THURSDAY EDITION

SPIE. | optics.org | THURSDAY, FEBRUARY 7, 2019

PHOTONICS WEST. SHOW DAILY

Brit Berry-Pusey walks away with it
Avenda Health wins Startup Challenge
Photo: George Nikitin

Prism Awards celebrate the best of photonics

The world's first cloud AI-based handheld Raman spectrometer; a system that derives accurate 3D measurements from 2D images; a handheld defect gauge that sizes manufactured parts as easily as taking a picture on a phone; and the first frequency-modulated continuous CW lidar for smart vehicles. These were just some of the technologies that are today the proud bearers of 2019 Prism Awards.

The eleventh annual Prism Awards took place last night at a gala event at San Francisco's Marriott Marquis Hotel.

Never before has the Prism Awards recognized such a broad range of innovation from so many different companies from so many countries around the world.

The 2019 finalists, from small companies to large, are advancing technologies in the areas of healthcare, security, transportation, manufacturing, scientific discovery, research, and more.

Winners, categories

CloudMinds' XI AI Raman Spectrometer (Detectors & Sensors category) is the world's first cloud AI-based handheld Raman spectrometer with 785nm laser excitation.

Double Helix Optics' SPINDLE (Diagnostics & Therapeutics) provides unparalleled precision 3D imaging and tracking, breaking through limitations in visibility to allow unprecedented study of inter- and intra-cellular interactions.

Leica's BLK3D (Imaging & Cameras) looks like a smartphone, but under the hood, it is a 3D measurement and documentation machine designed to deliver accurate 3D measurements derived from 2D images.

Winners all. Wilhelm Kaenders, Toptica; Scott Keeney, nLIGHT; Alexandra Yang, CloudMinds.

nLIGHT's Corona (Industrial Lasers) is a fiber laser with rapidly tunable beam quality. The Corona provides optimum beam characteristics for an unprecedented variety of processes and materials, addressing a key limitation of conventional fixed-beam lasers.

Smart Vision Lights' NanoDrive (Light Sources) is an embedded technology that allows tens of amps to reach the LEDs of a light in 500 ns or less, resulting in a light that reaches its full LED power/light intensity when strobing.

Modular Photonics' OMPlex (Optics & Optomechanics) devices are based on passive silica chips that increase data transmission rates and reach in optical fiber networks. The chip multiplexes a data signal into one mode in highly multimode fiber.

Toptica Photonics' DLC TOPO (Scientific Lasers) builds on years of company innovation to deliver wide tunability, narrow linewidth output, and hands-free digital control over the 1.45µm to 4.00µm spectral range.

4D Technology's 4D InSpec XL (Test & Measurement) is a handheld, non-contact part defect gauge that measures manufactured parts as easily as taking a picture on a phone. The device makes instant, qualifying, 3D measurements of surface features on manufactured parts being evaluated.

Blackmore Automotive's Doppler Lidar System (Transportation) is the world's first frequency-modulated CW lidar for autonomous vehicles. It gathers instantaneous velocity and long-range measurements of every detected point.

QD Laser's Retissa Display (Vision Technology) is a retinal projection laser eyewear—an optical see-through, head-mounted display device using a miniature laser projector to draw images directly to the wearer's retina.

MATTHEW PEACH

DON'T MISS THESE EVENTS TODAY.

INDUSTRY EVENTS

KEY LEGAL ISSUES: HAVE YOUR QUESTIONS ANSWERED, SIGN UP FOR A FREE SESSION
8 AM-12 PM, So. Exhibit Level

PHOTONICS INDUSTRY AND PUBLIC POLICY UPDATE
9:15-9:45 AM, Rm. 21, No. Exhibit Level

PHOTONICS WEST EXHIBITION
10 AM-4 PM, North and South Halls

STARTUP ALLEY
11 AM-12:30 PM, Hall E, Demo Area

For the full schedule, see the technical program and exhibition guide or download the SPIE Conferences app. Some events require registration. Read daily news reports from Photonics West online: spie.org/PWnews

Soft LED implants
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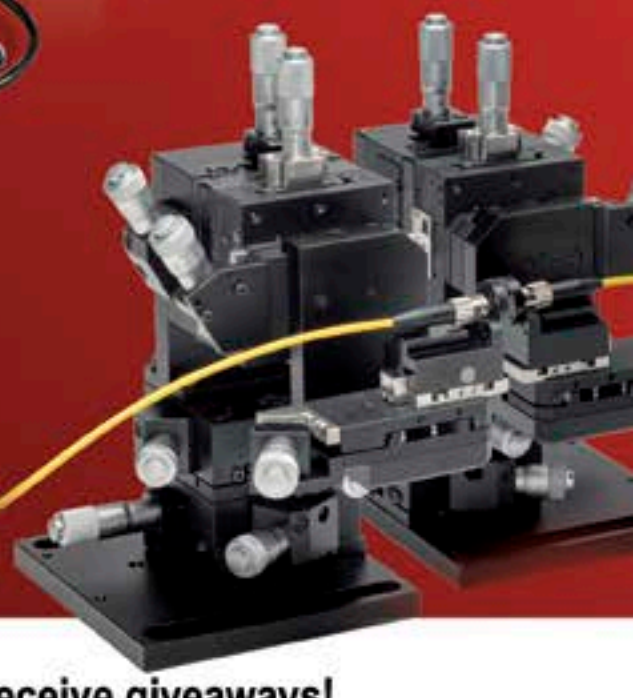

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Booth #1427

Future shapes emerging from the quantum fog

A leading expert in quantum technology markets is more cautious than most futurologists, but says there's still "plenty to dream about," especially when he considers telecom, atomic clocks, and R&D possibilities. "Further down the road, there will be yet more apps for finance and banking, online gaming, security, and defense," he predicts.

Thierry Robin, a partner at TEMATYS in France, serving companies like Coherent, Nikon, Siemens, Thales, and others in 18 countries, has reviewed current and potential quantum apps and markets.

"Other studies for quantum technology foresee billions of dollars in the near future. We are more cautious than most.

Toptica Photonics' Jürgen Stuhler stands beside the DLC MDL pro, which powers quantum computing and optical clocks. By contrast he is holding a 1940s mechanical calculator. Photo: Matthew Peach

There will not be many full commercial apps in the next 10 years, Robin told Tuesday's Industry Events audience.

Huge funding is moving the sector, in North America, Europe, and especially China. He pointed to the 65 quantum startups in the field, including PsiQ, which recently raised $65 million.

Main market areas are sensing, imaging, measurement, and communications.

Notable startups where sensors make use of atomic vapors include Twinleaf and QuSpin, Robin said.

For atomic clocks, the SWAP (size, weight, and power) is a challenge. "To have good sensitivity, you need a big SWAP. At the cheaper scale, sensitivity is not good, about the same as a quartz clocks. There's no big advantage," Robin said.

Atomic clocks now range from as low as $1,000 to the big ones at $1 million. That will form the first truly "huge market for quantum technology … the only one that will be really commercial."

For encrypted communications, cryptographic key management and sharing between remote parties is another challenge.

"How do you distribute the key?" he asked. Teams of human couriers can be employed to do key exchanges, using tamper-resistant hardware security modules, or HSM boxes, that can cost up to $80,000 each. Currently, quantum devices are used in time measurement and synchronization systems, for example with GPS networks.

In five years, there will be advances in measurement for integrated circuits, for currents in batteries, and for magnetometers, gravimeters, and R&D testbeds.

Robin's full study of markets, "Nanoscale Quantum Optics," will be available by late March on the website of the funding agency, the European Commission.

FORD BURKHART

CHALLENGES FACING SILICON PHOTONICS TECHNOLOGY

On Tuesday, industry experts gathered to discuss progress and challenges in silicon photonics design and fabrication. The technology, which integrates infrared laser sources with conventional electronics on silicon chips, accelerates data transmission to promise higher Internet speeds. Data centers, for example, use these chips. The chips could also serve a pivotal role in emerging technologies such as lidar in self-driving cars, for example, and as quantum computing components.

However, technical challenges remain, as speakers pointed out at the panel. "In particular, no one has figured out how to integrate a laser source onto the chip in a commercially viable way," said Philippe Absil of Belgium-based IMEC.

His company sells photonics transceivers that enable data rates of 50 gigabytes per second and beyond. It's difficult to engineer a laser based on silicon, so companies have largely used other materials, such as III-V semiconductors, to make a laser. But this introduces a host of other problems, such as how to bond the different materials together while maintaining cheap manufacturing costs.

That's why some companies are pursuing alternatives to silicon, such as indium phosphide-based photonics. Gloria Hoefler of Infinera, based in California, talked about her company's indium phosphide-based photonics, where they have been able to integrate passive and active components onto one chip. "Indium phosphide really provides a lot of value in closing high-capacity optical links," she said.

The industry is grappling with manufacturing efficiency. Luxtera has been able to automate much of their manufacturing processes, said Drew Guckenberger, who works at the company. After they started a new manufacturing facility in China, they were able to match its production in their other plants in just two weeks because the processes were so automated, he said.

In addition, the industry needs to outfit chip-making machines with a new capability to fabricate photonics designs, which are generally less orderly than electronics ones. Global Foundries is incorporating free-form design capabilities in which optical designers can draw arcs and circles that are crucial to photonics, said Steve Palmer, who works for the company.

Companies are also experimenting with different manufacturing models. Infinera uses a vertical integration model in which they design and fabricate everything in-house, including all hardware and software needed for their product. In contrast, Luxtera uses a fabless model, in which the company designs chips in-house but outsources the actual fabrication.

Speakers also pointed out that while many companies are pursuing monolithic integration—getting all the components on one chip—chip design is extremely application-specific.

Other speakers included Doug Gill of IBM and Ashok V. Krishnamoorthy of Axalume Inc.

SOPHIA CHEN

In uncertain times, 'keep your fingers crossed,' say CEOs

Four-executive panel counsels industry on how to prepare for China "softening" and tariff woes.

No strangers to stress, four top photonics executives told an Executive Panel how they are preparing for whatever 2019 throws at them.

Debbie Gustafson, CEO of Energetiq Technology, now owned by Hamamatsu, said she works with SEMI, a group that lobbies in Washington for settling trade issues with China. But how to really prepare? "You stay on top of things, you prepare for growth, but act quickly as needed.

"And we are keeping our fingers crossed," she said with a laugh.

Other panelists were Yves LeMaitre, chief strategy officer of Lumentum; Eric Mottay, president and CEO of Amplitude Systèmes in France; and Andreas Nitze, CEO of Berliner Glas Group in Germany.

"As CEO, a lot of my time is making sure people are feeling good, feeling like they are making a difference in the company. That great guy who's developing everything – is he still happy?"

Others echoed that principle. Said LeMaitre: "Keep the really smart people at your company and not going somewhere else. Then you can be the disruptive one."

What's the top issue you are facing?

Mottay replied: "Stay on top of innovation in photonics. We (Amplitude) are a very diversified company. I respect that and stay mindful of all the markets we serve, and stay ahead of the curve.

"In five minutes, I may be crying. It's not looking too good with the trade war with China." What will happen in 2019? "I don't know. I need to embrace uncertainty." To laughter, he said: "I will give you my prediction at next year's Executive Panel."

On the China issue, LeMaitre said: "China should be 30 to 40 percent of total consumption of photonics. You can't ignore what is going to happen there. We are very worried for the near future."

Asked for his key current issue, Nitze replied: "Cash. Make sure you have enough cash in the bank. Second, is strategy: everything we do is in line with the market and the desires of our customers. Third, keep a diversified customer base."

Which market segments offer the most potential for growth in 2019?

Said LeMaitre: "Security, safety, computer space, and gaming. And augmented reality is a big area for growth. There is a sudden need for more information, and for high bandwidth. Those are the top two."

"As sensors get more complex, and laptops get more involved, testing is more involved, So they will be spending more money on that side of equation. Sensors are everywhere. We see great potential in that sector."

FORD BURKHART

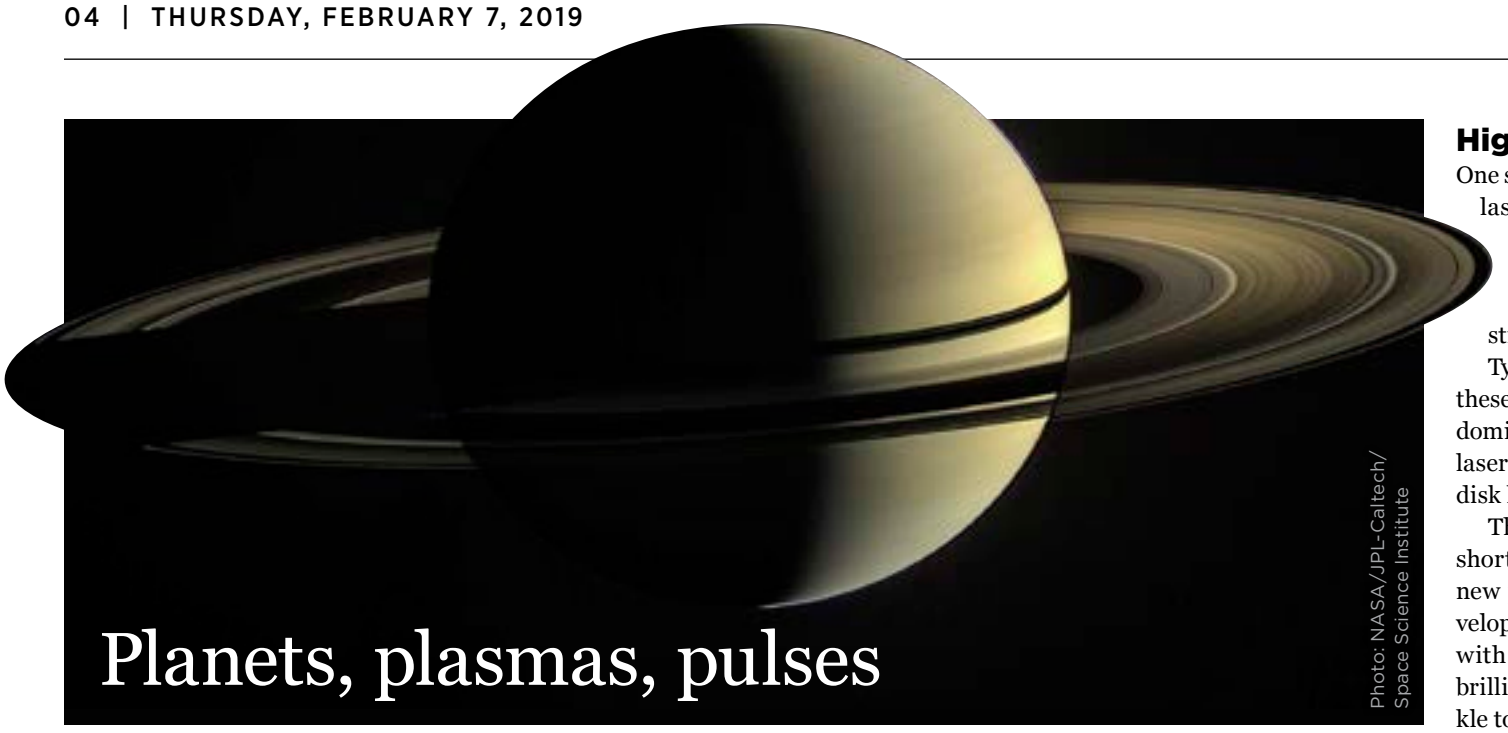


Photo: NASA/JPL-Caltech/ Space Science Institute

Planets, plasmas, pulses

The LASE Plenary covered the whole spectrum, from Cassini's survey of Saturn, through reinforcing nuclear reactors and at-risk bridges, to powerful diode pulses.

On September 15, 2017, the Cassini spacecraft plunged into the clouds of Saturn, completing a profoundly successful mission that had been exploring Saturn for more than a decade.

For most of the final six months before its scheduled demise, Cassini took a series of risky dives between Saturn and its rings, venturing into an unexplored and potentially hazardous region – something it was never designed to do. In the first LASE plenary lecture, Cassini project manager Earl Maize highlighted the efforts to repurpose the mission.

"We had to reconfigure a lot of the entire operating strategy for the mission in the environment inside Saturn's rings," Maize told *Show Daily*. "That was quite an engineering challenge."

Using Saturn's moon, Titan, as a slingshot, Cassini flung itself between Saturn and its rings. A missed shot and a collision with the rings would've been fatal, Maize said.

Once behind the rings, Cassini flew at 75,000 miles per hour, so fast that colliding with a grain of dust could destroy its instruments. Mission operators turned the spacecraft so that its antenna dish could shield it from such potential hazards.

On Cassini's other side was Saturn's atmosphere, which could disrupt the spacecraft or even pull it down. With the aid of new atmospheric models, Cassini managed to carefully graze the atmosphere and take a sample.

During the final descent, mission operators turned Cassini into a real-time probe, capable of collecting and sending data simultaneously – even until its last moments.

Cassini was a wild success with countless discoveries: geysers erupting from Saturn's moon, Enceladus – which seems to have the necessary ingredients for life; the relatively young age of Saturn's rings; and the alignment of Saturn's magnetic poles and its rotational axis, which contradicts many theories of planetary magnetic fields.

"We wrote and rewrote the books on planetary systems," Maize said.

Plasma peening

On more Earthly matters, Yuji Sano of the Japan Science and Technology Agency discussed recent advances in laser peening, a technique to make materials more resistant to fatigue and stress.

It works by using laser pulses to quickly heat the surface of a material, producing a rapidly expanding pocket of plasma. The sudden expansion generates shockwaves that propagate through the material, creating permanent strain and dislocations that strengthen the material.

Conventional laser peening requires a special coating to prevent the intense laser from melting or damaging the material. The need for such a coating makes laser peening difficult for some cases – for example, to prevent surface stress corrosion cracking in nuclear power reactors, which caused several accidents around the world in the 1990s.

Not only are nuclear reactors radioactive, the reactions happen underwater, making it difficult for workers to coat the material. However, by reducing the energy and duration of laser pulses, Sano and his colleagues developed a method of laser peening without any special coating. This technique has been used for nuclear reactors in Japan since 1999, and is now used in some reactors in the US.

More recently, in 2018, Sano and his colleagues designed a handheld laser system. The typical lasers used for laser peening are about a meter wide and weigh several tens of kilograms; but the new one measures just 10 centimeters across, weighs less than one kilogram, and costs ten times less, making laser peening more accessible and affordable for a wider range of applications. Airbus, for example, is planning to use this technology, Sano said. Such a device would also be useful in factories and maintaining infrastructure.

For example, the American Society of Structural Engineers said 9 percent of the US's more than 600,000 bridges were structurally deficient in 2017, requiring $123 billion to rehabilitate them. Cheaper laser peening could bring that cost down, Sano told *Show Daily*.

In another recent invention, Sano and his colleagues developed a laser peening technique that does not require water. In conventional laser peening, water helps constrain the burst of plasma, ensuring that the pressure is high enough to generate the necessary shockwaves. By using a femtosecond laser, the researchers found they could achieve high plasma pressure even without water.

Laser technology in general has been developing so fast, many advances in laser peening and other applications will likely be realized over the next several years, Sano said. "We can realize new technologies we couldn't imagine at present."

High-power diode lasers

One such technology is high-power diode lasers, which have seen tremendous progress as a workhorse laser in academia and industry, said Günther Tränkle of the Ferdinand Braun Institute (FBH) in the final plenary talk.

Typically based on gallium arsenide, these lasers are the world's most efficient, dominating materials processing. Diode lasers, for example, pump the fiber and disk lasers used in cutting and welding.

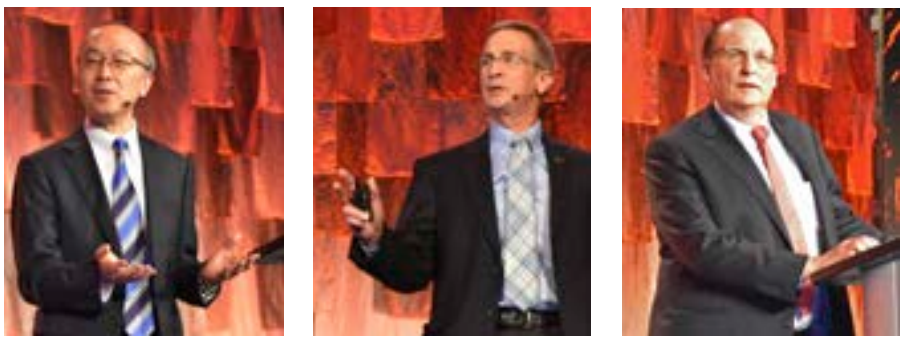
They are also crucial for the ultrashort-pulse high-energy lasers used in new particle accelerators. But such developments demand better diode lasers with improved efficiency, peak power, brilliance, and emission spectrum, Tränkle told *Show Daily*.

Recently, researchers at FBH have developed a triple asymmetric epitaxial layer design for the diode structure, which provides low resistance, low optical loss, low power saturation, and a low threshold current all at the same time. They reached record efficiencies that are 1.05 times higher than similar, symmetric designs.

This design can be used to make more efficient kilowatt laser bars. FBH is working with the German company Trumpf to design laser bars with ever increasing efficiency and beam quality.

Researchers have also been developing monolithically integrated gratings, increasing the power per emitter by 10 times, and doubling the efficiency. This technology enables diode lasers with a narrow and stable spectrum – suitable for solid-state laser pumping or sensing.

Diode lasers can be combined to create powerful, efficient, and compact direct diode laser systems. In one method, known as wavelength beam combining, an external grating is used to merge multiple diode lasers into a single beam. In a more sophisticated technique, called coherent beam combination, a laser is split into multiple beams that are then amplified. As this kind of research continues to advance, Tränkle said, diode lasers will become a part of ever improving technology, with applications in everything from medicine to the lidar systems used for autonomous vehicles.



L-R: Yuji Sano, Japan Science and Technology Agency; Earl Maize, NASA Jet Propulsion Laboratory; Günther Tränkle, Ferdinand Braun Institute. Photos: Stacey Crockett

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For ultra-precise measurement of MTF and other optical parameters TRIOPTICS presents the new ImageMaster® HR UP. It completes the proven ImageMaster® HR product line an image quality test station which focusses on highest accuracy and flexibility. At Photonics West TRIOPTICS shows an important application of this measurement station: quality testing of lenses for **3D-shape and -scene recognition systems.**

ImageMaster® HR TempControl - Testing image quality in temperature ranges from -40°C to 120°C

Many optical systems such as lenses and camera modules are used in a wide temperature range and must consistently maintain their full functionality and performance across varying temperatures. In addition to military and aerospace applications, cameras are also increasingly being used in the automotive industry as safety-critical systems whose properties must be tested and ensured across a broad temperature span.

In general, the image quality of lenses can be affected by temperature influences on the optical components and mounting materials. Crucial lens parameters such as effective focal length and flange focal length can be temperature-dependent and have an impact on the camera's focusing function.

The challenge for the optical design is to minimize the thermal effects on the optomechanical parameters by utilizing an athermal design.

The ImageMaster® HR TempControl is used to test the functionality of the athermal optical design across a wide temperature range spanning from -40°C to 120° C. For this purpose, the optical performance is determined for a set of parameters and the results are presented as a function of temperature ranging from -40 to 120°. In addition to determination of the MTF, the key measurement parameter is the change in both the flange focal length and effective focal length when the temperature changes.

For the measurement process, the test samples are placed in a thermal chamber, isolated from the environment via a vacuum, and tempered to various test temperatures ranging from -40°C to 120°C. The vacuum prevents condensation at low temperatures and the thermal chamber is designed in a way which ensures that temperature-related changes are minimized.

The ImageMaster® HR TempControl can be used for measurements in both the VIS spectrum and IR range, and the system can be easily converted from

VIS to IR – thereby covering the specific requirements from various areas, including the automotive industry, development of mobile phone lenses, and the military and aerospace sectors.

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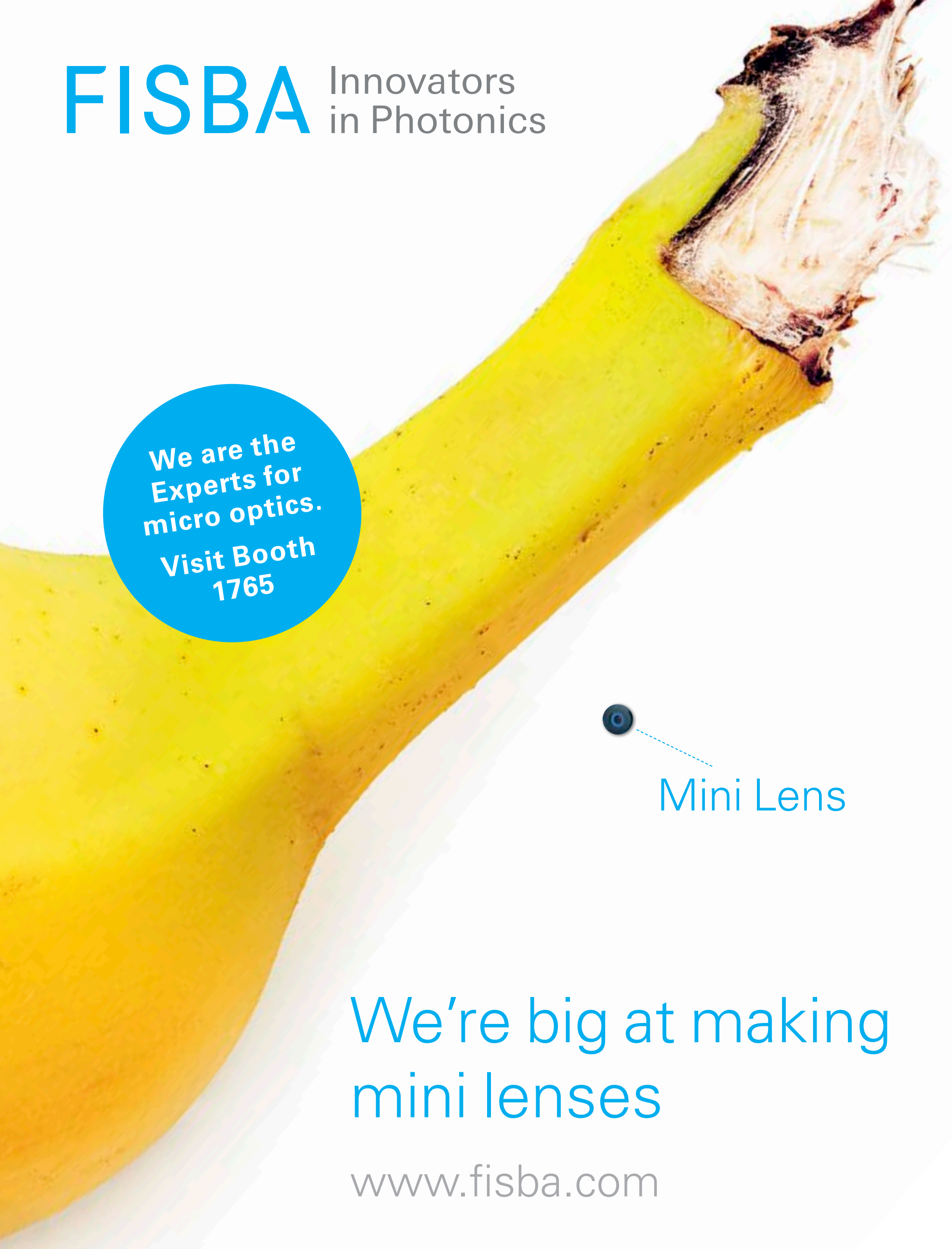

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BiOS Hot Topics: changing of the guard

The photonics community this year marked the retirement of long-time BiOS co-chairs Rox Anderson and James Fujimoto from those roles.

The near-capacity crowd at their ultimate session this week broke into applause as Anderson opened with "This is the largest meeting in the world for biomedical optics, and that's because of you!" He added that the reason BiOS has grown so popular is the diversity of the intellect and specialties that are featured in the symposium, such as those involved in medicine, bioscience, and physics.

James Fujimoto introduced the new BiOS co-chairs, Jennifer Barton of the University of Arizona and Wolfgang Drexler of the University of Vienna. Touching on the impressive backgrounds of each, Fujimoto noted, "we know the conference will be in good hands."

L-R: Rox Anderson, James Fujimoto, Kent Rochford. Photo: Stacey Crockett

"Rox and I would like to take this opportunity to thank SPIE, program track chairs, conference chairs, and all of you in the community for the opportunity and the privilege to serve as co-chairs of BiOS all these years," said Fujimoto.

"We'd all like to honor and thank Dr. James Fujimoto and Dr. Rox Anderson who have tirelessly served this community since 2004," said new SPIE CEO Kent Rochford as he presented the pair with awards for their service. "Their combined leadership has contributed significantly to the growth and importance of biomedical optics in the world and the BiOS symposium. Each has brought significant advances to how biomedical optics improve our healthcare."

Rochford pointed out Fujimoto's achievements as co-developer of optical coherence tomography (OCT), "a ubiquitous technology with many applications." He noted that Fujimoto's prolific career includes 15 patents, nine books, and more than 450 journal articles; and that he has received numerous awards for the development of OCT, including the 2017 Russ Prize from the National Academy of Engineering – considered the Nobel Prize of engineering.

Humanitarian efforts

"An active researcher, Rox Anderson conceived and developed treatments for birthmarks, lesions, and tattoo removal among other innovations," said Rochford, adding that Anderson, "brings the wonderful perspective of having degrees in science as well as in medicine." He noted Anderson's more than 60 national and international patents, and the fact that he has co-authored over 250 scientific books and papers. "We also applaud Dr. Anderson for his humanitarian efforts to help children in the world who are scarred or disfigured in need of this help," Rochford added.

Anita Mahadevan-Jansen of Vanderbilt University paid tribute to the late Warren S. Grundfest, professor of bioengineering and electrical and computer engineering at UCLA. "Grundfest was one of the founding fathers of BiOS, serving as symposium chair from 1998 to 2003," said Mahadevan-Jansen. He was a pioneer in the translation of biomedical and biophotonics technology for improving patient care."

The evening included the presentation of the 2019 Biophotonics Technology Innovator Award to Stephen Boppart of the University of Illinois at Urbana-Champaign. The award honors Boppart's achievement in computational OCT and its applications to basic and clinical sciences.

The SPIE-Franz Hillenkamp Postdoctoral Fellowship in Problem-Driven Biophotonics and Biomedical Optics was awarded to Jie Hui of the Boston University Photonics Center and Dr. Andreas Wartak of the Wellman Center for Photomedicine at Massachusetts General Hospital. Hui's research is focused on a light-based approach to treat MRSA-caused diseases in the clinic. Wartak's research will target an earlier, cheaper, and less invasive diagnosis of eosinophilic esophagitis (EoE), a poorly understood allergic inflammatory condition of the esophagus.

The final award presentation of the evening was the 2019 Britton Chance Biomedical Optics Award to Samuel Achilefu of the Washington University School of Medicine in St. Louis. Presented each year for outstanding lifetime contributions through development of innovative technologies that have facilitated advancements in biology or medicine, the award honors Achilefu's work in optical and molecular imaging that enables cancer care and treatment.

Cancer vision

Following his award presentation, Achilefu gave the evening's first technical presentation, "The Power of Light to See and Treat Cancer," where he described his "Cancer Vision Goggles" – a headset that allows surgeons to visualize cancer in the operating room.

"We have developed a simple fluorescent molecule for imaging solid tumors and a wearable head-mounted device to visualize cancer in the operating room," said Achilefu. "These combined products synergistically improve treatment outcomes. Now that we can visualize cancer in real time, we are using light from within the cancer cells to treat them."

In conclusion, Achilefu acknowledged the many people who worked on the project: "surgeons, clinicians, students, engineers, physicists, chemists, biologists – basically it takes a village to do what we are describing today."

Achilefu also acknowledged his friend and mentor Britton Chance. "Through his inspiration and the lessons learned from his hard work ethic, we've been able to push our technologies, not only to do the pre-clinical model, but also work with actual patients, and today we're taking our technologies around the world to improve healthcare," he said.

Long-time facilitator, Sergio Fantini of Tufts University,c opened the quick-fire Hot Topics presentations, which covered several new developments in biomedical optics, specifically diffuse optical imaging, spectroscopy, fluorescence spectroscopy, optoacoustic tomography, multiphoton endoscopy, and OCT.

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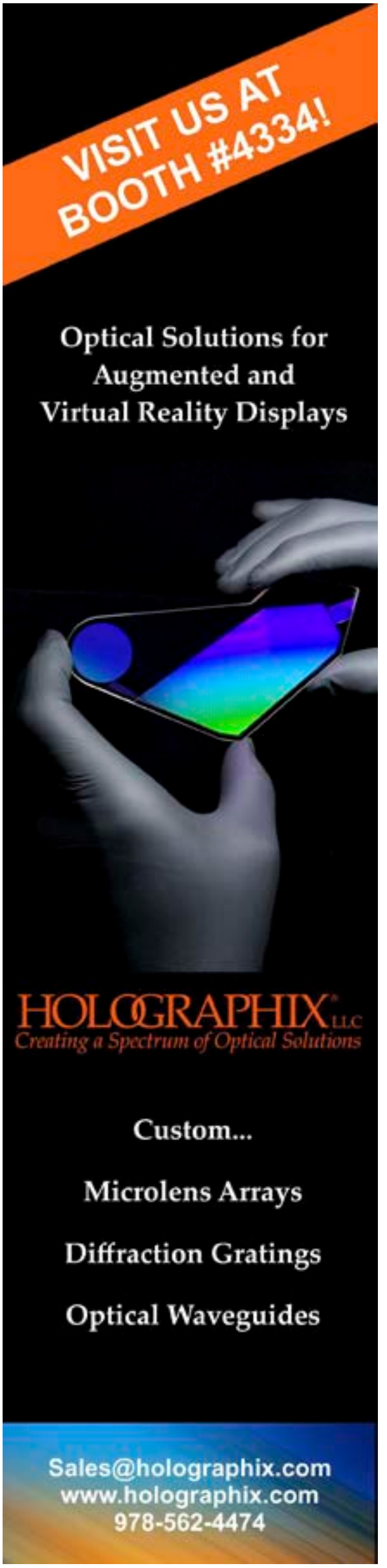

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NKT Photonics

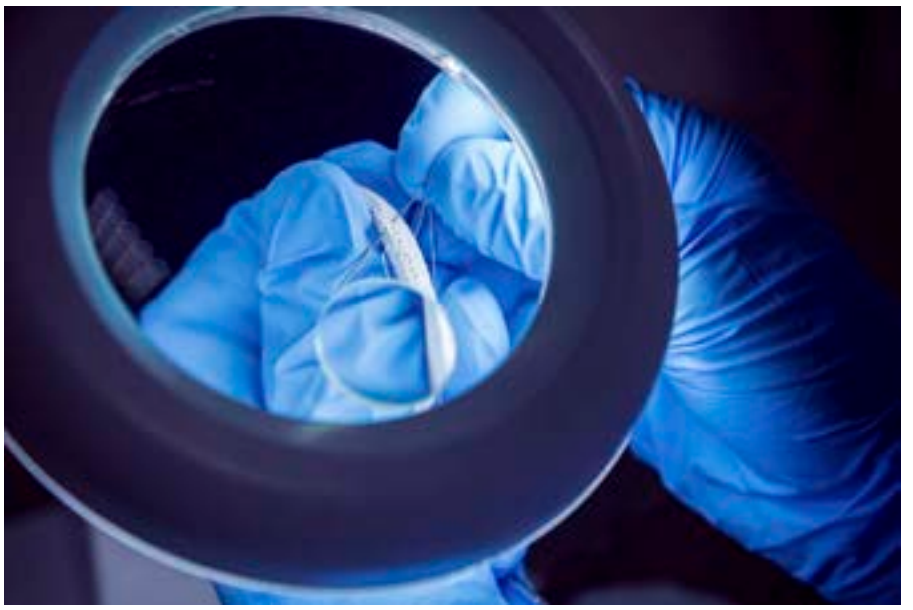
Photonics21 digs in for next phase of continental R&D

Building on some notable recent success stories, the European photonics platform is anticipating a busy 2019 for innovation.

With more than 2500 members, the Photonics21 "technology platform" represents much of Europe's photonics community, embracing industry and research organizations alike. Working closely with the European Commission (EC), its members develop and implement a common photonics strategy within the framework of a public-private partnership (PPP) supported by Horizon 2020 funding that is intended to use and develop photonics technology to spur innovation, growth and jobs in Europe.

The past year saw a significant change within the organization. Aldo Kamper arrived as Photonics21's new president in January 2017, but around 18 months later the Osram Opto Semiconductors CEO was recruited to head up the German cabling group Leoni, and departed his Photonics21 role.

As a result, the group is currently under the joint care of its two vice presidents, Giorgio Anania and Bernd Schulte. They told *Show Daily* about their hopes and plans for the organization and the wider industry through the coming year, and highlighted some new initiatives as the Horizon 2020 funding period draws to a close.



The knitted fabric made by Texinov delivers laser light for photodynamic therapy to every part of a patient's skin requiring treatment. Photo: Texinov Medical Systems.

"Photonics21 remains in a strong position to foster European innovation and is committed to harnessing the power of light to solve our greatest global challenges," Schulte and Anania stated.

From early 2019 onwards, we can expect to see further announcements of PPP-funded projects, as well as the return of the "#Next_photonics Prototype Your Idea" contest. This is a dedicated innovation challenge to push for more entrepreneurship in photonics, targeting PhD or Masters students, as well as creators with an idea for a photonics-based product that can transform into a real business. The competition, said to have proved very popular in 2018, offers a cash prize of €5000 and the opportunity to team up with the Brussels-based innovation incubator ACTPHAST EU.

Another important diary date coming up fast is Photonics21's annual meeting, taking place in Brussels at the end of March. This year's host keynote speaker will be Carl Buhr, deputy head of cabinet within the "Digital Economy and Society" commission led by Mariya Gabriel. During the associated workgroup sessions, priority topics for the first photonics-related calls under the forthcoming "Horizon Europe" research and innovation program – the follow-up to Horizon 2020 – will be officially launched.

"Photonics technologies have now become a part of everyday life, revolutionizing society with so many different new and innovative applications far beyond obvious lighting products," commented Anania and Schulte. "In the past few years alone, [photonics has] created exciting, game-changing products in terms of diagnostic tools for our health practitioners, improving our environment, and become a keystone component of Industry 4.0."

Looking to the future innovation program, they have some lofty aspirations. "If we can maintain a strong funding commitment, and strengthen the photonics PPP in Horizon Europe, then the instant diagnosis of major diseases, the eradication of all road accidents, and the creation of at least one million new jobs are some of the benefits that we expect will be generated by the photonics sector by 2030."

Microscope tackles sepsis

One primary example of that ongoing innovation is a proprietary interferometric, lens-free microscope that is said to provide the fastest ever detection of sepsis. A life-threatening condition, sepsis is an inflammatory immune response to infections caused by bacteria including *E. coli* and *Staphylococcus*, which can lead to conditions such as meningitis. On the rise with the emergence of antibiotic-resistant pathogens, sepsis now kills over 20,000 people every day worldwide – more than prostate cancer, breast cancer, and HIV/AIDS combined.

Approximately the size of a small book, the new microscope developed under the Photonics21 project entitled "Scalable point-of-care and label free microarray platform for rapid detection of sepsis", or RAIS for short, has the potential to simultaneously detect more than one million biomarkers – the tell-tale signs of sepsis and many other diseases. Whereas current techniques can take as long as one day to perform a similar test, the new method combines photonics, microfluidics, and

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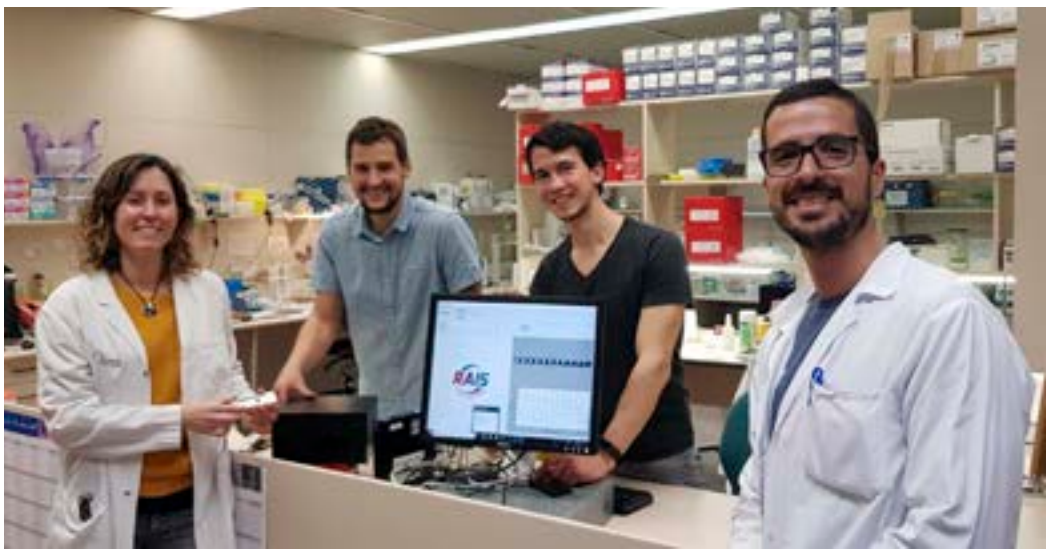
Photonics21 continued from page 09

molecular biology techniques to produce a result in just 30 minutes.

Coordinated by ICFO, the Institute of Photonic Sciences in Barcelona, Spain, RAIS is seen as a major success story for the photonics PPP. Josselin Pello, a senior researcher on the project at ICFO, explains: "Doctors need a quick, reliable way of detecting sepsis, and the stage it has reached. Current methods are too slow. They can only look at a couple of parameters at a time, and they will not tell the physician what type of bacteria is present that is causing sepsis. A doctor may not therefore prescribe the correct treatment in time."

Pello points out that the RAIS microscope can simultaneously detect many biomarkers, including micro-ribonucleic acids and interleukins. "[It] will let you know the bacteria source much earlier, allowing you to choose the correct treatment sooner," he says. The RAIS project received a grant of €3 million via the photonics PPP under the Horizon 2020 program, with the team estimating that a commercial device based on its beta prototype could potentially provide results at a cost as low as €50 per patient.



Under a photonics PPP project, the RAIS development team at ICFO has led development of a microscope offering a much faster way to diagnose sepsis. Photo: ICFO.

Laser pen for 'while you wait' cancer test

The Photonics21 team says that another successful PPP-related development has been delivered by the Automatic Detection of VAscular Networks for Cancer Evaluation (ADVANCE) project team. They have produced a portable laser scanner that can diagnose a malignant melanoma in less than one minute, promising to become what its developers describe as "the world's first while-you-wait test for skin cancer".

The imaging system, intended to eliminate discomfort and uncertainty for patients, is able to fit every stage of disease identification within the short time of a single doctor's appointment. Using a handheld scanner, they can peer beneath a patient's skin to examine the microscopic landscape of a suspect lesion, in a process that takes just 20 seconds.

Based on optical coherence tomography (OCT), a technique more commonly used in retinal screening, the scanner creates a 3D color image of microstructures and blood vessels under the skin – providing a diagnosis without the need for any invasive procedures.

Project leader Jon Holmes, from the UK company Michelson Diagnostics, explains: "Every melanoma above a certain thickness could have spread to other parts of the body. At present, all patients with such melanomas have to wait for a biopsy performed in a hospital under general anesthesia to discover if it is spreading. This can take weeks to perform, is very expensive and can be debilitating for a patient.

"About 80% of the time, the biopsy produces a negative result, with no sign of the cancer spreading. There has to be a better way: our scanner may radically improve the abilities of dermatologists to decide on the nature of a melanoma, [although] further clinical trials will be needed to conclusively prove the technology."

The ADVANCE project received a grant of €2.3 million under the Horizon 2020 funding period, and featured partners from Germany, Denmark, Italy, and Serbia.

Fabric treats skin diseases

Other, less dangerous but debilitating skin conditions such as actinic keratosis (scaly spots on sun-damaged skin, often pre-cancerous), psoriasis (autoimmune disease causing abnormal skin) and acne can now be treated in a single 150 minute session, thanks to a new wearable photonics technology. Under another Photonics21 project, scientists at Texinov Medical Textiles, based in La Tour du Pin, France, led the development of "Fluxmedicare" – a knitted fabric that helps treat inflamed skin or lesions with photodynamic therapy (PDT).

Described by some users as a "miracle cure" in clinical trials, the pain-free approach is touted as offering the fastest way to eradicate the identified skin conditions, with no side effects. The knitted fabric acts like a waveguide to deliver therapeutic laser light to the entire region of skin requiring treatment.

Nadege Boucard, general manager of research and development at Texinov, said: "Fluxmedicare is unprecedented in the field of treating skin conditions. Since the lighting textile wraps around the contours of a patient, the light emitted by our device is the same level at every part of the body under treatment, meaning the beams are homogeneous."

Photonics21 said of the project: "This development is yet another success for photonics technology. It has now been successfully tested in clinical trials and is ready to go, meaning more sufferers of such skin conditions will find new hope, quicker, easier, and in a painless appointment."

Fluxmedicare was developed under the "PHOS-ISTOS" consortium, which secured EC grant support of €2.4 million. The team comprised participants from across Europe, including the diode laser manufacturer and Photonics West exhibitor Modulight.

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Fellowship winners tackle twin healthcare challenges

Researchers supported by SPIE-Franz Hillenkamp Postdoctoral Fellowships are developing photonics technologies to treat MRSA infections and diagnose esophageal disease. Both projects could have significant impact in clinics.

The challenge to healthcare posed by MRSA is an enormous global concern, given the resistance to several widely used antibiotics that these bacterial infections can possess.

A traditional first line of defense in hospitals and clinics has been stringent controls on cleanliness, to limit the spread of infection. But an optical technique under development at Boston University's Photonics Center aims to eliminate the potentially deadly pathogens with a more targeted approach.

Jie Hui, a member of Ji-Xin Cheng's group at Boston, is working on the use of blue laser light to disrupt the antibiotic-resistant bacteria, potentially allowing a treatment to be developed specifically for MRSA-caused diseases.

"It has been well documented for more than a decade that blue light has an antimicrobial effect, but its underlying mechanism has been a mystery and the treatment efficiency is limited, which has blocked the translation of this approach into clinics," commented Hui. "Our research team discovered that staphyloxanthin, an endogenous pigment produced by the bacteria and bound in its membrane, is the specific molecular target for the blue illumination."

Staphyloxanthin has an antioxidant action, a key element in the microbe's defense against the reactive oxidation process employed by some conventional antibacterial treatments. Weaken or damage the staphyloxanthin, and you can deal a serious blow to MRSA's formidable toughness.

In 2017, Hui's project found that staphyloxanthin is prone to photobleaching by blue light, which ruptures cell membranes and kills the bacteria cells. This effect was proved to work on MRSA cultures, MRSA-infected macrophage cells, bacterial biofilms, and a wound infection model in mice. More recently, the project set out to address a long-standing question within the field: what is the best blue light source for killing MRSA?

"My recent work, grounded in the physics of staphyloxanthin photolysis, demonstrated that a pulsed blue laser source both reduces the potential photothermal effect when compared with continuous-wave light sources, and improves photolysis efficiency and depth, subsequently killing MRSA much more effectively," said Hui. "We also revealed the detailed killing mechanism for MRSA, which opens many opportunities for clinical applications of our technology. These findings are novel and have high potential for development into a therapeutic platform in the clinic."

> "Staphyloxanthin, an endogenous pigment produced by the bacteria, is the specific molecular target for the blue illumination."
>
> JIE HUI, BOSTON UNIVERSITY PHOTONICS CENTER.

This project builds upon work that won the group a Translational Research Award at last year's Photonics West, and Jie Hui is now a recipient of a 2019 SPIE-Franz Hillenkamp Postdoctoral Fellowship in Problem-Driven Biophotonics and Biomedical Optics. This annual award, recognized during Saturday's BiOS Hot Topics session, is one of a pair of fellowships targeted at interdisciplinary problem-driven research and opportunities for translating new technologies into clinical practice for improving human health.

Specific treatment strategies

"These findings are fascinating both to our research team and to the physicians we have met," Hui commented. "Clinical applications of our technology to benefit patients would be even more exciting. Right now, we are working towards the clinical translation of this technology to treat specific diseases, for example skin and urinary tract infections caused by MRSA. As it moves towards the clinic, we will certainly face some technical challenges. One example is the light delivery system, where we may need to develop specific strategies to match each application."

Jie Hui (left), a researcher at the Boston University Photonics Center, is working on a blue laser treatment for MRSA. He is hopeful that the approach could find use in early-adopter hospitals within two years. Photo: Boston University.

This may in turn involve different parameters for laser treatment in terms of dosage, illumination area, and treatment time, alongside the possible adoption of specific optical fibers for endoscopic and intravascular applications. The nature of each individual infected site and the general condition of a patient are also likely

continued on page 15

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Fellowship winners continued from page 13

to play a role. Ultimately, each specific disease may well require its own particular treatment strategy.

Successful translation of any new biophotonics technology, whether for diagnosis or therapy, needs to be grounded on solid scientific studies as well as strong collaboration among scientists, engineers, and physicians. For medical devices in particular, it also requires significant investments to be put in place in order to bring them to market.

"We are very positive on the clinical translation of this particular technique," Hui said. "Antibiotic resistance is currently a serious public health issue, and MRSA has been listed by the World Health Organization among its 'priority' pathogens — the 12 families of bacteria that pose the greatest threat to human health. This means our technique occupies a very valuable niche from the clinical point of view, as well as being simple, safe, and effective."

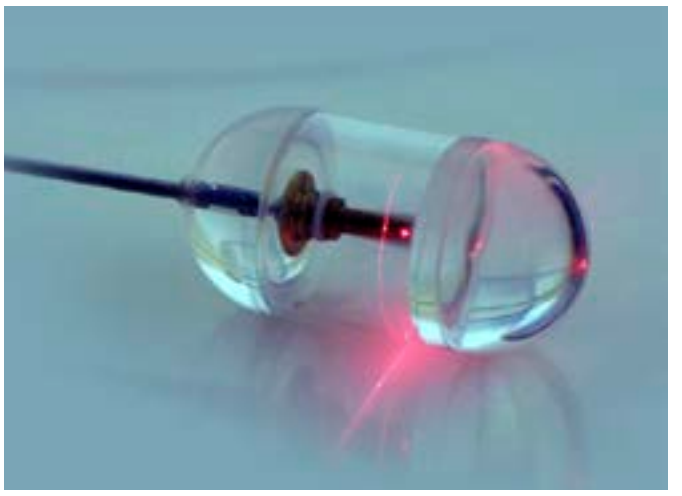
The group is currently initiating a proof-of-concept clinical study using the blue-light technology, likely to take place this year. After that, Hui is hopeful of a smooth path through larger clinical trials and regulatory approval, with early-adopter hospitals perhaps able to deploy the technology within the next two years.

"We really appreciate that the SPIE community recognizes our research work in this direction, by awarding both the prestigious SPIE-Franz Hillenkamp Postdoctoral Fellowship this year and SPIE Translational Research Award in 2018," he commented. "Both awards are highly selective, and target the most promising biophotonics technologies with high translational potential. These awards have already drawn more attention to our research findings, and will further accelerate the translation of our technologies into the clinic and into the market. In the long run, I think these awards will prove to have benefited both the SPIE research community, and patients in the clinic."

Diagnosing esophageal disease with OCT 'pill'

At the Wellman Center for Photomedicine, located at Massachusetts General Hospital (MGH), Andreas Wartak's research into optical diagnosis of eosinophilic esophagitis (EoE) is paving the way for earlier and less invasive treatment of this allergic inflammatory condition of the esophagus, a disease whose exact nature is still not fully understood.

Diagnosis of EoE normally involves a biopsy performed with an endoscope, followed by histopathology analysis of the sample to examine the influx of a certain type of white blood cell that characterizes the condition. But this is by nature invasive, expensive, requires sedation, and is prone to high sampling variability. The Wellman Center project, based in the lab of Guillermo Tearney, is developing a more attractive optics-based alternative.



Andreas Wartak's optical coherence tomography "pill", for diagnosing allergy-related inflammation of the esophagus. Photo: Andreas Wartak.

"We will apply a technique that has been recently developed in our lab, termed tethered capsule endomicroscopy (TCE), in which a pill descends down the esophagus when swallowed and is then withdrawn back up by means of a tether," explained Wartak. "This capsule will incorporate a sophisticated new form of optical coherence tomography (OCT), for visualizing the inside of the esophagus at the cellular level."

OCT's ability to record depth scans of living samples from backscattered light is well established, in particular for ophthalmic imaging. But it is also well on its way to becoming a major technology for intraluminal diagnosis, especially in the cardiovascular and gastrointestinal systems.

"Our project tries to further extend the portfolio of gastrointestinal diseases that already profit from OCT's tomographic imaging approach," commented Wartak. "We will investigate epithelial tissue inflammation, as well as structural changes and sub-epithelial remodeling in EoE. This complementary information will provide key insights into disease development and progression over time, that should ultimately lead to an advance in research, diagnosis and therapy for EoE."

As with most *in vivo* imaging modalities, the obstacles facing the Wellman Center project include the need for sufficiently fast imaging speeds to counteract the unavoidable sample motion. In this instance, movement mainly caused by peristalsis (muscle contractions in the digestive tract), which cannot be fully corrected by computational methods. Image resolutions able to reveal the smallest details of the biological processes under way in EoE are also essential, delivered in this case by exploiting recent advances in light sources and camera technology.

"The key challenge of this project is to merge specialized high-end equipment and customized components developed in-house, to build a high-speed and high-resolution instrument," Wartak said. "Since we only started recently, most of the work still lies ahead, but I feel that we have all the necessary building blocks available to make this project a success. Our lab has the required technological expertise and sophistication, and has gathered tremendous experience in advancing endoscopic OCT over the last two decades, while MGH offers an exceptional clinical environment. I am positive that we will reach our goals."

> "I believe there is now a clear trend of more biophotonic modalities, whether diagnostic or therapeutic, successfully making it into the clinic."
>
> ANDREAS WARTAK,
> WELLMAN CENTER FOR PHOTOMEDICINE.

Wartak currently expects an initial animal study to be followed by a pilot clinical trial in humans, to demonstrate safety and feasibility in both healthy subjects and EoE patients, adjusting the instrument design by iteration during the process. After that, larger-scale clinical studies are planned at MGH before potential multi-center studies.

Diverse teams ease translation

Eventual translation of the technology from the laboratory to the clinic is another major consideration. The hurdles involved in bringing a novel biophotonics technique to its chosen clinical markets are a natural topic of discussion at Photonics West, which is once again addressing the issue as part of the BiOS symposium.

From his perspective at the Wellman Center, Wartak recognizes that translation can be helped or hindered by a number of factors, and that optimizing the performance of a new imaging modality is not the end of the story. Translation also depends on successful collaboration between several different scientific departments, medical clinics, and industry, as well as the funding and regulatory agencies concerned.

Project teams incorporating all relevant stakeholders have the best chance of eventually entering the clinical market with their product, making it essential to have an interdisciplinary field of experts on board from the start of the effort.

MRSA bacteria, as seen under the electron microscope. Image: The Wellcome Trust.

"Bench-to-bedside translation can be a long and winding road, and there are definitely hurdles in the way of every technology striving towards the clinical market," he said. "I believe there is now a clear trend of more biophotonic modalities, whether diagnostic or therapeutic, successfully making it into the clinic, and the drive towards translation now seems more pronounced. Nevertheless, there is always room for improvement and, in particular, the need for suitable funding."

As a researcher from Europe now working in the US, Wartak has also observed some geographical differences in the translational funding structures, with the more extensive private funding opportunities available in the US potentially facilitating higher-risk proposals than the more conservative public agencies might opt to support.

Wartak's receipt of the SPIE-Franz Hillenkamp Postdoctoral Fellowship will also now play a part, by allowing him to focus entirely on the EoE research project, increasing the chances of a successful outcome.

"I personally feel motivated by the fact that my research not only seems meaningful to myself, but also to SPIE and thus to a wider general public," he said. "Congresses, meetings, and conferences such as Photonics West are essential. Research is all about sharing discoveries, inventions and results, but it is at conferences that scientists like us have the chance to experience research in a more personal and probably more relatable way."

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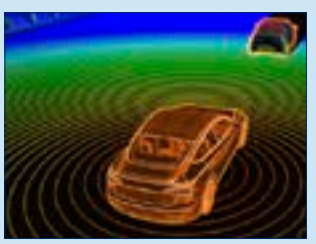

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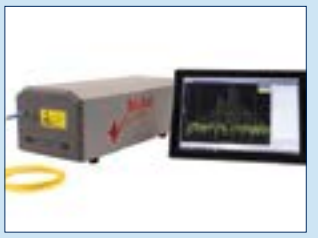

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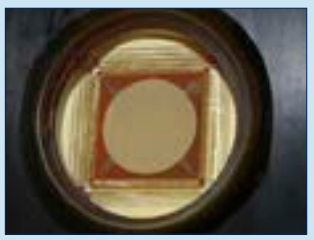

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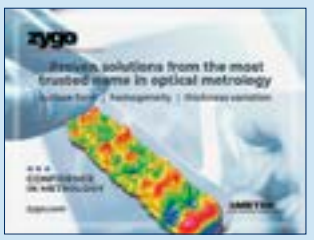

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Optics tech drives CES innovations

From smart glasses to autonomous vehicles, photonics technology and the world of consumer electronics seem closer than ever.

Photonics innovation has a long association with consumer electronics, right from the early days of liquid crystal displays, through the emergence of optical data storage in the 1980s, digital cameras, Blu-ray discs and the like. But the link has grown to such an extent in recent years that the topics under discussion at the annual CES event in Las Vegas and Photonics West have become increasingly intertwined.

At CES 2019 last month, that trend was once again in evidence. Photonics-based technology themes included the latest augmented, virtual, and mixed reality (AR/VR/MR) headsets and glasses, new micro-LED array displays, and a whole host of new lidar and camera systems designed for today's driver assistance and tomorrow's fully autonomous cars.

The clearest link between the two events is AR/VR/MR, and with good reason. Perhaps the greatest challenge facing the companies developing these technologies is to improve their size, weight, and performance to make them truly immersive and portable. And that comes right back to the fundamental optics involved, in particular the waveguides inside glasses and headsets.

Among those to present at Photonics West's dedicated AR/VR/MR conference was DigiLens, which at CES 2019 launched AR smart glasses said to offer a much-improved level of form-factor, optical efficiency (meaning longer battery life), and contrast.

The Sunnyvale, California, firm's new "DigiLens Crystal" platform is based around waveguides made under license by Taiwan-based Young Optics, and leverages digital light processor (DLP) technology from Texas Instruments. Glass companies offering the kind of high-precision wafers needed for mass production of suitable waveguides are also emerging as key players in the AR/VR/MR ecosystem, with Photonics West exhibitors Corning and Schott among those involved. Vuzix was another AR smart glasses vendor to present on the topic of waveguide technology at Photonics West.

In recent years CES has also become a key date in the calendar for the automotive industry, with car manufacturers using the post-holiday event to launch the latest features in their increasingly tech-oriented vehicles. Among this year's major draws was Toyota, whose US-based subsidiary Toyota Research Institute (TRI) rolled out its new "P4" test vehicle on the Las Vegas stage.

Augmented, virtual, and mixed reality (AR/VR/MR) technologies were again a huge trend at CES 2019, as well as the subject of a dedicated conference and expo at Photonics West earlier this week. Image: DigiLens.

Toyota's latest "Guardian" test vehicle for autonomous driving is mobbed by the media at CES 2019 in Las Vegas. The car features high-performance lidar units in its roof section, other lidar sensors around its chassis, radar, and numerous cameras. Photo: CES.

The P4 features high-performance lidar systems from Photonics West exhibitor Luminar Technologies on its roof, alongside a radar system, numerous cameras, and additional lidar sensors positioned around its body. Everything is motivated by improving safety and reducing the incidence of road collisions – nearly 40,000 lives are lost every year on US roads alone, among 1.25 million worldwide. And before unveiling the P4, TRI's CEO Gil Pratt showed footage of an alarming three-car crash collected by and involving one of the company's earlier "Platform 3.0" test vehicles, at the time in manual mode, on the I-80 interstate road close to San Francisco.

"Luckily, despite the severity of the crash, nobody was injured," said Pratt. "We show you this now, not to wow you with technology, but because I want to take you through a question that we posed to ourselves that very day: could a Toyota Guardian [TRI's driver assistance system] have prevented or mitigated this crash?"

The answer, he said, was yes. When TRI recreated the scenario on a test track, sensors on board the car showed that in the real crash it could have accelerated safely away from the encroaching vehicles as they approached, creating more space on the road and a safer driving "envelope".

Among the lidar companies highlighting new advances at CES 2019 was Prism Award winner Blackmore, whose frequency-modulated multi-beam system now boasts a remarkable range of 450 meters, alongside a wide field of view. Already available for pre-order and with initial samples shipping now, Blackmore says that full systems will ship to customers from Q2 this year. That high performance comes at a cost of "less than $20,000" to strategic partners.

Also at CES 2019 was the car parts supplier Valeo, whose "SCALA" scanner is claimed to be the only mass-produced automotive lidar system currently on the market. The France-based company signed a deal with Intel subsidiary Mobileye to develop and promote a new autonomous vehicle safety standard combining a multitude of sensors, including lidar, with Mobileye's mathematical safety model.

Set against the brave new worlds of artificial intelligence, alternative realities, and self-driving vehicles, the humble television might seem rather outdated at CES these days. But that didn't stop Samsung launching new models based on another emerging photonics technology – micro-LEDs. The Korean company's 75-inch screens rely on arrays comprising myriad tiny emitters, claiming advantages in terms of brightness, modularity, lifespan, and a bezel-free design.

"These transformative TV displays are made up of individual modules of self-emissive micro LEDs, featuring millions of inorganic red, green, and blue microscopic LED chips that emit their own light to produce brilliant colors on screen – delivering unmatched picture quality that surpasses any display technology currently available on the market," boasted Samsung.

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SPIE updates enabled-markets report

Figures show core components market growing at nearly 7%

On Thursday morning after the Photonics West exhibitor breakfast, the SPIE industry team releases the latest update to its biennial Industry Report. The presentation will focus on gains in the photonics-enabled marketplace, examine trends across major market segments, and include a review of the core photonics components manufacturing business.

SPIE and its industry team has been providing a benchmark study for quantifying this complex industry since its initial analysis of the photonics components manufacturing industry was unveiled at Photonics West in 2013. Since then, its biennial studies have delivered industry metrics with a robust, consistent, and transparent methodology.

As diverse and dynamic as ever, the photonics industry continues to exhibit impressive growth. The business comprises a diverse set of technologies that underpin nine major market segments ranging from advanced manufacturing to consumer and entertainment. Global revenues from all photonics-enabled businesses and services now account for more than a 13% share of the global economy – as measured by global gross domestic product (GDP) – and the prospects are for continued gains across multiple segments.

Underlying the nine end-use market segments is the global photonics components manufacturing industry. Valued at an annual $227 billion in 2016, this element of the photonics industry is also growing. The SPIE Industry Report has tracked core components manufacturing since 2012 and projects an overall compound growth rate of 6.6% from 2016 through 2018.

Beyond revenue growth, the industry has also seen a positive change in perspective by the investment community, at the same time as a change in geographical distribution of revenues.

Traditionally, firms that serve end-use markets like consumer, healthcare, or defense have created much of the value associated with photonics commerce. They include the likes of Apple, Illumina, and Thales, and do not typically see themselves as photonics companies. Nonetheless, photonics components are key to these companies' success. More recently, the technology and component providers have been able to capture a larger share of this value, and investment in photonics and photonics-enabled firms has skyrocketed since 2012.

As the overall investment in photonics and its vertical markets has grown, so has the concentration of photonics investment in Asia. The investment value of private placements in Asian targets is of substantially higher concentration in the photonics segment than in all other vertical segments combined, according to Linda Smith of Ceres Technology Advisors. As with the investment capital, the SPIE report shows a trend of photonics components revenues also shifting towards Asia, as China-based enterprises take a larger share of the components business.

For more on these and other industry trends, together with a detailed look at the photonics-enabled marketplace, join me and Jennifer Douris O'Bryan for the Photonics Industry and Public Policy Update at 9.15 am, after the Exhibitor Breakfast.

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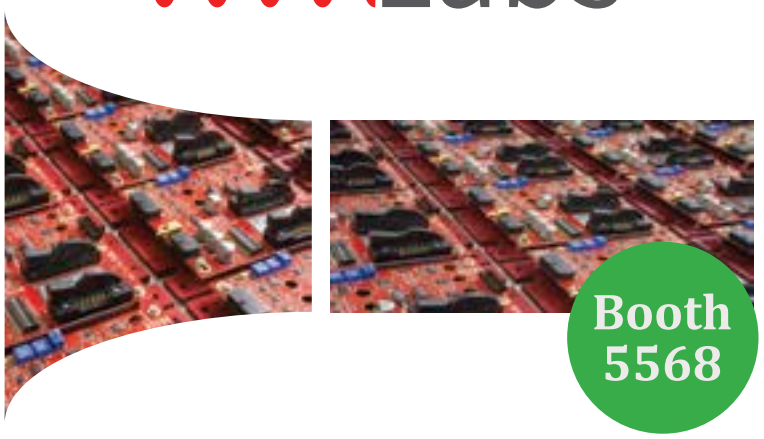

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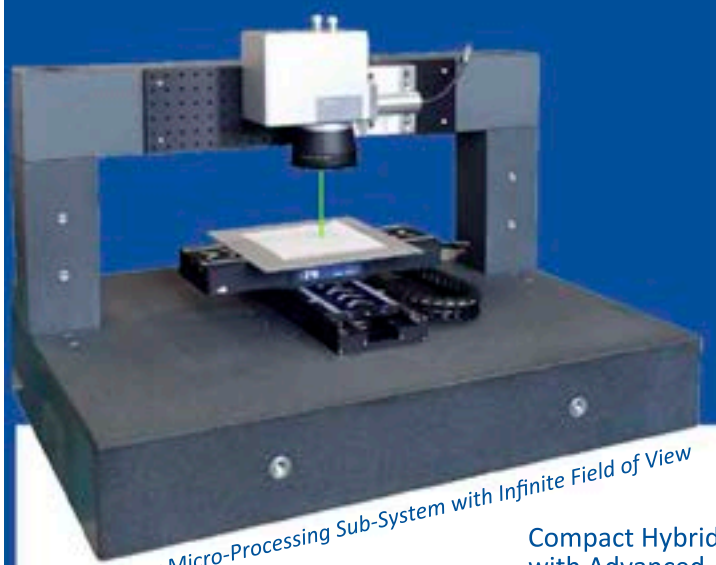

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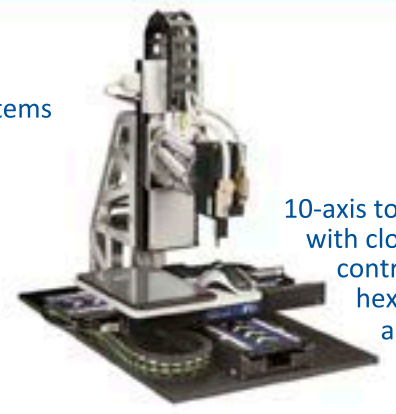

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Lasers make the grade in Earth observation and space exploration

Astronomers, weather forecasters, and Earth scientists are among those now benefiting from the application of solid-state lasers in space.

Even by stellar historic standards, it has been a remarkable few months for space probes and their on-board optical instrumentation. Late 2018 saw the erstwhile Voyager 2 probe – complete with interferometer, ultraviolet spectrometer, photo-polarimeter, and dual-camera imaging science system – finally leave the solar system. We've also witnessed some extraordinary imagery and data acquisition carried out by missions such as the Parker Solar Probe, the close encounter between OSIRIS-REx and asteroid Bennu, and ozone monitoring by the Earth-observing Sentinel-5P satellite.

Just weeks before Photonics West opened its doors the imaging instruments on NASA's New Horizons mission captured the unusual "lumpy snowman" form of Ultima Thule, and a couple of days later China's Chang'e 4 probe touched down on the far side of the Moon. Recent months have also seen the launch of the Bepi Colombo mission to Mercury, its payload featuring a laser altimeter and an ultraviolet (UV) spectroscopy probe, a laser-cooled atom experiment delivered to the International Space Station (ISS), and the deployment of laser terminals to quickly transmit huge data sets back to Earth from imaging satellites.

In terms of photonics equipment, perhaps most satisfying of all has been the recent arrival of a couple of solid-state lasers on board Earth-orbiting spacecraft.

Laser equipment for cooling atoms in space arrived at the International Space Station in July 2018 on board a Cygnus supply vehicle – seen here being collected by robotic arm. Photo: NASA.

Last August, the European Space Agency (ESA) finally launched its wind-monitoring Aeolus satellite. The first wind lidar instrument in space, it is based around a UV laser and is set to provide far more accurate and detailed monitoring of wind speeds than was previously possible.

Attempts to understand and forecast the wind date back as far as Aristotle in the 4th century BC. Today, wind profiles sampled down through the atmosphere are needed for accurate medium- to long-term weather forecasting, and are critical for modelling climate change. But until Aeolus, this information was not available from direct measurement: the best equivalent came from ground sensors and balloon monitors giving localized point measurements, followed by extrapolation through cloud tracking or computer simulations. Aeolus being in orbit changes that, and for the first time global wind fields can be mapped directly, in three dimensions.

Challenging development

"Using revolutionary laser technology, Aeolus will measure winds around the globe and play a key role in our quest to better understand the workings of our atmosphere," announced ESA following the launch of the 1.4-tonne satellite aboard a Vega rocket last year. "Importantly, this novel mission will also improve weather forecasting."

The ATLAS laser, part of NASA's much-delayed ICESat-2 mission, was launched in September 2018. It will provide high-precision profiles of ice sheets and sea ice for climate studies. Photo: NASA.

But the mission has also proved to be one of ESA's most technologically demanding. Problems with the "Aladin" UV laser, in particular the damage caused to its system optics over an extended operating period, had delayed the original launch schedule by more than a decade. Thanks in part to technical breakthroughs made with a similar source – the green laser at the heart of NASA's similarly delayed ICESat-2 mission – the Aeolus mission now looks set for major success.

A couple of weeks after launch, Aeolus sent back its first data, and in November Errico Armandillo, the retired head of ESA's optoelectronics section, reflected on the development. "Today Aeolus is returning more wind data than all ground-based measuring systems put together," he remarked. "But it took the sustained efforts of ESA labs and technical experts – in close cooperation with the Aeolus team – to make it fly."

In fact ESA set up two new laboratories to solve its laser issues. It called in additional support from the German Aerospace Center to produce entirely new technical standards, which are now being applied to all subsequent laser missions. "The commercial space industry by itself could not have gone to the lengths we took," Armandillo pointed out.

The idea of flying a wind-surveying lidar in orbit was nothing new. In fact it had been explored as long ago as the early 1980s, considered at one time for the ISS. And in fact the technology developed back then is now used to help guide rendezvous and docking operations with ISS-supplying cargo spacecraft.

Initially a high-energy carbon dioxide gas laser was earmarked for the lidar role, before the mid-1990s development of space-worthy pump laser diodes opened the door to far more compact solid-state designs. The Aeolus mission was pencilled in for a launch some time after 2000.

Based around a conventional Nd:YAG solid-state laser crystal, the UV wavelength selected is seen as essential for achieving the high level of back-scatter from both molecular and aerosol components to provide reliable lidar signals. But ESA saw the first signs of trouble in NASA's ICESat mission, which was using a UV laser to map ice. Around the same time, ground tests on Aladin began to show laser-induced contamination of optics.

The key problem was then identified: out-gassing of organic molecules from Aladin's laser equipment was accumulating on system lenses, before being carbonized by the high-energy UV laser pulses. As they grew, those deposits further absorbed the laser's heat, distorting and darkening the optical components.

It meant that the original performance of the UV laser within Aladin was nowhere close to requirements. ESA says that when it ran a prototype version of the lidar system, its laser optics degraded by 50% in less than six hours of operations – not much use for a proposed three-year mission.

"The first solution was to take extreme precautions to remove all organics," Armandillo said. "But this did not prove entirely possible. Even at just a few parts per billion of organics, contamination was still introduced."

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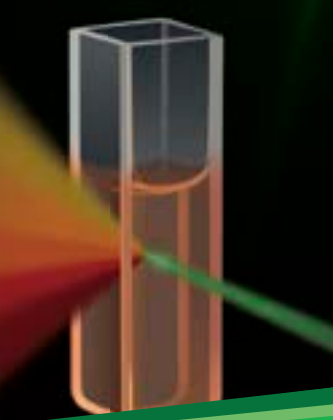

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For more clues the team approached users of high-energy UV lasers in terrestrial applications. That included working closely with two German optics companies, LaserOptik and LayerTec, as well as experts at France's Mégajoule facility – where lasers are employed to ignite nuclear fusion reactions – and the semiconductor industry. In principle, the answer proved remarkably simple. Injecting a small amount of oxygen allowed the contamination to burn up under the heat of the laser, in the process cleaning the lens. In tests, the ESA team says it saw this approach work in a matter of minutes.

Laser breathing

Rather than redesigning Aladin to work on a fully pressurized basis, small amounts of oxygen are released from a pair of 30-liter tanks. The oxygen gas flows close to the optical surfaces that are exposed to the UV laser, and gradually leaks out of the instrument enclosure.

"Just like us, the laser has to breathe," explained laser engineer Linda Mondin in a report by ESA. "It's very elegant because the burnt-up contaminants flow out of the instrument along with this oxygen, in the form of carbon dioxide and water." Only 25 Pascals of residual oxygen pressure is needed – just one four-thousandth of standard atmospheric pressure.

Though contamination was the key issue facing the Aladin team, it was far from the only problem. Heat produced within the volume of the laser transmitter also needed removal. This was solved using 'heat pipes', which cool the laser by evaporating liquid and moving it to a space-facing radiator.

Solving the various problems has ultimately created new technology that is set to benefit a range of future missions. Aladin's development has yielded ESA some world-leading optics and optoelectronics capability, along with a set of ISO-certified laser development standards for other laser-based missions – starting with the "EarthCARE" mission for clouds and aerosol monitoring. Pencilled in for launch in 2021, this will carry an atmospheric lidar instrument based around a 355 nm laser source to profile aerosols and thin clouds.

"It's proved an extremely complex mission, and we've learnt an awful lot about lasers," concluded Rondin, with Aeolus's instrument manager Denny Wernham adding: "The fact we have a high-power UV laser instrument now working in space is testament to all of the hard work, ingenuity, and inventiveness of many dedicated engineers in industry, ESA, and elsewhere.

"Aeolus is a world-first mission that will hopefully lead to many active laser missions in the future, and shows the true value of close collaboration between industry and ESA to find innovative solutions to very tough technical challenges."

"There were so many ways it could go wrong, we were worried," recalled Armandillo following the 2018 launch. "And then it worked! Those first wind profiles felt like Christmas coming early, a really amazing gift."

ICESat-2: up and running

Just as Aeolus and its Aladin laser were starting to return those initial wind profiles from space, NASA launched its 'ICESat-2' satellite from California's Vandenberg Air Force Base.

Like Aeolus, the mission – comprising a single-instrument laser altimeter payload – was delayed and significantly over its original budget. But it has now deployed its Advanced Topographic Laser Altimeter System (ATLAS), flying in a polar orbit at an average altitude of 290 miles. Its job is to monitor annual changes in the height of the Greenland and Antarctic ice sheets, to a precision of just 4 mm.

This master-oscillator power-amplifier (MOPA) laser module was launched on a sounding rocket in early 2017, to carry out the first laser-cooling experiments in microgravity. In November 2018 the German consortium that built it reported that 110 experiments were completed during its six minutes of space travel. Copyright: FBH/schurian.com.

Developed by the Virginia-based photonics and engineering services company Fibertek, the two flight lasers aboard ICESat-2 emit millijoule-scale nanosecond pulses at 532 nm and a repetition rate of 10 kHz. In continuous operation over the three years of the mission, that equates to around a trillion pulses in all – with Fibertek saying that the tough performance metrics represented a significant increase in the complexity and reliability requirements for a space-based laser system.

The optical design of ATLAS splits the laser source into three separate pairs of beams that are fired towards Earth at different angles, such that at ground level there is a 3.3 km gap between the beam pairs. This contrasts with the approach used on the original ICESat mission that flew between 2003 and 2009 but whose laser only operated at 40 Hz, and provides much denser cross-track sampling.

For Earth scientists and studies of climate change, the altimeter should yield a height measurement every 70 cm along the orbiting track, with Fibertek saying that elevation estimates in sloped areas and rough surfaces around crevasses will be much improved.

According to the ICESat-2 team, only about a dozen of the approximately 20 trillion photons that leave ATLAS with each laser pulse return to the satellite's telescope after a round trip that takes around 3.3 milliseconds. To detect those scarce returning photons, the system is equipped with a 76 cm-diameter beryllium telescope. A series of filters ensures that only light of precisely 532 nm reaches the detectors, eliminating any reflected sunlight that might influence the results.

Just three months after launch, ICESat-2 was already exceeding scientists' expectations. NASA said that the satellite

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Earth observation

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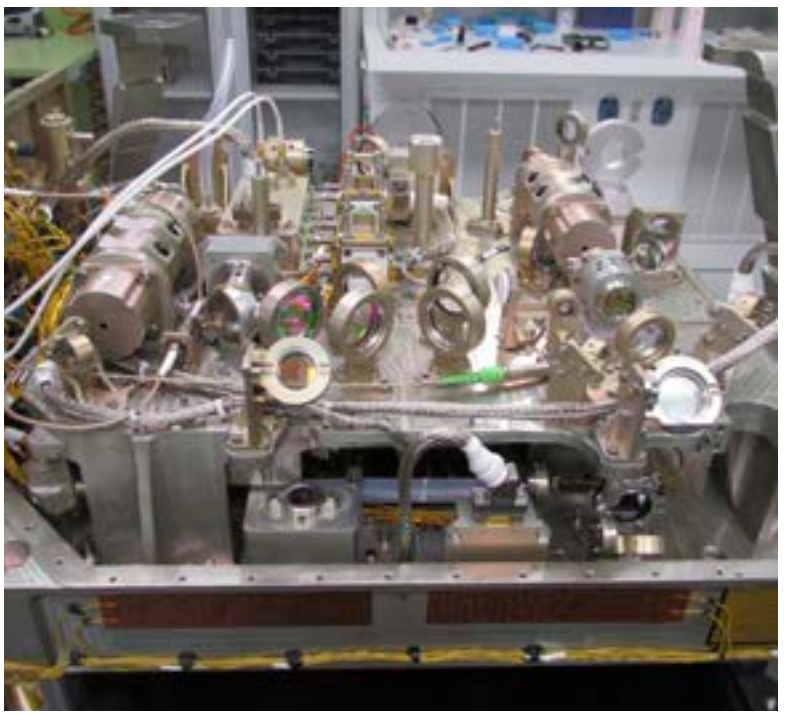
had measured the height of sea ice to within an inch, traced the terrain of previously unmapped Antarctic valleys, surveyed remote ice sheets, and peered through forest canopies and shallow coastal waters.

"ICESat-2 is going to be a fantastic tool for research and discovery, both for cryospheric sciences and other disciplines," said Tom Neumann, ICESat-2 project scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. Neumann and others shared the first results from the mission at the American Geophysical Union's December 2018 meeting in Washington, DC.

"It's spectacular terrain," reported Benjamin Smith, a glaciologist with the University of Washington, Seattle, and member of the ICESat-2 science team. "We're able to measure slopes that are steeper than 45 degrees, and maybe even more, all through this [Transantarctic] mountain range."

The returning photons have shown high ice plateaus, crevasses in the ice 65 feet deep, and the sharp edges of ice shelves dropping into the ocean. Those first measurements will help fill in current gaps in maps of the Antarctic, Smith said, although the most critical science of the ICESat-2 mission is yet to come. As researchers refine their knowledge of exactly where the instrument is pointing, they can start to measure the rise or fall of ice sheets and glaciers.

"Very soon, we'll have measurements that we can compare to older measurements of surface elevation," Smith said. "And after the satellite's been up for a year, we'll start to be able to watch the ice sheets change over the seasons."



The Aladin laser, seen here in ground tests before launch, is at the heart of the Aeolus satellite. It is now in polar orbit, providing direct measurements of global wind patterns for improved weather forecasting. Initial results are said to be excellent. Photo: Selex-ES.

Cold Atom Lab

Not long before the launch of the Aeolus and ICESat-2 sources, another laser system made its way to the ISS, where it is now carrying out quantum research inside the orbiting Cold Atom Lab (CAL). Part of a scientific payload that arrived in May 2018, it is based around commercial laser equipment and capable of trapping potassium and rubidium isotopes.

By July, the space lab had produced Bose-Einstein condensates (BECs) of rubidium atoms in orbit for the first time, controlled by scientists on the ground at NASA's Jet Propulsion Laboratory (JPL) in California. Robert Thompson, CAL project scientist and a physicist at JPL, said at the time. "It's been a long, hard road to get here, but completely worth the struggle, because there's so much we're going to be able to do with this facility."

Although shrinking the BEC-making equipment to the size demanded for launch to the ISS has been a huge challenge, the advantages of the environment are enormous, from the point of view of quantum experimentation. Unlike on Earth, the persistent microgravity allows scientists to observe individual BECs for 5-10 seconds at a time, and to repeat measurements for up to six hours every day.

In fact this was not *quite* the first cold atom experiment in space. In January 2017 the "MAIUS-1" sounding rocket launched a diode laser system for laser cooling and rubidium atom interferometry to an altitude of 243 kilometers, before returning to the ground. Developed by Humboldt University Berlin's optical metrology research group, initial results confirmed that it was possible to carry out research on laser-cooled atoms in space, and in November 2018 the German consortium reported that it had carried out a remarkable 110 experiments on BECs during the six minutes of space travel that were possible.

Another diode-pumped solid-state laser currently traversing the solar system sits inside an altimeter setup destined for the planet Mercury. Launched by the ESA in October, the Bepi Colombo probe is a collaboration with the Japan Aerospace Exploration Agency (JAXA).

Designed and built by a Swiss-German-Spanish team led by engineers at the University of Bern, the altimeter kit will be used to map Mercury's topography and surface morphology in unprecedented detail, and is said to be the first such instrument developed for a European interplanetary mission. Based around a Q-switched, nanosecond-pulsed Nd:YAG source operating at 10 Hz, it will fire relatively high-energy (50 mJ) bursts of 1064 nm light at the planet, and collect reflections from the surface around 5 ms later using a silicon avalanche photodiode, via a narrowband filter.

Elsewhere in the solar system, NASA's OSIRIS-REx mission has just completed its approach to the asteroid Bennu, where it is now in close orbit. Ultimately, it is set to grab a sample from the surface of the orbiting rock and bring it back to Earth, but before that Bennu had to be mapped in considerable detail to ensure that the spacecraft could be maneuvered into exactly the right orbit to achieve the close fly-by.

That operation relied on another laser altimeter featuring a lidar scanner, to generate a detailed three-dimensional map of Bennu's shape. Built by the Canadian Space Agency, it will help the OSIRIS-REx team identify the best location from which to grab a sample. Two lasers are on board: a high-energy source to scan the asteroid at distances between 7.5 km and 1 km from the surface, and a second low-energy emitter that can be used for rapid time-of-flight imaging down to 225 m.

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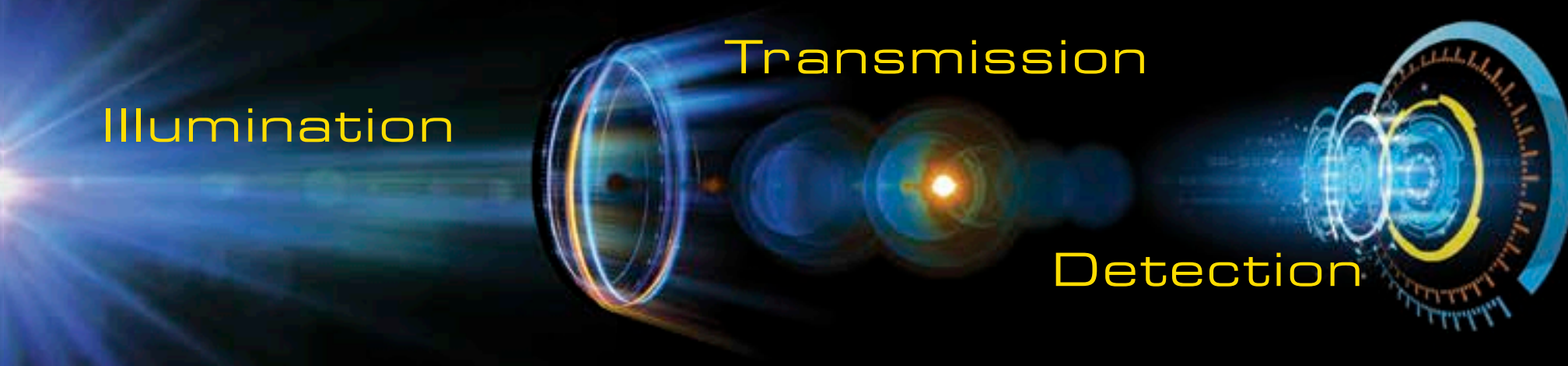

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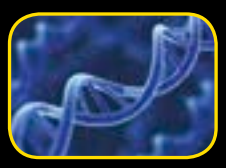
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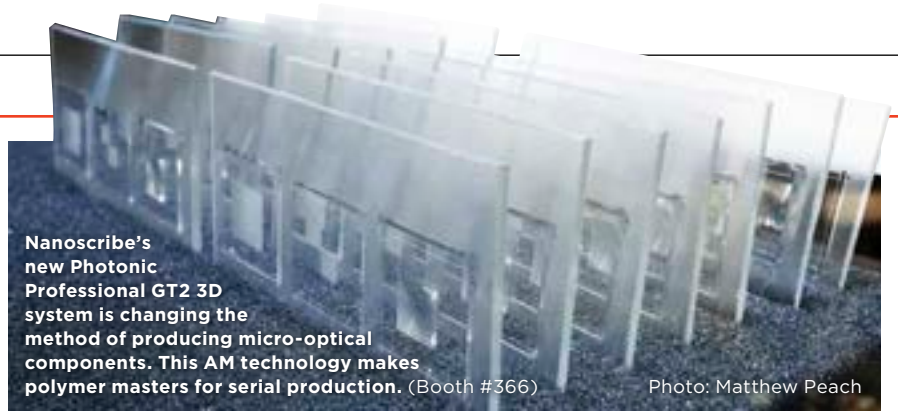


Nanoscribe's new Photonic Professional GT2 3D system is changing the method of producing micro-optical components. This AM technology makes polymer masters for serial production. (Booth #366) Photo: Matthew Peach

'Speedier, smarter' 3D world

Faster speeds and more detail are must-do items for the future of 3D printing. Taking six days to grind out a single part is unacceptable, a panel of four 3D experts agreed.

Industry panelists saw the needed 3D evolution on the horizon. The 3D Printing and Industry 4.0 panel included Ralf Kimmel of Trumpf; Melissa Orme of Morf3D; Behrang Poorganji, of GE Additive; and Lynn Sheehan of Allagi Inc.

Kimmel said that if 3D can achieve higher productivity, that will mean faster printing, "and the payoff will be a shorter build time. Multiple lasers and better performing scanner systems are required for the next step," Kimmel said. "We will see multiple lasers working on many scanners, well coordinated and synchronized, with better control of the power over the beam path.

"Control over power distribution together with scanner performance is key."

Today, if a scanner comes to an edge, it slows down, and then has to accelerate again, he explained. "You must correlate all this, the speed, power, and movement position. There is a lot to do.

"It is happening, but we're not on a perfect level. To be more productive, you need to add more operating systems."

For Orme, the current powder bed approach, now at 50 microns diameter, needs to go smaller, to 10 microns in diameter. She admitted powder bed will remain the standard. "It is necessary, and we can make very complicated parts can be made. But it's just a step to whatever the future technologies will be. In 20 years, perhaps there will be technologies other than powder-bed fusion that will be faster, with better resolution, and finer details.

"We need 3D to be able to make parts faster, at higher resolution, and cheaper. I'm certain new technologies will point the way to reach those goals."

At GE Additive, Poorganji said 3D additive manufacturing is "the new revolution," from medical to automotive apps. "We are expanding our inventories," he said, using power from 25-100 µm, and 3D has created a $5 billion cost efficiency.

GE analyzed an A-CT7 aircraft engine and found that 70 percent of the engine could be 3D printed. And they found that engines with many parts made in a single 3D printing have more durability, can save fuel, and weigh less, with up to 60 percent reduction in time to market.

At Allagi, Sheehan said a hardware set called Opticus for monitoring additive manufacturing makes a digital twin of a part being created. It can stop the process and even fix the problem, he said.

FORD BURKHART

Changing how we see light

On Tuesday, a panel of LED lighting experts provided examples of the innovative applications that go well beyond the simple replacement of conventional sources with more efficient LEDs. The panel offered insights into the technology innovations that are providing new benefits and capabilities that were never achievable with conventional sources.

In his opening remarks, panel moderator Robert V. Steele noted that the lighting market is undergoing a transformation of a magnitude not seen since the invention of the incandescent bulb. Energy efficiency and cost savings have been the main drivers of this transformation, but other factors, such as light quality, color tuning, and controllability, have become equally important in moving the market forward.

Benno Spinger of Lumileds Germany discusses adaptive driving beam technology. Photo: Adam Resnick

LED technology embodied in lamps and luminaires have captured more than 50% of the $80 billion worldwide lighting market, and the near-complete penetration of this market with LED sources is in sight.

"Several technology companies are now working on controls of various types to control light levels in buildings with occupancy sensors, daylight sensors, etc.," said Steele, a solid-state lighting consultant. "Lumileds and Osram are the major LED suppliers working on adaptive lighting; European auto companies such as Audi and Mercedes are taking the lead on incorporating automotive forward lighting technology into their cars."

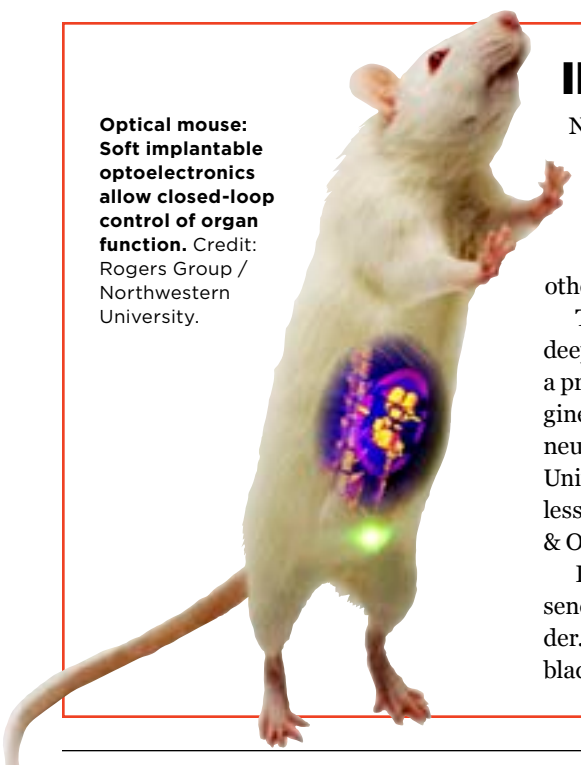
Jay Shuler, Director of Product Marketing at Xicato, opened the session talking about general trends in LED lighting that are going "beyond on and off." As an example, he showed a quick case study being done at the Smithsonian's National Portrait Gallery using controlled lighting to "create a whole new viewing experience for visitors."

Instead of constant bright light being shown on each picture, the lights remain in dim lighting until someone walks in front of the portrait, then the lighting slowly increases to full light, boosting the color as the picture comes into view. After the viewer walks away, the light slowly dims. "This makes for a more interesting display," said Shuler. "This also helps preserve the art."

Benno Spinger from Lumileds Germany discussed Lumiled's work with adaptive headlighting enabled by pixelating LED sources – in particular, adaptive driving beam technology for road vehicles. "At the moment, headlamps are really complicated with the LEDs, it's more of an electro-mechanical system," said Spinger. "These systems can make a complex system much simpler."

The final speaker, Thor Scordalis, General Manager-Americas at Leotek LLC, talked about what he termed "Non-Energy Benefits" of LED lighting. These included improved safety and health of the user, reduced operating and maintenance costs, as well as increased productivity and comfort for users.

KAREN THOMAS



Optical mouse: Soft implantable optoelectronics allow closed-loop control of organ function. Credit: Rogers Group / Northwestern University.

IMPLANTED LEDs HELP MANAGE ORGAN DYSFUNCTION

New soft, wireless implants can monitor and modulate organ behavior using LED light, a demonstration at Photonics West revealed. Implants remove the tethers used in other nerve-stimulation systems.

The technology will be useful in deep brain research, said John Rogers, a professor of materials science and engineering, biomedical engineering, and neurological surgery at Northwestern University and keynote speaker on wireless optoelectronics at the Optogenetics & Optical Manipulation Conference.

In one project, his system was used to send and receive signals from the bladder. The system detected an overactive bladder in a lab animal, and used LED light to reduce the urge to urinate. That approach, Rogers said, could treat incontinence and an overactive bladder.

The wireless systems provide closed-loop control over the nerves that govern organ function and "can eliminate disease or dysfunction without drugs," Rogers said.

His approach uses thin, battery-free implants that control an overactive bladder in animal models using a microscale LED. It emits photons that illuminate nerves in the bladder, where injected proteins make the cells sensitive to light.

Whenever the system detects frequent voiding events, the sensing relies on a soft band that wraps around the bladder to electronically determine, through a change in resistance, the extent of bladder filling at any given time. A battery-free control unit in the abdomen captures that data and sends it to an external PC for an assessment of bladder activity using advanced data analytics.

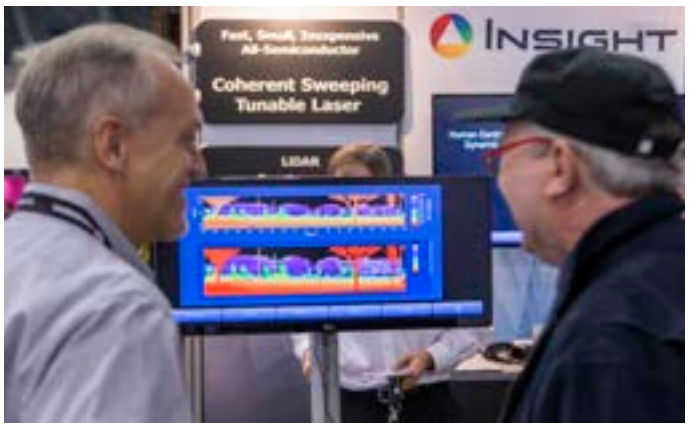
"If overactivity is identified, then a signal is wirelessly passed back to the control unit, which then causes the LED to activate," Rogers said. "The light inhibits the activity of bladder nerve endings, thereby preventing voiding."

Rogers' team has developed an app that runs on a phone to display the data and the system's recommendation, and can let users intervene in the decision to stimulate or not.

FORD BURKHART

Frequency-modulated lidar sensor enhances control of autonomous vehicles

Insight LiDAR has developed Digital Coherent LiDAR, a chip-scale, long-range lidar sensor targeted at the autonomous vehicle market. Digital Coherent LiDAR is based on Frequency Modulated Continuous Wave (FMCW) technology, which offers certain advantages over the current generation of Time-of-Flight (ToF) lidar sensors. This company is a spin-out of Insight Photonic Solutions, a developer of highly linear, swept-wavelength laser sources for imaging and sensing applications.



Screen saver: The long-range lidar sensor targeted at the autonomous vehicle market. Photo: Joey Cobbs

Autonomous vehicles require a variety of sensors to interpret the world around them and to make accurate, timely decisions. While ninety-three percent of autonomous vehicle experts interviewed by UBS investment bank believe that lidar is a prerequisite for autonomous vehicles, today's legacy lidar sensors either do not provide the performance or the price needed for wide-scale deployment. Legacy lidar either does not have the ability to see faint objects at a distance, or it cannot meet industry cost targets, due to expensive laser sources and fiber amplifiers.

Insight's Digital Coherent LiDAR was developed based on more sensitive FMCW detection techniques and software-programmable waveforms that have been used in FMCW radar for over 40 years. Insight LiDAR's FMCW sensor offers a factor of 10 to 100 higher sensitivity than ToF lidar while simultaneously offering direct Doppler velocity measurement.

The higher sensitivity, enabled by FMCW detection, drives Digital Coherent LiDAR's long-range capability; 200 m to dim (<10 percent reflectivity) objects like car tires, and 250 m or more to vehicle bodies, trees, and other obstacles.

Direct Doppler velocity measurement enables much faster recognition and classification of objects, especially critical for safe level 4 and 5 autonomous vehicle operation.

Digital Coherent LiDAR is further enhanced by Insight's proprietary true solid-state, fast-axis scan architecture. This unique feature enables Insight LiDAR to both precisely steer the beam and encrypt the critical fast-scan axis through software alone, with no moving parts.

"It's an interesting time in this market," commented Michael Minneman, CEO of Insight Photonic Solutions. "Level 4 and 5 autonomy needs a level of performance, range, resolution, frame rate, and immunity that legacy ToF sensors just can't deliver."

Couple that to cost goals that can only be met with a true all-semiconductor solution and you see the challenge. "We've been designing and manufacturing the core technology in this FMCW lidar sensor for more than 10 years," commented Dr. Chris Wood, head of Insight LiDAR's development and technology.

"Lidar designers have long known the advantages of FMCW detection, but the critical laser sources have been large and expensive. Over the past ten years, we've developed and refined unique, patented methods to manufacture and control the laser sources driving world-class performance in a tiny chip-scale package."

MATTHEW PEACH

OUTSMARTING TUMORS: LASERS BOOST T CELLS

To fight the toughest cancers – those in the pancreas – an evolving method combines tumor-killing lasers to bolster the immune system by boosting T cells.

The strategy, called immunotherapy, has been developed by Wei R. Chen of the University of Central Oklahoma. Since 1995, Chen's team has been developing a combination of targeted laser phototherapy and injection of an immune system stimulant that releases new antigens.

"We needed to find a mechanism to activate the immune system to fight against the cancer," Chen said. "When a tumor appears, antigens stimulate T cells to kill it.

"But the tumor is very smart, and sends out checkpoints to deactivate the T cells. Immunophotonics counters with a checkpoint inhibitor, to break down the checkpoint so T cells can be activated to kill the cancer cells."

Pancreatic cancer, with few early symptoms, has a low survival rate, leaving up to 80 percent of victims with low levels of T cells and hopeless as the tumor migrates. Chen's approach gives the checkpoint inhibitor more T cells to work with.

His team has started a company called Immunophotonics Inc. in St. Louis, with subsidiaries in China and Switzerland. The biotech company grew out of a meeting of future partners at the 2009 SPIE Photonics West meeting. Chen said getting the team's approach to markets is about five years down the road.

FORD BURKHART

BiOS Hot Topics continued from page 07

BRIGHT ideas

Clare Elwell of University College London opened the session with her research using new optical imaging techniques to understand the human brain, including the Gates Foundation-funded BRIGHT (BRain Imaging for Global HealTh) project. She and her team use functional near infrared spectroscopy (fNIRS) to investigate the impact of malnutrition on infant brain development in The Gambia, and conducting the first brain imaging of infants in Africa.

"We were using NIRS for decades in high-resource areas, unaware of the need for it in a global health project," said Elwell.

Elwell noted how NIRS studies of the developing brain are paving the way for early markers of autism. And following its successful implementation in resource-poor settings, NIRS is now finding application as a brain-imaging tool in global health studies.

Zhiwei Huang discussed the work of his group in the Optical Bioimaging Laboratory at the National University of Singapore with spectroscopic cancer detection. He and his team have developed an integrated Raman endoscopy and wide-field imaging technique for real-time *in vivo* tissue Raman measurements during clinical endoscopy.

"We developed an endoscope-based autofluorescence imaging and spectroscopy system for *in vivo* tissue diagnosis and characterization," said Huang. "Preliminary results show that combining spectroscopy with imaging techniques can improve both the diagnostic sensitivity and specificity for discriminating early cancer from normal tissue."

"We've been to the moon, but still haven't been able to see the lymphatics," said Eva Sevick-Muraca of University of Texas Houston in her opening remarks on aging as seen through the lens of translational biomedical optics. There is strong evidence that chronic inflammation contributes to a number of conditions prevalent with aging, including peripheral vascular disease, rheumatoid arthritis, and Alzheimer's disease, she noted.

Samuel Achilefu, Washington University School of Medicine, with Jim Oschmann. Photo: Stacey Crockett

Alexander Vahrmeijer of Leiden University Medical Center explained how targeted molecular imaging can facilitate precision surgery. "Optical imaging that exploits invisible near infrared fluorescent light has the potential to improve cancer surgery, minimize the time patients are under anesthesia, and lower health-care costs largely by way of its improved contrast and depth of tissue penetration relative to visible light," said Vahrmeijer.

KAREN THOMAS

PHOTONICS WEST. SHOW DAILY

PUBLISHED BY
SPIE, 1000 20th Street
Bellingham WA 98225 USA
Tel: +1 360 676 3290
www.spie.org

EDITORIAL
Original Content Ltd.
Tel: +44 (0)117 939 4887

ADVERTISING SALES
Lucent Media
Tel: +44 (0)117 905 5330

PRODUCTION & PRINTING
Tradeshow Media Partners
200 Valley Drive, Suite 36
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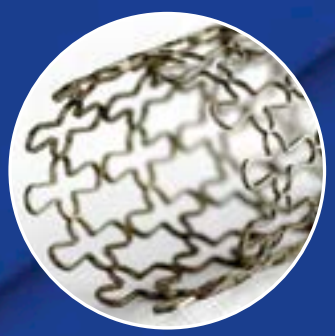

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