PHOTONICS WEST SHOW DAILY

Invisible touch

Visitors to the AR/VR/MR exhibitions get their hands on the latest versions of alternative realities.

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Photo: Adam Resnick

In the 'Quantum Supremacy Age' Google's Trond Wuellner wows. Credit: Adam Resnick

Sustainability is good business thanks to cloud, says Google

In the next wave, we will do ever more of our "compute" on the network, as the old idea of planned obsolescence gives way to sustainability as a "better business model," predicts a top tech guru.

Trond Wuellner, a group product manager at Google, stepped on the stage Monday in the tech supremo uniform of black Tshirt and jeans. Quickly, he mesmerized a standing-room only crowd – he loves to speak of "our compute," a cool touch – for his presentation "Product Design for the Next Wave of Computing."

These are already the days of targeted, specialized computers. "It's part of matrix multiplication," he said. "We are in a superstage, having achieved quantum supremacy. And that says that this system basically works."

Wuellner traced the rise of planned obsolescence in the 1930s with examples from when Pontiacs and Cadillacs stole market share from Henry Ford's uniform Model T, which soared to sell 17 million cars, costing $575. Computer devices did the same, for decades.

In the old days of "product segmentation," a 1930 Cadillac would give way to the 1933 models' new wheels and cute bumpers. That reduced the time of ownership, and, decades on, something similar happened with PCs and the phones in your pocket.

But now, in a time of specialized computers, instead of selling new machines and software, companies will derive revenue from selling

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IMEC drives into the future

IMEC, the Leuven, Belgium-based innovation hub focused on nanoelectronics and digital tech, on Monday, oversaw ITF Photonics 2020, in which speakers discussed the versatility and potential of silicon photonics technology. While silicon photonics is a main way to scale optical interconnects to meet the growing demands of artificial intelligence, cloud computing, telecom and datacom, the technology has applications in many other areas, from healthcare to agriculture and food analysis.

"We position ourselves somewhere in between the academic world and the industry," said Nora Maene, a business development manager. Its facilities provide both breadth and depth in expertise, as well as infrastructure, which includes two clean rooms and multiple labs. It works with hundreds of partners around the world, forming an R&D ecosystem, Maene added. "It's really more of a cooperative approach where our partners learn from us."

"IMEC is unique in its approach," said Brian Sapp, Senior Director of Technical Performance and Partnerships of BRIDG, a non-profit public-private partnership organization in semiconductor R&D, which partnered with IMEC in 2016 to establish a new design center in Florida, dubbed IMEC USA. "They have a broad set of application platforms and expertise, which enables them to create R&D solutions for all types and sizes of projects."

Keep it clean: IMEC technicians enjoys the latest R&D facilities. Credit: IMEC

Today, IMEC has offices across Belgium,

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DON'T MISS THESE EVENTS TODAY.

SPIE STARTUP CHALLENGE FINALS – Healthcare
9:30 – 11:30 AM, RM 2003 (Level 2 West)

LASERS IN MANUFACTURING
10 AM – 12 PM, Industry Stage, Hall DE (Exhibit Level)

PHOTONICS WEST EXHIBITION
10 AM – 5 PM, No. and So. Halls

JOB FAIR
10 AM – 5 PM, Hall C, (Exhibit Level)

EQUITY, DIVERSITY, AND INCLUSION LUNCH & LEARN: Growth Mindset Leadership
12 – 1 PM, Industry Stage, Hall DE (Exhibit Level)

PHOTONICS MOBILITY FORUM
1:30 – 4:30 PM, Industry Stage, Hall DE (Exhibit Level)

SPIE STARTUP CHALLENGE FINALS – Deep Tech
1:30 – 3:30 PM, RM 2003 (Level 2 West)

SPIE STARTUP CHALLENGE AWARDS & RECEPTION
4 – 5 PM, (Level 2 West)

OPTO POSTER SESSION
6 – 8 PM, Level 3 Moscone West

PRISM AWARDS CEREMONY & BANQUET
6 – 10 PM, Marriott Marquis Hotel, Yerba Buena Ballroom

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

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Want to reconfigure images on a chip? DARPA has a strategy for you

A top goal at DARPA these days is to multifunction, providing the ability to select a part of an image, say a battlefield, and look at that content with special software, on a chip.

"That's our desire," said Whitney Mason, a program manager at DARPA, the US Defense Advanced Research Projects Agency, on Monday. "We want infrared imagers that can turn data into information at the chip level. This solves the power problem, the latency problem. Having smart cameras is the goal of all of this."

Field-proven: DARPA's content-based mobile edge networking in action. Credit: DARPA

Mason, whose research areas include novel device structures, optics, and imaging electronics, was the keynote speaker at the Quantum Sensing session. Her focus was on a software-reconfigurable imaging DARPA program called ReImagine.

ReImagine aims to produce underlying readout integrated circuits (ROICs) with "revolutionary capabilities," and to develop underlying theory and algorithms to collect the most valuable information when a sensor is configured for a variety of measurements. These ROICs will show that efficient computation within an ROI can enable real-time analysis on much more complex scenes than traditional systems. The system will deliver "more actionable information to the warfighter than has ever been possible from a single imaging sensor."

Most current imaging systems perform only a single set of measurements. To multifunction with reconfigurable sensors is "an exciting area … one of the biggest things that this program is going to be able to do," Mason said. "We will be able to take different types of measurements across an array. We will be able to change the measurement based on the scene content."

In the selected portion, the user could, say, employ a faster frame rate and a higher resolution for certain objects.

"There are 8 billion cameras in the world," Mason said. "We need to be able to use AI-based embedded intelligence to help narrow down the content from the sensors to achieve the desired image."

She predicted the goal can be reached "in my lifetime," in maybe even ten years. Sony, she said, is already able to do processing against the focal plane array. "We'll see it," she added.

"We are trying to build a technology, not a product," Mason said. It's not a matter of just spotting movement in a scene. "Think about ferns moving on a pond, or bees moving on a pond. We need to pass on only information that is relevant."

FORD BURKHART

IMEC continued from page 01

the Netherlands, in the US, as well as India, China, Japan, and Taiwan. It employs more than 4,000 researchers from more than 90 countries.

Partners pay fees for IMEC's services, which the organization uses to expand its resources and develop expertise in more fields, Maene said. IMEC's revenue has steadily grown since its founding, reaching €583 million in 2018, 72% of which was from industry sources (the rest comes from regional grants, and government and EU funded programs). Its estimated revenue in 2019 grew to €640 million.

The company's services include R&D programs that can span multiple years, with results—and costs—that are shared among multiple partners. One example is the Optical I/O program in silicon photonics, whose partners include foundries, system companies, and fabless accounts. They then share the resulting technology, such as advanced high-speed optical modulators and photodetectors.

But what have become increasingly popular, Maene said, are bilateral projects in which a partner works with IMEC on a specific project. A company might, for example, need help with prototyping a photonics chip. IMEC provides the facilities and expertise to transform their design into a higher-performing device.

In December, 2019, IMEC proposed its forksheet device as an extension of its vertically stacked nanosheet devices. Simulations show that, compared to gate-all-around nanosheet devices, the forksheet device results in a 10 percent performance increase and more than 20 percent reduction in area.

There are many other highlights from the past year. IMEC and TNO, the Netherlands Organization for Applied Scientific Research, presented a new disposable health patch that monitors vital signs, is comfortable, and features a long-lasting battery. IMEC also introduced a radar transceiver that can be used to detect the presence of people, gestures, and even monitor vital signs.

MARCUS WOO

Wuellner continued from page 01

specialized quantum computing at distant cloud sites, Wuellner said. And the "brilliant engineers" at Google are figuring out how to make it happen.

Today, Verizon, Sprint, and AT&T are figuring how to base new business on recurring revenues to subsidize the new networks.

Smart phone growth is slowing. And replacing old phones has its own costs.

"They generate enormous quantities of waste," Wuellner said. "Downturns can go horribly wrong," he added, as he showed a slide of a dreary urban scene that was once a Packard car site in Detroit. New cars soon are ones that "will last forever," and "Detroit could not keep up."

"We overlook the consequences of our business models on the environment and society," Wuellner said. "There are massive negative consequences."

FORD BURKHART

THE LYNX FACES REALITY

The world now has its first standalone mixed reality headset: the LYNX R1. On Monday, CEO Stan Larroque of France-based startup Lynx unveiled the product at the AR/VR/MR conference in Moscone West. Larroque brought the first two prototypes of the device to show off at the exhibit.

The meaning behind the buzzwords? The device is a headset capable of both virtual reality and augmented reality, allowing the wearer to experience either AR, the real world in front of them superimposed with more information, or the canonical fully immersive VR experience. It is "standalone" because it doesn't need to be connected to a computer.

Larroque explained that the headset will primarily be for the business-to-business market, especially to assist doctors in surgery. He wants to develop business-to-consumer apps like gaming.

The heart of the device is a Qualcomm XR2 chip, and it comes with eye tracking, hand tracking, and a battery at the back of the headset.

Larroque, who won SPIE's Optical Design Challenge as a student in 2018, said that the device costs $1499, with expected shipping this summer. Customers can place an order with a $150 down payment. "I can't wait to see people try it," he said.

SOPHIA CHEN

ULTRALIGHT WAVEGUIDE

WaveOptics, a developer of diffractive waveguides for AR devices, launched its new Katana platform at the AR/VR/MR Expo, Monday. Katana features guides that are ultra-lightweight and offer wide fields of view. These waveguides utilize Schott's RealView wafers, based on the company's high 1.8 refractive index glass, already proven in mass production. At only 7 g and 1.15 mm in thickness, Katana is the latest addition to WaveOptics' range of waveguides that product designers can integrate into a range of AR systems.

The partners say this deal "marks the latest milestone in the development of a scalable ecosystem for the manufacturing of wearable AR devices."

MATTHEW PEACH

Katana is the latest addition to WaveOptics' range of waveguides for AR. Credit: WaveOptics

VividQ shows how holography helps AR

Cambridge, UK, startup VividQ has revealed a new prototype demonstrator headset based around its holographic augmented reality (AR) technology at the SPIE AR/VR/MR event in Moscone West.

The world premier showcases the fruits of a developmental effort with Arizona-headquartered Compound Photonics, something that it is hoped will help accelerate the adoption of AR/MR devices across a range of industrial and consumer applications.

Software-focused VividQ says its approach is able to generate highly realistic holograms of any real or computer-generated objects, by reflecting laser light from a high-resolution display capable of modulating the phase of the reflected light's wavefront.

"The phase liquid crystal on silicon (LCoS) displays produced by Compound Photonics are ideal for this application as they give extremely precise phase control and high resolution in a compact and lightweight form factor," announced the UK firm.

Its team has developed the algorithms and software to compute the highly complex phase patterns, and to project holograms in real time, on relatively low-power computing platforms.

Speaking during the AR/VR/MR conference sessions, VividQ CEO and co-founder Darran Milne said that the prototype display "showcases exactly what holographic technology can do for AR."

He added that future work would look towards mixed reality (MR) applications, with the aim of reducing the power budget, expanding the field of view, and increasing resolution to create a more immersive experience for users. Echoing the company's own tag-line, Milne told attendees: "The world isn't flat, so why is your display?"

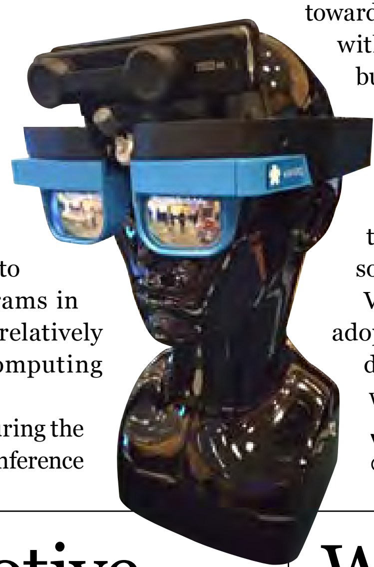
VividQ believes that AR devices adopting the holographic approach devised with Compound Photonics will be able to solve some of the major issues that have plagued AR headsets so far, namely eye fatigue and vergence-accommodation conflict, which can make users feel nauseous.

"These solutions will provide sufficiently bright images at low power and reduce the overall size and weight of future headset designs," VividQ added.

Compound Photonics CEO Yiwan Wong highlighted the company's development of LCoS phase display solutions based on a small (3.015 µm) pixel pitch, and with up to 4 million available pixels. "We see VividQ's computational holography software as a key enabler to providing a complete solution for holographic AR/MR applications," he said.

News of the collaboration comes just a couple of weeks after VividQ said it had raised a further $3.1million in funding from investors including Osram Ventures.

MIKE HATCHER



VividQ's prototype headset. Credit: Mike Hatcher

Intel targets automotive lidar with silicon photonics

Intel is developing its silicon photonics technology platform with a view to applications in automotive lidar. Jonathan Doylend from the Santa Clara chip giant addressed a packed session of the Silicon Photonics XV conference Tuesday, saying that the technology was at "exactly the right moment" in its evolution to help make autonomous vehicles a reality.

Doylend explained that while a camera-only system made autonomous driving possible – in 2017, Intel acquired Mobileye for $15 billion – for truly "superhuman" driving capability it was necessary to have two independent systems capable of driving the car, thus minimizing the potential for errors.

Running through the different lidar options, Doylend said that although the more conventional time-of-flight systems could use existing optics and photonic components, they had a number of issues. Those include requiring high peak power laser pulses to work at long ranges, being prone to cross-talk, and the inability to make direct velocity measurements.

The emerging alternative is frequency-modulated continuous-wave (FMCW) lidar, where a chirped laser signal generates a direct velocity measurements using the Doppler effect.

The downside of FMCW lidar is that it demands some pretty complicated optics and relies on a narrow-linewidth laser. "Enter silicon photonics," Doylend told attendees, detailing some of the work that Intel has done so far to be able to deliver an entirely chip-based FMCW system.

The company's hybrid silicon laser, made by bonding indium phosphide material to a silicon-on-insulator wafer and emitting at 1310nm, is key to making that happen. Building on Intel's initial targeting of optical communications applications, where it has now shipped some 3 million transceivers, Intel's Silicon Photonics Products Division has worked to integrate the emitter element with a combination of beam-splitters, optical amplifiers, and photodetectors needed to produce a workable, all-chip lidar transmitter.

With what Doylend indicated was a large team of people working on the technology at the company, Intel's developers have shown the ability to boost the chirped laser output to 100mW, alongside strong reliability and stability characteristics.

MIKE HATCHER

Intel's Mobileye self-driving technology is based on a combination of cameras and machine learning. Credit: Intel

Wearable NIRS probes monitor brain function

Researchers at the University of British Columbia (UBC) in Canada have tested a new tool that combines electroencephalography (EEG) monitoring of brain waves with near-infrared spectroscopy (NIRS).

Speaking during the opening session of a new BiOS conference dedicated to wearable biophotonics technologies for sports medicine and health monitoring, Shabhaz Askari from the group said the combination device had been tested on five healthy subjects while they were under the oxygen-restricting effect of artificial hypoxia.

Featuring ten photodetectors and two pairs of light emitters operating at 740nm and 850nm, alongside 16 EEG electrodes, the probe was placed on the subjects' foreheads while they experienced reduced oxygen levels for between three and five minutes.

Using it, Askari and colleagues from Guy Dumont's UBC group found that cerebral changes to brain function take place around 10-15 seconds before peripheral effects are seen.

Later in the same session PhD student Anupam Kumar from Vanderbilt University highlighted the development of a new and highly portable functional NIRS (fNIRS) system that is intended to help study measurable indicators of mental health.

Kumar said that the Bluetooth-connected velcro headband, which can already be produced at a cost of just $100, is based around two pairs of LEDs and four silicon photodiodes. Weighing only 142g, the current version operates at 3Hz, although Kumar said that this could be increased to 15Hz.

Audrey Bowden demonstrates a wearable fNIRS brain-monitoring headband, designed for children. Credit: Joey Cobbs

Suggesting potential applications in the study of attention-deficit hyperactivity disorder (ADHD), he added that the headband had undergone some initial validation tests with standard breath-holding exercises that cause blood to rush into the head.

Audrey Bowden, head of the Bowden Biomedical Optics Laboratory (BBOL) at Vanderbilt, demonstrated the headband during Sunday's neurotechnology plenary session.

MIKE HATCHER

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Shedding light on new automotive applications

Light-based applications are increasing as vehicles become autonomous, even if many questions remain concerning LiDAR.

Photonics-based sensing for vehicles is "currently in a very exciting phase" according to Jörg Strauss, General Manager and Vice President Visualization and Laser, at Regensburg, Germany-headquartered Osram Opto Semiconductors. He notes that advanced driver assistance systems (ADAS) that exploit technologies like infrared light-based driver monitoring and pre-crash sensing are becoming more common. "We are even seeing autonomous vehicles on public roads in some communities," Strauss stresses. "The amount of light-based applications within the automotive area increases year by year."

Cars are becoming increasingly driver-friendly, safer and more comfortable, Strauss underlines. "Thanks to automation, drivers have fewer systems to operate manually, allowing them to concentrate more on traffic," he says. "Many systems automate, generate or analyze visible and non-visible light for such tasks. Current examples include adaptive speed control, pre-crash sensors, and blind spot monitoring. Besides this, driver-monitoring systems are getting more important – and will still be relevant for level 3 and 4 of autonomous driving."

Delivering these capabilities challenges car-makers because current ADAS are very complex. "A fully autonomous vehicle, for example, needs a full 3D view of its surroundings for the algorithms to determine the car's next action," Strauss says. "Cameras, radar and Light Detection and Ranging (LiDAR) are the key sensor technologies. Individual systems will be combined. The top players in the field are having fundamental evaluations about which direction their business should go in future."

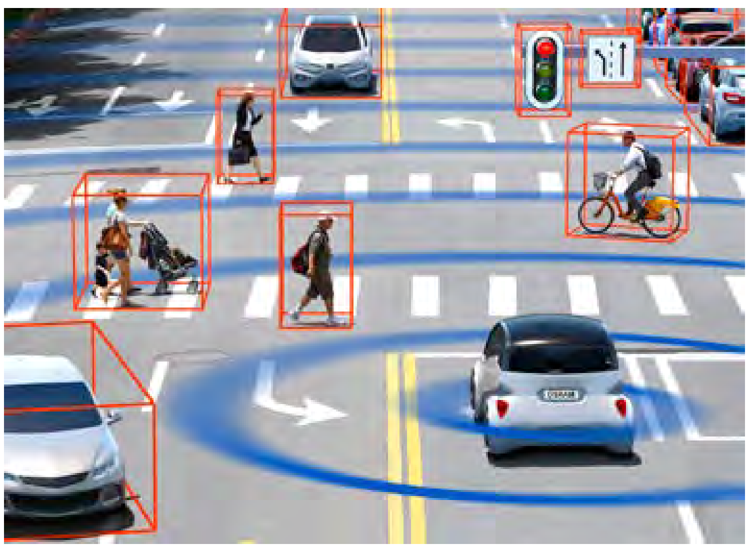
The optical technology getting perhaps the greatest attention for automation in vehicles is LiDAR. "Unlike human drivers, these systems never get distracted, nor do they take precious seconds to act," says Strauss. "Scanning LiDAR sweeps an infrared laser beam across the car's surroundings and creates a high-resolution 3D image. The systems today can detect large objects, such as cars, from as far as 200 meters."

There are two main types of LiDAR systems, explains Jake Li, Business Development Manager – Auto LiDAR, at Hamamatsu, Japan-headquartered Hamamatsu Photonics. In time-of-flight (ToF) LiDAR, pulses of light emitted from a light source travel through space. When they hit objects, light is reflected back and detected by the photodetector. In this approach, Li explains, the round trip time between light emission and return can indicate the distance to an object. Frequency-modulated continuous wave (FMCW) LiDAR looks at the frequency shift between the a reference frequency transmitted and received. This provides information about both an object's distance, and its velocity through the Doppler Effect. Building images requires scanning light across the environment using beam-steering components, such as MEMS mirrors or mechanical spinning mirrors.

"LiDAR is the leading sensor, and for good reason – it provides both day and night vision," adds Joseph Shaw, from Montana State University, US. However Shaw notes that the need to avoid damaging people's eyes, places constraints on laser power, which limits LiDAR range. Larger receiver optics can extend range, but also increase the size of the LiDAR, which must be as compact as possible. Shaw notes that atmospheric conditions including fog, rain and snow all affect LiDAR performance, which "gets talked about less than it probably should." Another challenge is building a picture of the surrounding world fast enough. To achieve this, system designers are increasingly adopting several cheap LiDARs with narrow fields-of-view, rather than an expensive one that scans the entire environment, Shaw says.

LiDAR's unclear outlook

Shaw suggests that the best solution for autonomous vehicles will probably be a synergistic combination of LiDAR and passive imaging. "I've never seen a problem yet that was solved by just one sensor," he says. Shaw believes that thermal imaging is likely to be an important addition because of its low cost, high supply, and ability to see in the dark. Yet he also disagrees with Tesla founder Elon Musk's assertion that LiDAR is "a fool's errand." "Information produced by a LiDAR system is very valuable for the perception problem," Shaw says, superior to visible and thermal cameras alone. "You really can't beat the idea of LiDAR for reaching out into the dark."



LiDAR systems today can detect large objects, such as cars, from as far as 200 meters, pick up a pedestrian 70 meters away or spot road debris at 50 meters away. Image credit: Osram Opto Semiconductors

Yet the stringent automotive qualification process is a key challenge for optics companies looking at selling products for use in LiDAR, Li adds. To pass such tests, carmakers demand reliable performance in harsh and humid environments, over temperature ranges spanning from -40°C to 105°C. Longer detection range is also need-

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New automotive applications continued from page 07

ed, requiring higher power lasers with narrower pulses and higher sensitivity/lower noise detectors to improve signal-to-noise ratios.

Most systems exploit 905nm light, which can be paired with lower cost silicon detectors, Li explains. However, this visible wavelength range imposes restraints on laser power due to greater concerns about eye safety. 1550nm light, which requires InGaAs detectors, is considered to be safer for human vision. Companies can therefore use much higher output sources like fiber lasers at this wavelength, enabling longer detection ranges, Li explains. At Photonics West, Hamamatsu will discuss such issues at an all-day event from 8am on Wednesday, February 5 in Room 2004. At this event, on its booth, which is number #1227, and elsewhere, Hamamatsu will seek to help LiDAR system makers navigate the range of component choices available for the different wavelengths. "Unlike others, Hamamatsu offers a very complete product line of detectors and light sources," Li says. "Therefore we are in the position to provide most unbiased recommendations for each unique LiDAR design."

Reducing cost is also critical to make the devices suitable for the high volumes demanded by automotive applications. Li says that this is forcing LiDAR and component makers to make significant improvements. "We're working on different manufacturing refinements and design changes, to hopefully allow our customers to meet pricing targets," Li says.

Hamamatsu will also present its view on the automotive LiDAR market's challenges and trends at Photonics West, Li explains. He adds that his company can help its customers by offering different levels of optical assemblies and high-level integrations with detector, light source and various electronics in the future. Hamamatsu is working towards enabling more integration possibilities to reduce the manufacturing complexity of LiDAR system designs. All detectors need electronic components like amplifiers to boost output signal, filters to block the ambient light, application-specific integrated circuits (ASICs) for signal processing, he emphasizes. Integrating such components into detector packages provides multiple advantages. Most critical is reducing the number of components needed to put through qualification processes before use in cars, Li says.

Due to such challenges, widespread LiDAR adoption in commercial vehicles will probably start in 2021–2025 in ADAS safety systems, Li says. LiDAR in fully automated vehicles will come in much later, after 2030, although LiDAR will also be adopted in fleet vehicles, buses and taxis, Li adds. Delivery systems, industrial automation, robotics, mining, and agriculture will probably adopt LiDAR before automotive applications. Yet, Li notes great market diversity, with no consensus on the optimum solution, and companies instead exploring different concepts.

Driver monitoring systems will be important all the way through to level 4 vehicle automation. Image credit: Osram Opto Semiconductors

Resolution revolution

Jennifer Ruskowski, Head of 3D Sensors at Fraunhofer Institute for Microelectronic Circuits and Systems (IMS) in Duisburg, Germany echoes this point. "Nobody knows what is right, what is the best choice, and what is the cheapest choice," she says. And when it comes to vehicle automation, which application to focus on is also an open question, Ruskowski believes.

In terms of detector choice, for most designs that exploit 905nm light avalanche photodiodes (APDs) are popular. That's in part because they have good gain and high photon detection efficiency (PDE), Ruskowski explains. But they are difficult to form into arrays, which create the images in many LiDAR system architectures, as they are bigger and "consume a lot of power," she says. This makes it hard to achieve LiDAR resolution necessary for automotive applications. APDs are also sensitive to changes in temperature, making them challenging to use in the extremes of heat and cold vehicles can experience.

As such, Ruskowski sees a trend away from the use of APDs in favor of single photon avalanche diodes, or SPADs. SPADs can be made cheaply using silicon CMOS processes, and their associated electronics are easy to implement, but currently SPADs don't have the same PDE as APDs. That's one of the many aspects of SPADs that the IMS team is working on improving.

And, in the next few years, the IMS will be working to improve SPAD technology to enable 3D integration techniques that will improve other performance metrics. "When you think of flash LiDAR, you need high resolution – VGA or QVGA – it's nice to have," Ruskowski says. "The biggest thing is to achieve a fill-factor with high pixel resolution, and also increasing PDE on the same time." On Sunday morning, February 2nd, in session 2 of Quantum Sensing and Nano Electronics and Photonics XVII, she presented a new SPAD detector architecture for high-resolution 2D arrays.

Another feature of IMS' LiDAR detectors is that it considers weather conditions, in particular "background light," noise originating from sunlight. The researchers implement several algorithms on the chip level, using special measurement methods. This approach enables them to determine sunlight photons because their arrival is not correlated with the emission of a laser pulse. Several SPADs "have to be fired in a distinct time frame before you can say "OK, this is a signal and not sunlight," Ruskowski says. This approach offers an improved signal-to-noise ratio, which allows longer-range measurement distances, even under strong sunlight conditions.

"Due to the fact that we built one component of LiDAR, we tried to build a camera to see how well the detector works, and the improvements that can be seen in our live videos," explains Ruskowski. "We can implement

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New automotive applications continued from page 09

other laser sources and our customers can see what is good for the different applications." A live demo of IMS' flash LiDAR camera with the latest SPAD detector solution will be presented on booth 4361.

Elsewhere at Photonics West, Osram Opto Semiconductors will participate in sessions about blue laser technology and quantum-dot based LEDs, Strauss notes. The company will also present its latest VCSEL products at booth 5447. Markus Arzberger the company's General Manager, Product Line Sensors, will chair the Photonics Mobility Forum on the industry stage Wednesday afternoon. "This session will highlight the growing role of optics and photonics in today's autonomous systems marketplace," Strauss says.

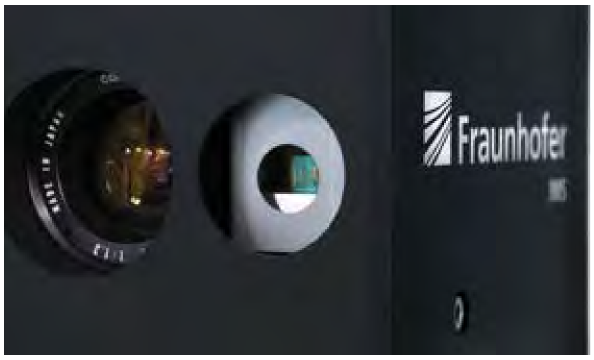
Huge demand

Together with Joyson Safety Systems, Osram's products enable "Super Cruise," the industry's first true hands-free driving technology for the highway. Osram's infrared LEDs, or IREDs, and LEDs, are embedded in Joyson Safety Systems' steering wheel in the Cadillac CT6, Strauss explains, allowing the system to monitor driver attentiveness. "Multi-color LEDs are used to alert drivers if they look away from the road too long and to show the vehicle's autonomous status," he says. Osram also cooperates with Rinspeed, a Swiss automobile manufacturer, which "shows how autonomous cars could look in future." "You get access to the car through biometric identification technologies like facial recognition," Strauss says. "Thanks to Human Centric Lighting, the car adjusts the brightness of ambient lighting to help passengers feel more comfortable."

Osram believes that the more its components improve in terms of brightness and reliability, the more they help the overall systems which are needed for autonomous driving to progress. "It is essential that infrared lasers for LiDAR cover a long distance and enable high-resolution pictures for the infrared cameras," Strauss stresses. "In general, the better each component of the complete system gets, the more reliable they become and the faster they can be adopted by customers."

At Montana State, Shaw works at the system level, designing LiDARs for many different applications, most recently using MEMS devices to scan the environment. In the afternoon of Tuesday, February 4 at Photonics West, he used his knowledge to teach a course called "Introduction to LiDAR for Autonomous Vehicles." "It's a half-day short course that covers the basic principles and physics, as well as the optical layout of LiDAR," he explains. "We discuss the challenges presented by autonomous vehicle LiDAR and how that drives the design and development of new technologies to enable better systems at a lower cost."

Such a course is needed, because ADAS are appearing rapidly, Shaw notes. Currently, ultrasonic systems and radar are commonplace in high-end cars. Radar is the best-developed, fully integrated low-cost solution in ADAS, but it is nowhere near the capability of LiDAR. Shaw believes that there will be a greater uptake

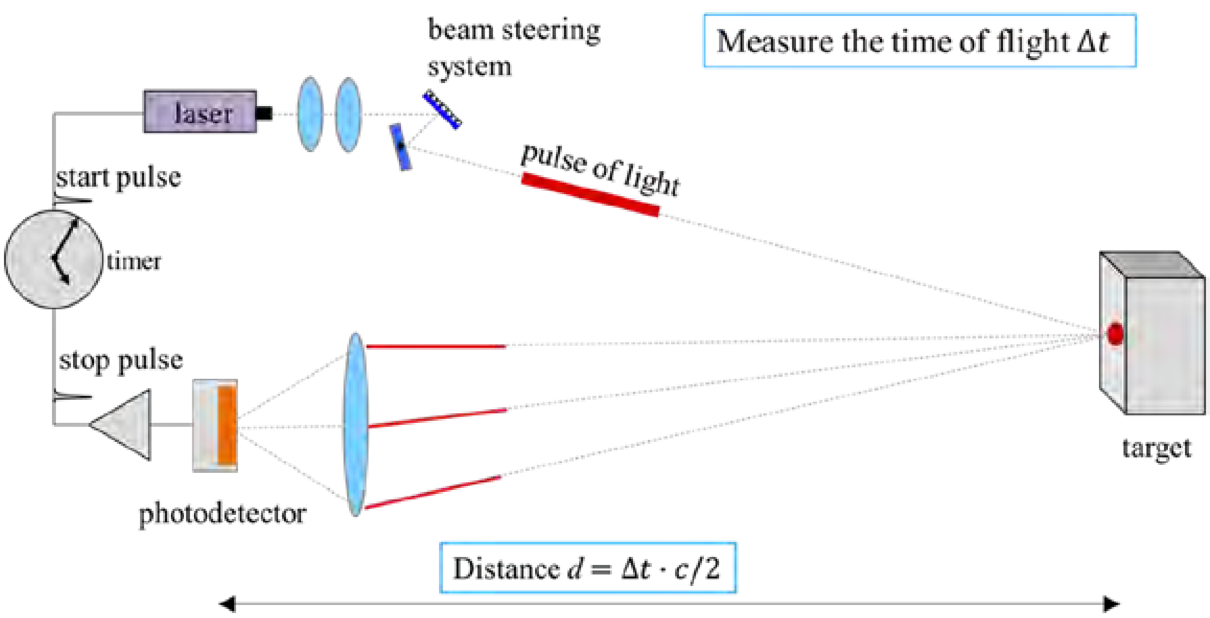


Fraunhofer IMS has built a flash LiDAR camera to show the capabilities of its SPAD detectors. Image credit: Fraunhofer IMS

of LiDAR when full autonomy is a bigger thing. "Behind closed doors, a lot of this is being done very quietly and people are trying to just run faster than each other and then reveal their great product when it comes time," he says. "There's a huge demand for people who can work with the software and hardware of LIDAR systems. But the number of academic programs that actually teach people and give them hands-on experience with designing, building and using LiDARs is extraordinarily small."

Progress in the field underlines the need for better LiDAR skills in particular. "The driver assistance world has grown very rapidly and is becoming quite mature already," Shaw stresses. "There are a lot of sensors that are being deployed already that are very low cost and very practical, but they're nowhere near the capability of the LiDARs that we're considering as tools to be fully autonomous."

ANDY EXTANCE



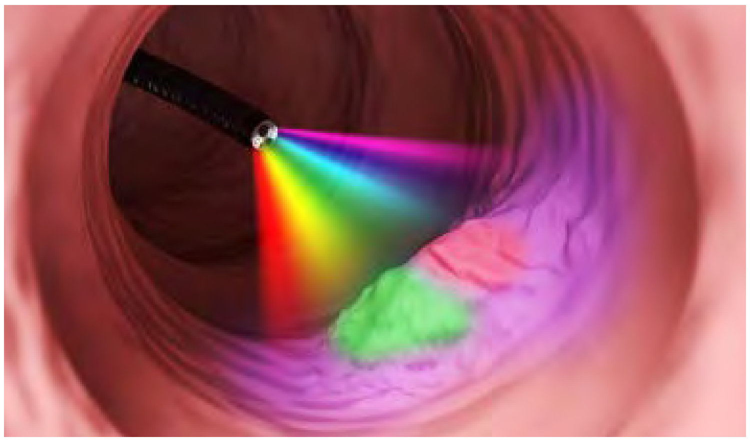
Time of Flight LiDAR uses the time between light emission and detection after reflecting off an object to determine its distance from the detector. Image credit: Hamamatsu

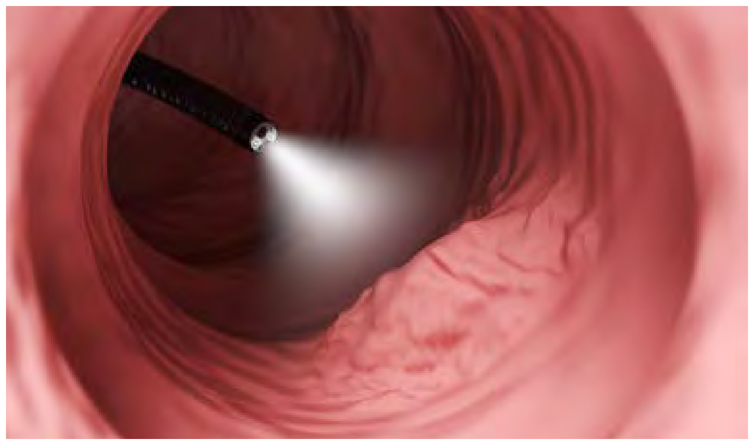
Clinical applications and narcotics detection beckon for hyperspectral systems

As hyperspectral imaging systems become ever more sophisticated, the number and range of applications continues to expand. Some experts believe that future success will require multi-disciplinary teams to develop application-specific solutions, with others pointing to the need for a 'killer' application outside the lab. Could that turn out to be fentanyl detection?

Hyperspectral imaging systems gather and process data from across the electromagnetic spectrum to help users with key tasks like finding objects, identifying materials or detecting processes – and are increasingly used for a wide range of scientific, commercial and other applications.

One of the key growth areas in recent years has been in the field of clinical applications – where a fast and accurate hyperspectral imaging system is essential to overcome challenges related to image distortion caused by patient motion. As Jonghee Yoon, Postdoctoral Associate in the Department of Physics and Cancer Research UK Cambridge Institute at the University of Cambridge, explains, several hyperspectral imaging systems have been proposed recently using advanced filters and computational imaging methods, which show the capability for translation of hyperspectral imaging technologies in practical clinical applications. Alongside the development of hyperspectral imaging systems, artificial intelligence (AI)-based hyperspectral image analysis methods have also been rapidly developing due to the high complexity of hyperspectral data and the need to present such data in a meaningful way to the clinician who has to interpret it to make a diagnosis.





Yoon and his team in Cambridge, UK, are working on a clinically translatable hyperspectral endoscopy (HySE) system and related analysis methods for better diagnosis of gastrointestinal disease – and of esophageal cancer in particular. The latest developments were presented yesterday, as part of the ***Advanced Biomedical and Clinical Diagnostic and Surgical Guidance Systems XVIII*** conference.

"Hyperspectral images contain huge information about spatial and spectral characteristics, which makes it challenging to extract key features. With developing convolutional neural networks (CNNs), AI is becoming more versatile for this application and essential tools in hyperspectral image analysis have emerged over the past year," says Yoon.

At Photonics West 2020, Yoon will be presenting details of his team's work on the development of a clinically translatable hyperspectral endoscopy (HySE) system and analysis methods for the improved diagnosis of gastrointestinal disease – including esophageal adenocarcinoma (OAC), an aggressive cancer with a poor prognosis that has a 5-year-survival rate of less than 20%. According to Yoon, if the early stages of OAC, or preceding dysplasia, could be sensitively detected, outcomes would be 'markedly improved' due to the availability of non-invasive endoscopic intervention. Current endoscopic methods for OAC diagnosis include white-light, autofluorescence, and narrow-band imaging, but dysplastic lesions are difficult to identify due to poor contrast. A novel multimodal approach, measuring tissue images with multiple imaging techniques, has also shown promise for improving the contrast of dysplastic lesions, but currently requires time-consuming sequential imaging and complex optical setup. In order to perform multimodal imaging of the gastrointestinal tract in real-time, Yoon and his team exploited a hyperspectral imaging (HSI) technique that measures both spatial and spectral information at high resolution, which is sensitive to structural as well as biochemical properties of tissue.

"Our hypothesis is that HSI will enable the early diagnosis of OAC by detecting distinct spectral features of dysplastic

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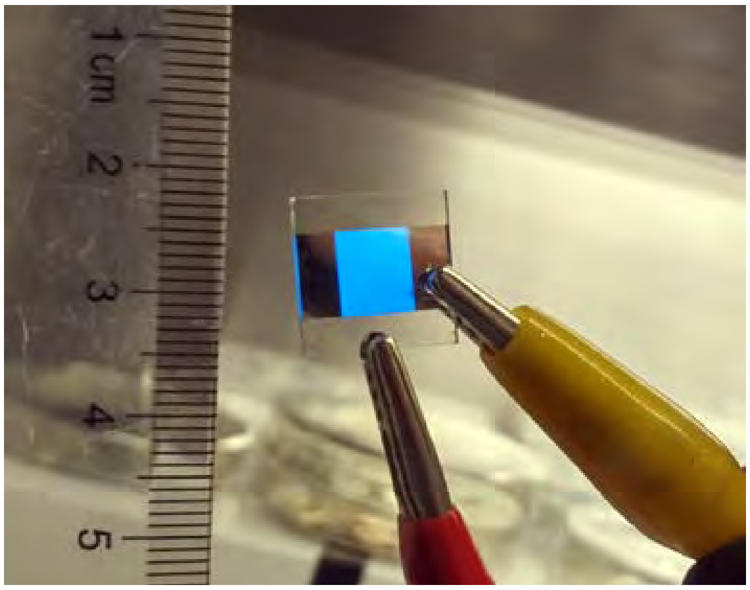
Pushing perovskites past photovoltaics

Using the revolutionary solar material's properties in light emission and detection applications might lead to commercial applications even faster.

Hybrid organic-inorganic perovskite materials have taken solar cell research by storm over the past decade – and now researchers are bringing them to other photonic applications. From a material perspective, photovoltaics and LED applications in particular are very similar explains Yizheng Jin, from Zhejiang University in Hangzhou, China. Other than indirect-bandgap silicon, "researchers recognize that a good photovoltaic material, which possesses low defect density, by definition should be a very good luminescent material," he says.



Yizheng Jin from Zhejiang University and co-workers have made blue LEDs using bromide perovskites, exploiting quantum confinement effects. Image credit: Yizheng Jin, Zhejiang University

It's relatively easy to produce halide perovskites with the formula ABX_3 from solution by mixing low-cost salt solutions together that "work amazingly," says Jin. The A component is typically an organic cation, such as methylammonium or formamidinium, while the B component is a metal cation such as lead or tin. The X is usually a halide ion, like iodide or chloride. It doesn't take strict conditions to grow very good semiconductor crystals, Jin says. Therefore many groups are now involved in studying the material, including outside photovoltaics, with some presenting at Photonics West 2020.

"The remarkable performance of perovskite solar cells can be largely attributed to long carrier lifetimes and suppressed non-radiative recombination rates," explains Yitong Dong, from the University of Toronto, Canada. Both properties come because perovskites can tolerate defects better than other semiconductor materials, thanks to their electronic band structure. Such defect tolerance also enables higher photoluminescence efficiency in light-emitting applications, Dong explains. The perovskite structure is also immune to forming trap defects that in traditional semiconductors restrict movement of charge carriers, he adds.

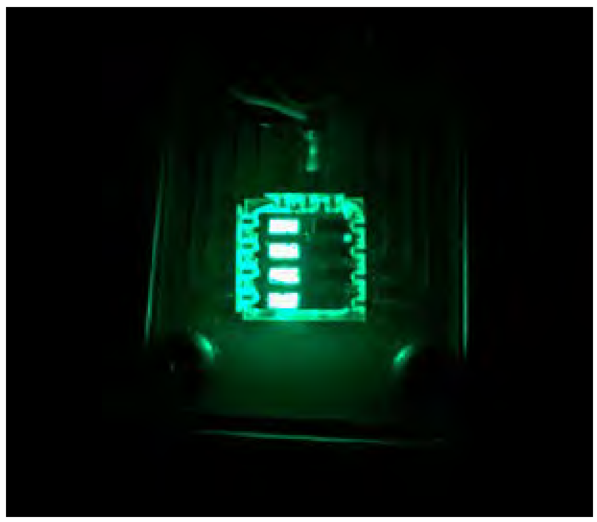
Perovskite materials also have narrow photoluminescence (PL) linewidth, which gives "purer" color emission with similar efficiency, useful in both displays and lasers, Dong adds. Researchers have demonstrated green and red LEDs with narrow linewidth, below 20nm, and high efficiency, he notes. That compares with emission linewidths above 40nm for OLEDs and above 25nm for quantum-dot (QD) LEDs. For lasers, scientists can make single crystals and nanocrystals of perovskites with low defect densities. For example, they have made lead halide perovskite nanowire devices that have very low lasing thresholds around 200nJ/cm² and high Q factors, around 3600, Dong highlights. Researchers have also achieved continuous-wave lasing at around 100K with organic-inorganic perovskite thin films.

The unique way defects behave in perovskites also produce sharp colors, adds Sam Stranks, from the University of Cambridge, UK. "We don't see any emission from defects, which would lead to a broader emission spectrum," he says. The high-quality, pure colors that perovskites offer can also span the entire wavelength spectrum, Stranks adds. "You can tune the color by changing the composition, in principle continuously, all the way from the UV to near-infrared," he says.

Spots and funnels

Stranks' team intentionally used compositional variation within perovskite materials to create very bright "hot spots, where there's lots of emission from particular small regions in the sample," he says. Their project team will present the work in the morning of Wednesday 5 February in Session 3 of *Physics, Simulation, and Photonic Engineering of Photovoltaic Devices IX*. "We can funnel the charges to particular regions in the sample where they're extremely emissive," Stranks says. His team is also studying nanostructured materials for blue LEDs, which are more confined. "That pushes the emission energy further into the blue," Stranks says. "It is a really nice true blue, about 460nm, that we want for the display industry." However with efficiency at just 1%, this is still a very early-stage technology.

Working in Ted Sargent's Toronto group, Dong has helped to develop LEDs that also "funnel excitons to the lowest bandgap emitter embedded in a solid-state mixture perovskite material." The devices are based on "quantum-size-tuned grains," Dong explains. 'These concentrate charge carriers, ensuring high luminescence quantum yield," he says. "We have made high-efficiency bright red and green LEDs based on this strategy." The Toronto team has also investigated interactions between electrons and vibrations in chemical bonds holding perovskite materials together. They varied the A cations, showing that different chemical structures could reduce the detrimental effect that vibrations have on LED performance. "We demonstrated perovskite crystals with high photoluminescent quantum yields and narrow emission linewidth, promising for LEDs and lasing materials," Dong says.



Sam Stranks' team at the University of Cambridge has produced green LEDs using $CsPbBr_3$ perovskite. Image credit: Miguel Anaya, University of Cambridge

Other potential applications that Sargent's group has investigated include using single crystals of perovskite for high-gain, high bandwidth photodetectors and electro-optic modulators. They are potentially promising as photodetectors thanks to their high carrier mobilities and large absorption cross sections, Dong says. The heavy elements that perovskites often contain also mean they could be used in gamma-ray and x-ray scintillators, he adds.

But possibly most impressively, Sargent's team has shown that perovskite quantum dots (QDs) are promising materials for lasing. "They have shown a low gain threshold as well as high Q-factors," Dong explains. "One benefit is low-cost synthesis, as many groups have demonstrated scalable, low-cost, room temperature, perovskite QD synthesis." However perovskite QD stability poses a challenge for applications. Halide perovskites are known for degrading rapidly on exposure to moisture, for example. The Toronto researchers are therefore exploring coatings and other methods to protect them.

More generally, researchers have explored integrating perovskite into silica-alumina materials to boost stability, Dong explains, but the insulating shell harms optoelectronic device performance. Chemical modifications known as passivation likewise seek to protect perovskites. However, they fail to prevent a unique problem originating from their ionic semiconductor structure, namely that the halide X ions migrate through the material. Chloride and iodide-based perovskites have bandgaps in the UV and near-infrared regions, Dong says. Mixing them can therefore provide red and blue LEDs and lasers. "Under heat and electric field, phase segregation happens, and this results in emission shifts," Dong observes. "Compared with perovskites in PV devices, size-confined perovskites are required in light-emitting devices for higher exciton binding energy. This brings more interfaces and potentially more defects, facilitating ion migration."

Seeking protection

Dong also warns that fabricating perovskite LEDs with both high carrier mobility and high photoluminescent quantum yields remains hard, especially blue devices. "The labile surfaces of halide perovskites make inorganic passivation such as core-shell structures a true chemical challenge," he says. Perovskites' electronic structure also makes finding suitable transport layers with good hole injection efficiency difficult, Dong adds.

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

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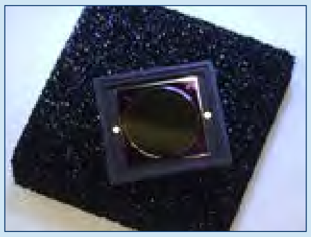

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Perovskites

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Nevertheless, the Toronto group worked with Zhanhua Wei's group at Huaqiao University in Quandong, China, on fabricating and passivating perovskite thin films. Together they produced perovskite LEDs with external quantum efficiency exceeding 20 per cent.

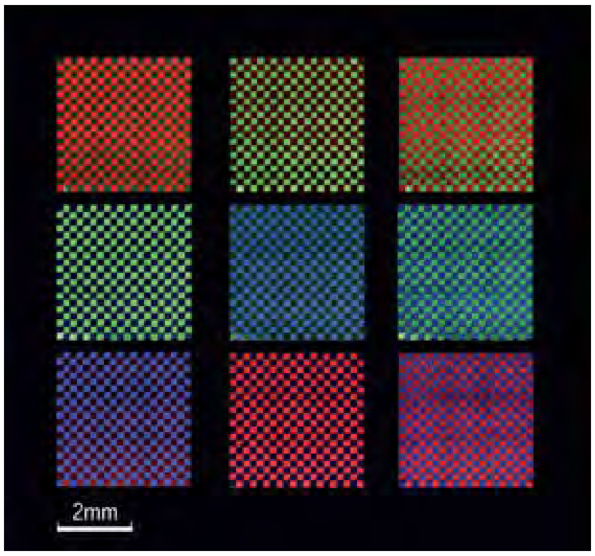
Jin notes that encapsulation techniques developed for OLED technology are potentially suitable for perovskites. OLEDs must withstand "strict and harsh conditions," with packages that ensure low oxygen and water concentration, Jin says. As such he feels extrinsic instability is "solvable," but intrinsic instability arising from ion migration is a "more challenging problem" in LEDs and lasers compared to photovoltaics, because the electric field strength is higher. LEDs "put about 2-4V into a 100nm layer," Jin says. "In photovoltaics there is 1V over about 500nm."

Nevertheless Jin believes "that we can conquer this problem in the near future. As long as we can adjust the intrinsic ion migration problem under working conditions, I am very optimistic on this material for light-emitting applications," he says. That's partly because the Zhejiang University team recently developed an approach to make efficient blue perovskite LEDs without needing problematic mixed halides. "Our approach is to use the quantum confinement effects to enlarge the bandgap of the bromide perovskites," Jin says. To achieve that confinement, the researchers used bromide perovskite nanocrystal QDs. Working together with Richard Friend's University of Cambridge team, and other co-workers from China, the approach attained 9.5 per cent external quantum efficiency.

Another key problem often brought up for halide perovskites in photovoltaics is the fact that they almost all use lead as the B atom, with other options like tin performing less well. Yet as lead brings toxicity concerns, many think perovskite devices should avoid lead. Jin thinks that this should be easier in light-emitting devices. Photovoltaic cells have more stringent restrictions on charge transport, to enable generated current to flow and leave the device, and bandgap, to absorb the right color light.

"For LED material, the restriction on the material choice is a little bit looser," Jin says. "We can find some other lead-free materials." Jin goes further still, suggesting perovskite semiconductor devices may succeed in niche light-emission and light-detection applications before they do so in photovoltaics. "I think the challenge of photovoltaic applications is still huge, because crystalline silicon is very good, very stable," Jin says. "There are so many things that semiconductors can do, and perovskite is a very good solution process semiconductor."

There's "quite a bit of activity" looking at lead-free perovskites for consumer



Using polarizing filters, 3D-printed perovskite nanowire LEDs enable adjustable multicolor displays. Image: N. Zhou et al., Sci. Adv. 5, eaav8141 (2019)

electronics, Stranks notes. "For example, double perovskite structures and other nanocrystal, nanostructured versions of perovskites that are lead-free are starting to come through that are quite interesting," he says. "In terms of performance they are still far behind the lead-based systems. Generally, there is this family of lead-free materials that seem to be very promising for emission, it's just whether we can actually control the emission recombination and process them into devices. There are lots of examples out there where seemingly toxic materials are used but in such low quantities and in well-packaged and well-protected forms that it's not an issue. I wouldn't say it's a showstopper, but it's something that of course the field will keep innovating on."

Exploration and progress

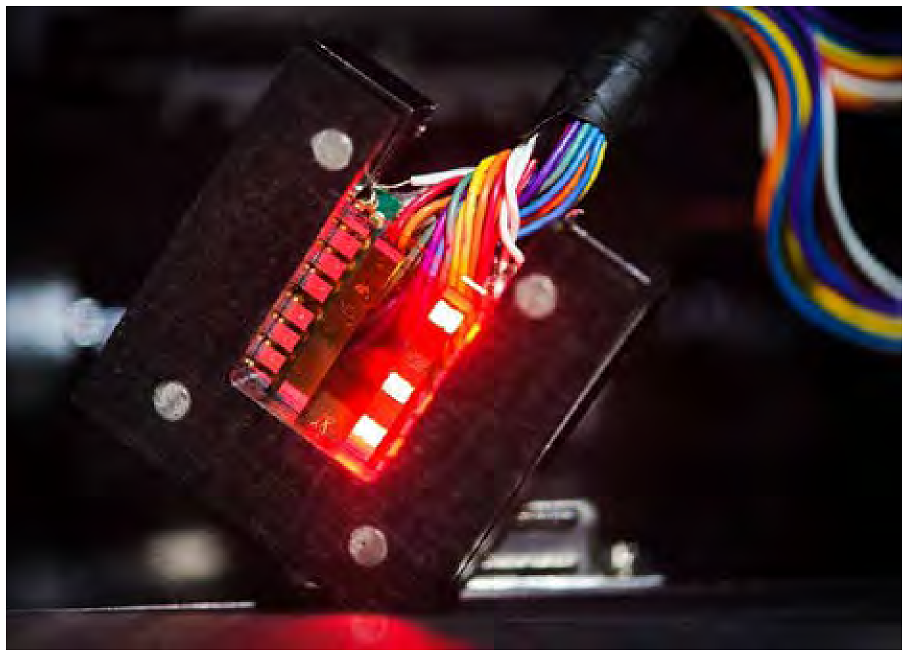
Stranks believes that the charge densities found in LEDs and lasers will make stability a much harder problem to resolve. "This is the real challenge, to move from something that in a lab we can show as a reasonable efficiency, to show that efficiency can last for a sufficiently long time," he says. "It seems encouraging that from the PV side we have made a lot of progress compared to where we were even three years ago. They're now extremely stable." Design is understandably crucial. "You can take a solar cell as is and run it in reverse and you get light out," Stranks says. "But to make it an efficient light emitter, we do have to design it in a different way. We use tailored charge injection layers, rather than the charge extraction layers used in solar cells. The other factor is, of course, the light out-coupling. We need to ideally design it so that you can maximize the light coming out. That really hasn't been explored that much yet for perovskites."

Mansoor Sheik-Bahae and his group from the University of New Mexico (UNM) in Albuquerque, NM, US, is now exploring perovskites for thermal imaging and non-contact temperature measurements. Existing materials have limitations, he stresses. "You cool to just 20°C below room temperature and thermal cameras typically are not sensitive anymore." In seeking better techniques, his team looks for materials to detect temperature whose photoluminescence spectrum shifts, broadens, or narrows significantly depending on whether they're heated or cooled. Such materials should have good quantum efficiency, so that they don't generate any heat when their atoms are excited. They should also be resilient to thermal cycling.

Recently, Sheik-Bahae's team has been studying QDs made of conventional semiconductors for this application. QDs can easily be mixed with polymers, coated onto arbitrary objects, and detected with inexpensive commercial CCDs or spectrometers, explains UNM team member Alexander Albrecht. These detectors measure when the QDs are excited by UV, and track changes in their emission. "Because you are detecting visible wavelengths, rather than infrared, you can actually get higher spatial resolution," Albrecht explains.

Semiconductor QDs worked well, but degraded quickly, so the team has now moved to perovskite materials. "They're known for having high quantum efficiency," Sheik-Bahae notes. This application should have fewer problems with ion migration, as the QDs have fewer grain boundaries compared to the thin-film counterpart, and are not exposed to long-term electrical current, or even high-intensity light, according to UNM postdoc Davide Priante. "That helps us to avoid photodegradation," says Albrecht. "If they are enclosed in a polymer, which we like to do anyway so we can apply QDs to different materials, they are also protected from the atmosphere. So we actually think that the degradation is not a big problem." The UNM team will present preliminary results from this project in the poster session at *Photonic Heat Engines: Science and Applications II* in the evening of Wednesday, February 5th.

Though halide perovskite research outside photovoltaics is still in its early stages, companies are showing tentative interest. German industrial giant Siemens was recently involved in an x-ray detector review paper, Stranks notes. In the UK, Richard Friend and University of Oxford perovskite pioneer Henry Snaith have founded a perovskite LED startup called Helio Display Materials. "What's interesting is that there aren't yet lots of startup companies like there have been in PV," Stranks says. "We'll see if that changes though."



Researchers at Princeton University have refined the manufacturing of perovskite LEDs. (Photos by Sameer Khan/Fotobuddy)

Stranks notes that technologies usually take at least ten years from first invention in the lab to commercial products. That would mean that the earliest perovskite LEDs might emerge would be 2022. "But I'm excited," he adds. "It's an area that, if we can stabilize them, if we can get the high performance and the long lifetimes, they could quickly become a mainstream technology."

ANDY EXTANCE

LEDs are just a holding place: get ready for laser LiFi

Laser light offers faster speeds and a longer range. It seems like the way to go for wireless light-based communication. But will fiber optics without the fiber really work?

On October 26, 1958, Pan American World Airways whisked 111 passengers on a Boeing 707 from New York to Paris. With that, the age of commercial jet travel was on. Piston-driven propeller planes would continue, but jet engines such as the one on the 707 flew faster and farther. They would rule the skies.

Now the developers of laser LiFi hope that their own 1958 is coming soon.

Like the early developers of jet engines, they believe they have a technology that will usher in significant strides in velocity, distance, and several other key performance areas compared to the propellers they are trying to replace – in their case, LiFi transmitted via LEDs.

"Any motivation to want to use LiFi to begin with is the reason that one would want to ultimately go with laser LiFi," said Paul Rudy, co-founder of Santa Barbara, CA-based SLD Laser, where he is also senior vice president of business development. "Laser has substantially higher speed capability. You're talking about orders of magnitude faster than any LED."

"Father of LiFi" Harald Haas, a professor at the University of Edinburgh, where he is Chair of Mobile Communications,

Chao Shen, co-founder and technical lead of SaNoor Technologies, the spinout of Thuwal, Saudi Arabia's King Abdullah University of Science and Technology, picked up the thought.

"There are many advantages to using lasers," Shen said. "One can have 100 times higher speed and 100 times longer transmission distance when using laser LiFi in comparison with LED LiFi."

And none other than the man regarded by many as the "Father of LiFi," Harald Haas, sees the technology's future lying in laser light, despite having a commercial interest in LED LiFi. Haas cited several reasons why lasers will emerge, with speed among them.

"It can go an order of magnitude faster – I see a clear path to 100 gigabit per second in the next year or two, and we are looking at one terabit per second in the next five years," said Haas, a professor at the University of Edinburgh in Scotland, where he is chair of mobile communications.

By comparison, 100 Gb/s is 100 times faster than the 1Gb/s that Haas'

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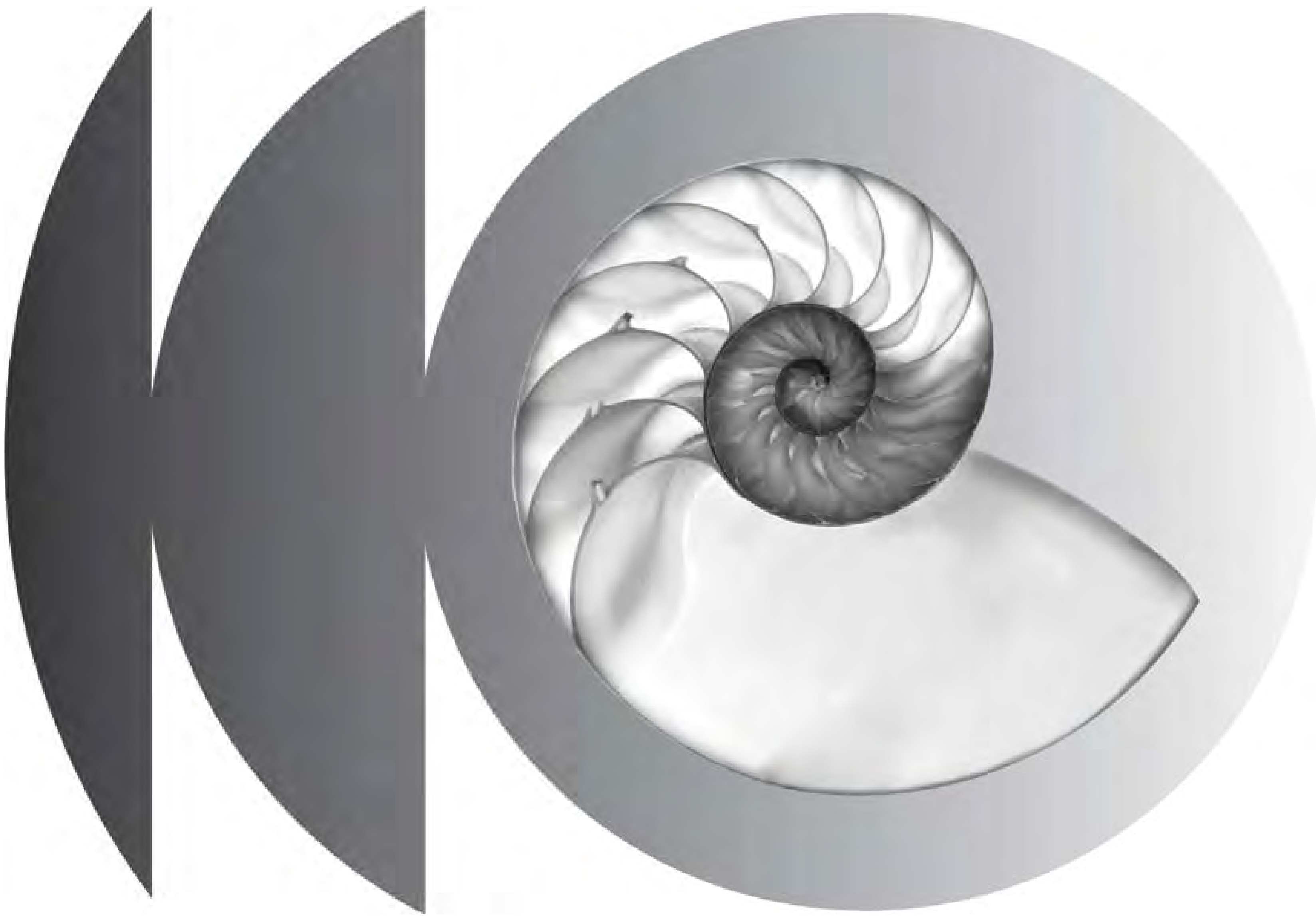


Laser LiFi continued from page 23

commercial enterprise, pureLiFi, has experimentally demonstrated in public using LEDs, and probably 400 times or more faster than LED LiFi has achieved in any practical setting. Add a factor of 1,000 by the time laser speeds hit a terabit.

Shen, Rudy and Haas will all be presenting today [Wednesday, 5th], where they will join a number of other laser and light communication experts in the 90-minute Light-Based Sensors and Communication panel session, starting at 2pm.

They will describe the progress to date and the challenges that lie ahead on the road to making laser diodes a mainstay of wireless data communications.

Light v radio

To appreciate the journey, first, a quick LiFi primer: LiFi, short for light fidelity, is an evolving wireless communications technology that transmits data through the air via a modulated light source. It uses light waves rather than the radio spectrum tapped by WiFi, cellular, Bluetooth and other more commonly known wireless systems.

LiFi comes with other benefits as well. Lightwaves do not cause electromagnetic interference the way radio waves do. That means they can potentially transmit in areas where other wireless technologies can cause problems, such as in hospitals, on a factory floor or in a plane. There's a security benefit too in that they are harder to intercept than radio waves because they require a direct line of sight to the light source – they do not travel through walls.

Although LiFi traces its commercial roots back to 2012 when Haas co-founded pureLiFi in Edinburgh to deliver LiFi through LED light sources, it has yet to take off in any big way.

One reason is that makers of smart phones, laptops and gadgets have yet to embed LiFi receivers in their devices, the way they do with WiFi. And they look unlikely to do so until at least 2021, as a standards battle drags on between backers of protocols from the Institute of Electrical and Electronics Engineers (IEEE) on the one hand, and of an approach endorsed by the International Telecommunication Union (ITU) on the other.

Until then, end users will have to attach USB sticks or other types of optically equipped "dongles" to their devices in order to communicate via LiFi.

Meanwhile, optical specialists like Shen, Rudy and Haas are working hard at advancing the state-of-the-art, trying to move it from LED chips to laser chips.

"Why would anyone want to use LEDs [for LiFi] in the first place? The answer is LEDs are in light bulbs today, are safe and reliable and you can leverage the fact that the cost structures are already sort of consumer style," noted SLD's Rudy.

Horses for courses

"LEDs are wonderful for lots of things, but LEDs are not high-speed devices," he continued. "What's happening is you're getting data rates that are pretty similar to WiFi. Maybe you'll get tens or hundreds of megabits per second. But you're not going to get 10 or 20 gigabits per second from a high lumen light bulb that lights up a room. LED LiFi is constrained by the device."

A high-speed laser LiFi transmitter developed by SaNoor Technologies allows the LiFi transmission data rate going beyond 10 Gb/s. Credit: SaNoor Technologies

And as SaNoor's Chen explained, the device – the LED – uses a fundamentally different and slower light emitting process than does a laser chip. The LEDs' spontaneous emission technology is paced by a relatively sluggish electron link, while the stimulated emission of laser chips can be modulated at much higher frequencies, meaning much faster connection speeds can be delivered.

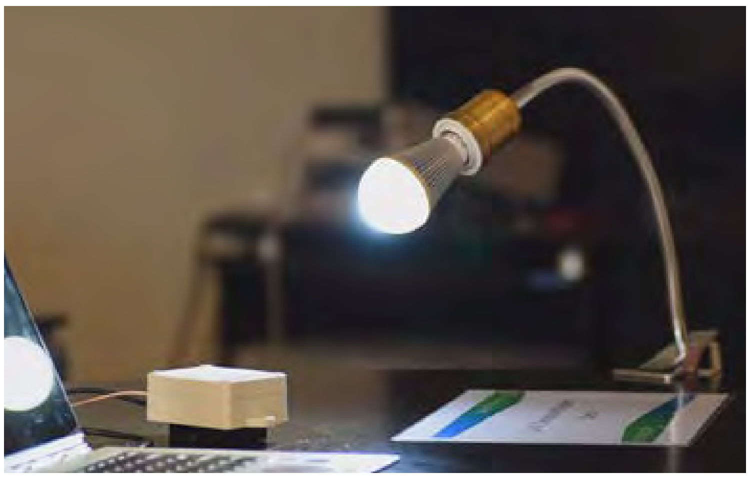
With that and other attributes working in lasers' favor, Haas at the University of Edinburgh is confident of breaking speed barriers. As part of a joint five-year project led by the University of Leeds and including Edinburgh and the University of Cambridge, Haas foresees demonstrating 100 Gb/s speed "within one-and-a-half to two years."

The project, called Terabit Bidirectional Multi User Optical Wireless System for 6G (TOWS) does not intend to stop there. As its name implies, it is targeting a terabit a second, a threshold it thinks it can hit by March 2024, when not coincidentally its £8 million funding from the UK government's Engineering and Physical Sciences Research Council (EPSRC) expires.

The project also includes a long list of external academic and industrial collaborators who have pledged support from around the world.

One of those collaborators is Airbus, perhaps because laser LiFi enthusiasts believe that the technology could become a medium for plane-to-plane or plane-to-ground communication. (Air France recently trialed LiFi-delivered data service on a Paris-to-Toulouse flight aboard an Airbus A321).

Other industry collaborators include Babcock International Group, Cisco, Microsoft, Deutsche Telekom and the BBC. From academia, King Abdullah University of Science and Technology – which will also be part of today's Light-Based Sensors and Communication panel – is connected to the project, as is China's Tsinghua University and the University of Science and Technology of China, as well as Britain's University of Oxford, University College London, and Bristol University, to name just a few.



A high-speed laser white light bulb developed by SaNoor enables more than 1 Gb/s data rate LiFi communication link. Credit: SaNoor Technologies

In the distance

SLD, which already makes laser light sources that emit light at a distance for illumination purposes such as flashlights and car headlights, is adapting them for LiFi communication purposes as well, with some amount of speed and distance trade off. Rudy noted that an SLD flashlight is currently capable of throwing light across a kilometer; that sort of distance could probably handle data transmission speeds of around 10 Gb/s, he said.

Haas envisions distances even longer than a kilometer, a target that he called "only a threshold." While his Edinburgh team thus far has maxed out at about 80 meters at a Gbit per second speed, he is confident in stretching that distance. "We'll see how much we can get beyond a kilometer," he noted.

A lot of the work on laser LiFi will proceed in lockstep with work on laser lighting in general, as developers try to move laser chips more and more into general and specialty lighting applications.

But while laser light for general illumination might compromise on communication specifications, the speeds and feeds should still be superior to LED LiFi.

Laser LiFi will come in a variety of forms. Sometimes laser chips will be purpose built for LiFi communications, with no illumination in mind. Case in point: SaNoor's Chen noted that infrared laser LiFi could overcome the efficiency challenges that face high-speed laser LiFi, so SaNoor is working on infrared.

But it is also developing green and blue lasers, again not for illumination, but specifically for data transmission underwater, where infrared is ineffective. In fact, underwater is a major target application for SaNoor, to help marine exploration vehicles transmit data to ships, buoys and so forth. (SaNoor also makes lasers for illumination underwater and in other settings).

Collectively, Chen, Rudy and Haas see a broad set of applications for laser LiFi, as it potentially helps on-road cars and trucks communicate with each other, supports vehicle-to-infrastructure communications, plane-to-ground, plane-to-plane and so on.

It could also become a broadband transmission technology when outfitted on streetlights. Another potential application: Haas sees laser LiFi supporting individualized replays at sports stadiums that focus on particular players and might include augmented reality features.

It will come with plenty of challenges. While lasers in principle can modulate much faster than LEDs, engineering them to do so will take some doing, noted Haas. Equally, in its early stages, high-speed laser LiFi is energy inefficient. He quipped, "We have to make sure that we don't need a power plant next to the transmitter and receiver to make it operational."

"We are only at the start of the LiFi revolution. It is really important to unlock the wireless connectivity of the future."

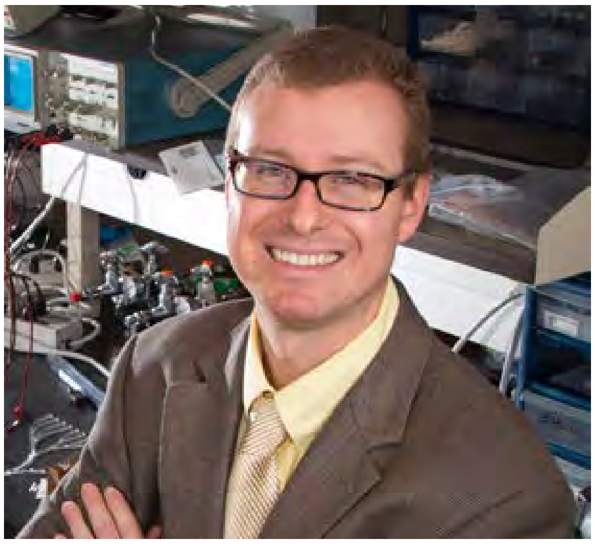
MARK HALPER

Hyperspectral systems continued from page 13

tissue, which is not achievable by conventional color imaging methods," he says.

Among many HSI techniques, a line-scanning HSI method was employed, which Yoon reveals provides a hyperspectral image with high spatial and spectral resolutions and enables flexible adjustments of spectral range and bandwidth of the HSI system. However, controlled imaging conditions are required to allow a wide-area hyperspectral image to be reconstructed from the line-scanning spectral images, a task that is challenging under clinical conditions due to the random and continuous movements of the endoscope. To overcome these issues, the Cambridge team combined the line-scanning hyperspectral system with a CMOS camera that records wide-field images for co-registration of the hyperspectral data – and employed a computer vision technique that extracts spatial features in each wide-field image and calculates geometric transformation matrices (GMs) by comparing features among wide-field images.

"Then a single panoramic image was created by using the estimated GMs, which provides the information required for accurate hyperspectral image reconstruction. Therefore, the HySE system enables free-hand HSI in the esophagus, which enables the translation of the proposed method to clinical applications," says Yoon.



Silas Leavesley, Associate Professor in the Department of Chemical and Biomolecular Engineering at the University of South Alabama

"The developed HySE could be potentially used in clinics for improved disease diagnosis in the gastrointestinal tract," he adds.

Looking ahead, Yoon predicts that the identification of optimal optical properties, including spectral range, spatial and spectral resolution, imaging speed, field of view and illumination power, will be 'very important for clinical applications of hyperspectral imaging technology' in the coming years.

"The ideal optical parameters are likely to vary across the target disease, and thus the development and optimization of hyperspectral imaging systems based on applications would be key trends in the future," he adds.

Fluorescence excitation

Another interesting example of the cutting-edge development of hyperspectral systems is a project at the University of South Alabama, where a team of researchers have been working on the use of optical simulations for determining the efficacy of new light source designs for excitation-scanning high-speed hyperspectral imaging systems. As co-author Silas Leavesley explains, he and his team have been working to develop an approach that is somewhat different from the majority of hyperspectral imaging microscope systems, which typically function by acquiring spectroscopic data that samples the fluorescence emission spectrum. As an alternative, they have developed systems that acquire spectroscopic data that samples the fluorescence excitation spectrum. The system – outlined in a paper entitled *Optical simulations for determining efficacy of new light source designs for excitation-scanning high-speed hyperspectral imaging systems*, and presented at a BiOS poster session at this years' Photonics West – works by scanning illumination wavelengths sequentially, a sampling approach that can provide increased sensitivity for a subset of sample types, while still maintaining the ability for spectral unmixing or other spectral analysis.

> "Our results have shown us that there is an important balance between transmission efficiency, optical path length, numerical aperture, and the number of narrow-bandwidth sources that can be combined."
>
> — SILAS LEAVESLEY, THE UNIVERSITY OF SOUTH ALABAMA

"We began research in developing hyperspectral imaging technologies over a decade ago, when we found that we were limited in acquisition speed and signal sensitivity when using some of the technologies that were then available," says Leavesley.

Development of the fluorescence excitation-scanning technique required modelling and optimizing a range of optical configurations that could provide both high-speed and high-power illumination across a wide range of wavelengths. The team also used Monte Carlo based optical ray trace simulations to perform a range of sensitivity studies, with emphasis placed on the ability to combine illumination output from an array of many narrow-bandwidth illumination sources.

"Our results have shown us that there is an important balance between transmission efficiency, optical path length, numerical aperture, and the number of narrow-bandwidth sources that can be combined. Performing these studies has allowed us to optimize performance for a given application – our main target application thus far has been in fluorescence microscopy," says Leavesley.

In an effort to move the technology towarda commercial reality, Leavesley reveals that he and his team have recently formed a startup company called

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Hyperspectral systems continued from page 27

SpectraCyte, which he describes as an 'exciting extension of conceptualizing and developing a new technology.' Looking ahead, he also predicts that a growing emphasis on quantitative analysis and interpretation of image data, especially microscopy and clinical image data, is a 'likely trend.'

"Hyperspectral imaging approaches provide a valuable tool for quantitative imaging applications. An additional and complementary trend will be the use of machine learning and deep learning in analysis of image data; where again, hyperspectral imaging may prove to be highly complementary to these analysis approaches," he says.

"I believe that key challenges in this field will be in developing hyperspectral imaging technologies that are both sensitive and fast, and in designing analysis and visualization approaches that make hyperspectral imaging data accessible to a broad user base, such as in the clinical community," he adds.

In the field

Meanwhile, imec, Belgium's world-leading research and innovation hub in nano-electronics and digital technologies, continues to work closely with its customers on the development and deployment of a wide range of hyperspectral applications. According to Andy Lambrechts, Program Manager for Integrated Imaging Activities at imec, successful use of the power of spectral imaging, requires control and understanding of 'illumination, lens and other system aspects.'

"Recently, different mobile and portable systems are being developed, in order to enable the use of spectral imaging in the field. This is the next step, to take hyperspectral systems out of the lab, factory or hospital and take them out into the field," says Lambrechts.

"Some difficult projects truly require multi-disciplinary teams to solve them. Hence, application experts, sensor and camera builders, system engineers and data analytics experts are forming these teams and are developing systems that are fully tuned towards the application," he adds.

Recent projects at imec have focused on the use of custom light sources, with miniaturized embedded smart spectral cameras, running real-time object classification in a very compact form factor- which Lambrechts reveals enables 'decision-taking without storing large amounts of data and simplifies the full workflow.'

"The key challenge is that this is not a 'push-the-button' technology. Making it work in a real industrial or medical environment has a great potential, but requires a deep insight in the application as well as in the technology, and not all potential users have that expertise. Key innovations and trends are directed towards easing this effort, by providing spectral imaging toolboxes, tunable components and calibrated systems, from the sensor up to the data analytics. By doing so, we can show the full potential of the technology in many application areas," he adds.

Handheld instruments

Elsewhere, leading spectroscopy consultant Richard Crocombe, agrees that the continued emergence of handheld hyperspectral instruments is a key recent trend – both commercially from companies like BaySpec, HinaLea and Hindsight, and prototypes from research institutes like VTT. This has been combined with the reduction in size, weight and power in instruments made by established hyperspectral imaging companies like Headwall.

"Technologies that enable portable hyperspectral have come from the optical field in general, but also following their use in portable – single spot – spectrometers. These technologies include transmission gratings, linear variable filters, low-cost discrete filter arrays [and] scanning Fabry-Perot filters," says Crocombe.

"Another set of enabling technologies obviously comes from consumer electronics like batteries, processors, memory and high pixel-count CMOS cameras," he adds.

According to Crocombe, who will present an invited paper on portable spectroscopy and hyperspectral imaging at this year's Photonics West, the lowest-cost devices use silicon-based detectors, meaning they operate in the region of ~400nm – 1000nm. Moreover, although a lot of work has been done in that region in the agricultural sector, and some in medical (e.g. oxygenation) he observes that the chemical information available there is 'limited' – and that, for chemical applications, moving to longer wavelengths (e.g. with InGaAs arrays, operating at ~1000 - 1700nm) is required, but the cost will be 'substantially larger, especially for two-dimensional arrays.'

Commenting on general ongoing trends in the development of small hyperspectral devices, Crocombe observes that the hardware is currently 'ahead of the applications' – with portable hyperspectral instruments in a similar position to that occupied by portable single-point spectrometers fifteen years ago.

"The technology is there, but applications, including libraries, calibrations and algorithms are not. In the case of portable spectrometers, drivers came from the safety and security and military communities after 9/11. That jump-started the portable optical spectrometer area, and enabled manufacturers to develop some scale," he says.

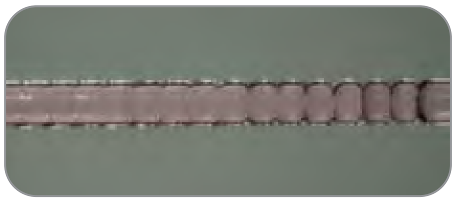
Although he points out it is 'not yet clear' what the commercial drivers will be, or what 'killer apps' will be developed in the field of handheld hyperspectral instrumentation, Crocombe believes that possible areas include 'detection of frauds, detection of contamination and adulteration, and precision agriculture using drone-mounted instruments.'

"Given the extremely high potency of fentanyl and its derivatives, there may also be applications in street narcotics where the active ingredient may be present as sparse particulates," he adds.

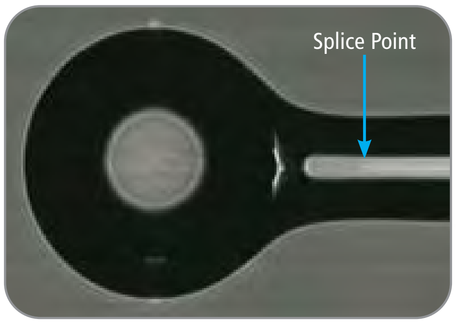
ANDREW WILLIAMS

Snappy: imec's Snapscan hyperspectral imaging camera. Credit: imec

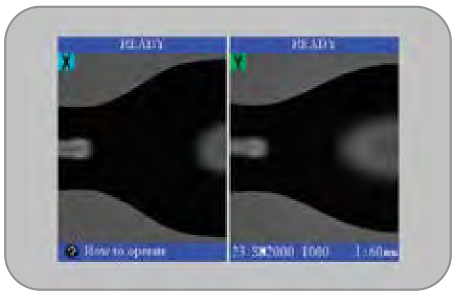
SMART TECHNOLOGY



Laser Ablated Cladding Mode Stripper



Coreless Ball Lens to
Collimate SMF Fiber Output



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The supercontinuum laser celebrates golden birthday

For the 50th birthday of the supercontinuum laser, researchers at Photonics West celebrated with rich chocolate ganache cake. The color of its coconut frosting was, perhaps, a nod to the instrument's signature ability to produce broad-spectrum white light. In several sessions on Sunday, researchers revisited the history and evolution of the instrument and discussed its emerging applications.

The co-inventor of the supercontinuum laser, Robert Alfano, now at the City College of New York, recounted its beginnings. Alfano, working with Stanley Shapiro at GTE Labs (now Verizon), published the laser's seminal papers in 1970. By shining green laser pulses into glasses and crystals, and later in rare gas liquids such as argon and krypton, Alfano and Shapiro demonstrated how to convert the green light into a bright, broad spectrum—white light—via nonlinear optical processes in the medium.

The first supercontinuum lasers, Alfano said, emitted a spectrum spanning from around 400 nanometers to 700 nanometers. Today, its spectrum can extend as far as 1400 nanometers.

One milestone was the invention of a fiber-based supercontinuum laser, said Alfano. These machines allowed for much more compact designs. Researchers are continuing to develop fiber supercontinuum lasers for specific applications such as telecom and biomedicine. Angela Seddon of the University of Nottingham in the UK is developing a mid-infrared supercontinuum laser. She presented her work on glass fibers made of a class of materials called chalcogenides.

Researchers are also looking to improve the laser's efficiency, the rate that it converts the input light into broad-spectrum white light. Alex Risos of the University of Auckland in New Zealand presented a technique, yet unpublished, on how to produce brighter supercontinuum light more efficiently.

The application area projected for largest growth is the medical field, said Mohammed Islam of the University of Michigan. Islam is working to apply supercontinuum lasers to study the frontal lobe of the human brain. His team has developed a machine called SCISCCO, which they have used to perform spectroscopy of an enzyme called cytochrome C oxidase (CCO), a marker of brain cellular metabolism. In their study, they monitored the levels of CCO in 25 healthy participants during an attention test. They found that the levels of CCO decreased during the test.

Abolutely Super: Alex Morrison, NKT Photonics' Sales Manager, US Southeast, with the new SuperK Fianium supercontinuum white light laser source. "Its output is as broad as a lamp and bright as a laser," he says. The SuperK delivers high brightness, diffraction-limited light across the entire 390-2400 nm region. And by adding one of NKT's filters, the SuperK can be converted into an ultra-tunable laser. Credit: Joey Cobbs

Alfano thinks that the supercontinuum spectrum could be pushed under 400 nanometers, which has yet been impossible because shorter wavelengths begin to produce multiphoton effects in the laser's medium. In terms of applications, Alfano highlighted the potential of developing supercontinuum lasers for telecom, "to get into pentabits per second and terabits per second," he said.

SOPHIA CHEN

Quantum Initiative sets ambitious goals

Paul Dabbar, President Trump's Under Secretary of Energy for Science, told *Show Daily* his agency has ramped up its grant programs by about 500 percent in quantum and information science and is vigorously reaching out to industry and academic institutions as the Office of Science and Technology Policy implements the National Quantum Initiative, created in December 2018 when the bipartisan legislation was enacted.

In the months ahead, Dabbar says, there will not be one giant quantum and information development grant. "Rather there will be a number of $20 million chunks in different topics, item by item. They will be in areas like new materials, algorithm development, quantum sensing."

"What's important for us," he said, "is that we are driving America's leadership in computing. We are the pointy end of the spear. With any new architectures, we are the first purchaser of the next thing to be developed in semiconductors."

"We have been, and still will be, driving innovation by being that first purchaser. Whether it's IBM, or Cray or Intel, we will be doing cooperative research with them to build the next chip."

To fire up the research, the DOE has created five Nanoscale Science Research Centers, or NSRCs, located at DOE National Laboratories around the nation. The national laboratories invited to make proposals included the Center for Nanoscale Materials at Argonne National Laboratory, near Chicago; the Molecular Foundry at Lawrence Berkeley National Laboratory, in the San Francisco Bay Area; the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory, in Tennessee; the Center for Functional Nanomaterials at Brookhaven National Laboratory, on Long Island; and at the Center for Integrated Nanotechnologies, jointly managed by Los Alamos and Sandia National Laboratories in New Mexico.

Quantum ready: M Squared's new Equinox single frequency 532nm green laser. In October it was announced that Strathclyde University, Glasgow, and M Squared will develop photonics-based quantum computing technology. Above, M Squared's CEO Graeme Malcolm and Nils Hempler, Head of Innovation. Credit: Joey Cobbs

"Our primary swim lane is research," Dabbar said. In addition to the new NSRCs, the National Science Foundation and the National Institute of Standards and Technology, or NIST, located in the Commerce Department, will be key players in engaging with the private sector to take on roles in the research network, with a goal "to build out the quantum industry" working toward the time of "quantum supremacy," Dabbar said.

"Quantum supremacy" refers to a time when a quantum computer can outperform a classical one at the most difficult tasks. And at that point it could, in theory, help with problems from study of black holes and dark matter to innovation in manufacturing, transportation, and drug development.

"We very consciously included language in the bid section to include not just the national labs but also universities and the private sector, or consortiums thereof," Dabbar said. "We very much want to have flexibility to allow us to open up to the private sector, and frankly that language is there to encourage the possibility of different skill sets working together."

Although the initial research push will begin at the new DOE centers, the agency is determined to involve varied communities as well.

"We think it's a good idea to work with consortia that have other parties who bring different strengths to the table. We want industry players and we would look favorably on proposals that bring different skill sets into consortiums," Dabbar said.

A major administration partner in the quantum effort is the White House Office of Science and Technology Policy, or OSTP, headed by Kelvin Droegemeier, former vice president for research at the University of Oklahoma. Its chief technology officer is Michael Kratsios, one of the top US science policymakers.

The OSTP has also established the NSTC Subcommittee on Economic and Security Implications of Quantum Science. Jointly chaired by the Department of Defense, the Department of Energy and the National Security Agency, the subcommittee will provide guidance on the benefits of and challenges to economic growth and enhanced national security through quantum R&D.

The NQI has set up a National Quantum Coordination Office, or NQCO, to connect up federal quantum efforts.

In 2019, Dabbar and the other leaders put together two recent White House conferences on quantum issues, one for industry, the other on basic research. "We are seeking to do 'user-inspired research,' and to do that we are talking to our potential customers, asking them where we should have our focus," Dabbar said.

FORD BURKHART

Optical groups meet to pool their expertise

On Sunday, SPIE hosted the third meeting of optics and photonics societies. The first was held at SPIE Photonics West 2019; the second at Laser World of Photonics in Munich.

SPIE President John Greivenkamp welcomed the attendees noting that he hoped these meetings would help build relationships and strengthen the global optics and photonics community through cross-society communications and collaboration. He turned over the meeting to SPIE Past President Jim Oschmann, who led the evenings' discussions.

Oschmann recapped the first two meetings, which included discussing outreach activities and plans for the International Day of Light (IDL); reviewing new national initiatives, diversity programs, and anti-harassment policies; and creating a resource bank for sharing information among the societies.

UNESCO representative and IDL co-chair Joe Niemela updated the group on IDL plans for 2020. Instead of holding a flagship event this year, the central focus will be on grassroots events with the goal of having 1000 IDL activities take place world-wide.

Oschmann added that in 2019, the group recommended creating a global PR campaign for IDL and the IPS, OSA, and SPIE worked together with a public relations firm to develop a campaign focused on the general public. The concept was endorsed by the IDL Steering Committee in June. The PR campaign will focus around the tagline, "See the Light" and will be aimed towards raising awareness in the general public around the impact optics and photonics has on their daily lives. Resources will be made available for the optics and photonics community to use in outreach events globally in conjunction with the International Day of Light.

Oschmann announced that SPIE had created resources to help celebrate the 60th anniversary of the laser which included a new logo that is available at spie.org/laser60. He then opened the floor for representatives from each society to share activities from their individual institutions, including market reports, diversity programs, and national policies.

Oschmann closed the meeting by thanking all of the participants for attending and reminding them to take advantage of the resource library and to add materials that should be shared with the group.

SPIE CEO, Kent Rochford in summarizing the event for *Show Daily*, said, "Optics and photonics societies around the world share many of the same interests and concerns, so it's beneficial for the societies to meet regularly and work together on common issues. Photonics West provides a great venue for us to gather, as everyone is already here. We are already reaping the benefits of these meetings by sharing policies and practices and as we discussed tonight, we are looking forward to working together on a fantastic International Day of Light in 2020 as we celebrate the 60th anniversary of the laser."

KAREN THOMAS

Seeing the light: optical societies from around the world gathered at Photonics West. Credit: Stacey Crockett

Equal access to working in photonics: that's a start

From the difference between equality and equity to the more pragmatic issues around hiring women and other underrepresented groups, the Equity in Industry panel at SPIE Photonics West on Sunday generated a dynamic discussion by a group of eloquent CEOs: Openwater's Mary Lou Jepsen, Double Helix's Leslie Kimerling, and Chromacity's Shahida Imani, moderated by SPIE's Career and Diversity Specialist, Meg All.

"Equality," said Kimerling, kicking off the conversation, "is the idea of equal access: we passed the 14th amendment in this country to ensure equal access, and that's a start. But equity is the support that you give people in their work. Are we as managers and CEOs and leaders giving everyone the same support, independent of their gender, religion, sexual orientation? To me those are the real issues around equity."

As a business leader, Jepsen, Kimerling, and Imani agreed, you need to establish and drive companies that ensure equity: that includes fair compensation and proper advancement, as well as, for example, the appropriate approach when employees re-enter the workplace.

This is an area where, Imani pointed out, governments working with industry could help create more equitable structures around maternity and paternity leave. "If you look at Scandinavian countries, they support men taking their paternity leave for up to two years. Look at that model: equal support of males as well as females. Don't exclude the men from this." It's also critical, she added, to be proactive with retention policies. "When your employees return after the life-changing experience of having a child, for example, don't just accept them back, support them – have the compassion and empathy to welcome them back into the workplace from a personal perspective as well as professional one. Don't exclude them from exciting projects, make sure they want to come back to work and that they want to stay."

Recognition is key to retaining underrepresented groups, said Kimerling. "It's really important that people feel like they belong, that people feel that they have opportunities. That's our job: we have to help people to find their place and their confidence so that they can move up. Creating that confidence, hopefully that is my contribution to my employees' experience."

"Technology moves fast," Jepsen added. "If you discriminate, you're going to lose. People join my company because we don't all look the same; people want that diversity. The future is changing all the time: do you want the best talent or not? People ask me how to hire women and minorities and the answer is simple: just hire them. If they're doing a good job, give them more opportunity. The only way you can scale yourselves is if you delegate to other people and see what they can do. Empowerment is so important."

"I think people make choices and that's fine," Kimerling noted of more rigid company structures. "Don't let their choices constrain you. I don't want to spend my life trying to fight someone in order to change their point of view; I want to go find my good people and build my life around them because it's going to be much more enjoyable and more satisfying and probably much more successful. Don't be shy: reach out, find the people who will support you and encourage you and who will enable you and you can reach the stars."

Be resilient, said Imani, to a question from an early career professional. "Keep trying, and don't take no for an answer," a sentiment that Jepsen echoed: "Hunker down and be excellent at what you do and ultimately in doing it you will be recognized. Don't give up.

"Above all, don't forget to utilize the resources available to you. I love Photonics West," said Jepsen, "It's the largest optics conference in the world and you can meet all kinds of people. This camaraderie that you see here, that's been very important to me."

DANEET STEFFENS

The Equity in Industry panel discusses employment policies, supportive leadership, and the importance of perseverance in the optics and photonics professional community.
Credit: Joey Cobbs

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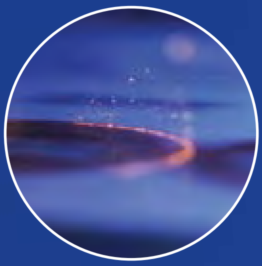
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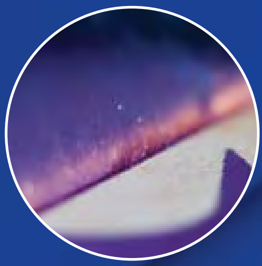
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