which enable customers to share the cost of allocations rather than paying for an entire wafer to be processed — and related services for integrated circuit manufacturing.

On Tuesday the companies hosted a workshop that provided a detailed overview of IMEC's platform and how the MPW model can be used to design silicon photonic prototypes and products from a fabless perspective.

KATHY KINCADE

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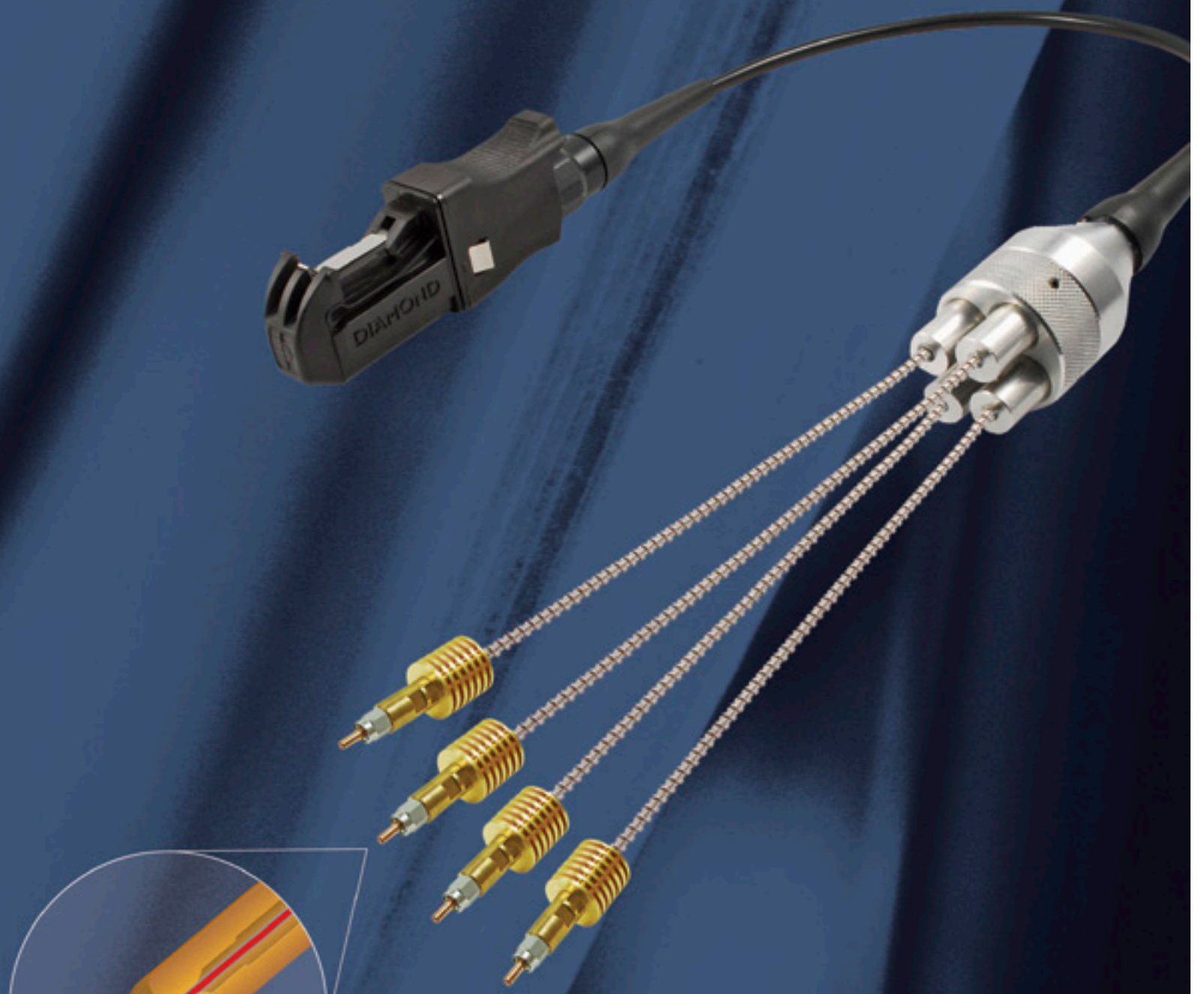

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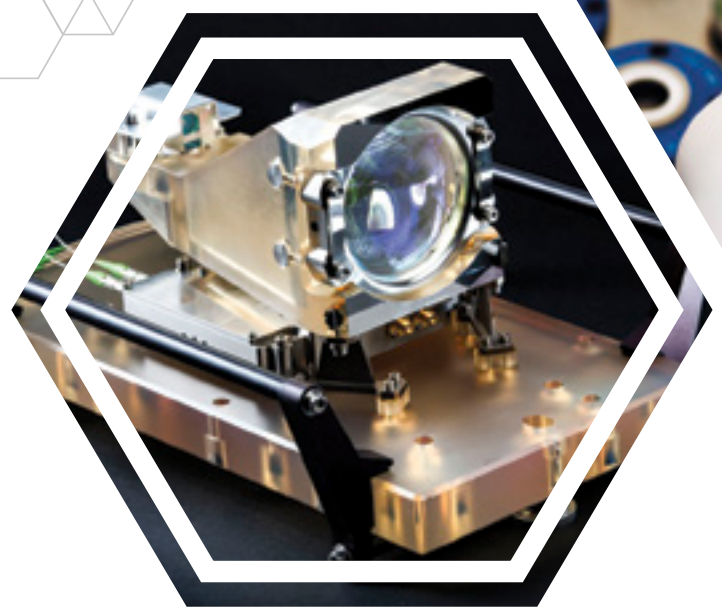

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