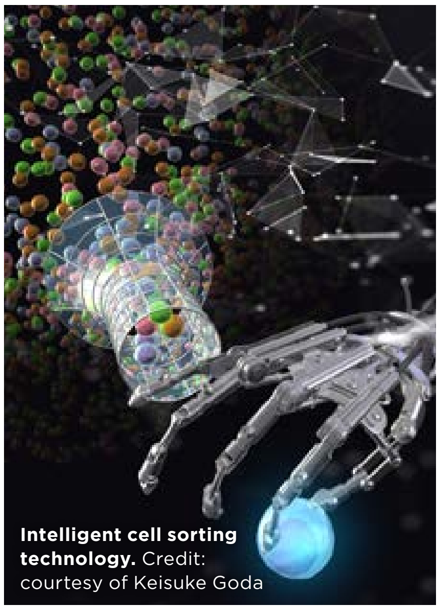
WEEKEND EDITION

SPIE. | optics.org | February 1-2, 2020

PHOTONICS WEST
BIOS SHOW DAILY

BiOS 2020 chairs Wolfgang Drexler and Jennifer Barton have organised a fascinating conference program for attendees.

Dynamic duo energize 2020 BiOS Hot Topics



Intelligent cell sorting technology. Credit: courtesy of Keisuke Goda

The world's largest meeting for biomedical optics opens a new decade of developments in light-based biomedical technologies.

Saturday night's BiOS Hot Topics session will be the first with new BiOS symposium co-chairs, Jennifer Barton of University of Arizona, and Wolfgang Drexler of the Medical University of Vienna. Last year, both Rox Anderson and James Fujimoto retired as BiOS co-chairs after having served 15 years in their roles. At the time, Fujimoto noted, "We know the conference will be in good hands."

Drexler, with nearly 30 years of experience in optical imaging, is head of the Center for Medical Physics and Biomedical Engineering, a large research center that focuses on the development of cutting-edge technology for translational medical diagnosis and therapy.

Barton is director of the BIO5 Institute, an interdisciplinary institute that tackles "big issue" problems, such as how to detect cancer earlier, how to feed nine billion people, and how to ensure a health span that matches our lifespan.

"This is *the conference* in biomedical optics," says Barton. "SPIE has done an amazing job bringing this community together and growing this conference. I feel like I've grown up with it, so it's really exciting to have an opportunity to lead it."

"I feel very honored to be the first European co-chair of this prestigious conference, and being allowed to shape it to continue to be an exciting event for the entire scientific

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Biophotonics revenues rebound

New industry data released this week by SPIE highlights the continuing strength of the biophotonics (* see page 18) marketplace as it recovers from a significant revenue dip in 2015. Industry revenues for 2018 grew to a global total of $121 billion, a compound annual growth (CAGR) of 16% since 2015 [see chart1]. Factors driving this growth include emerging technologies – such as wearables, novel imaging techniques, and the advent of nanotechnology in biophotonics—and societal factors including the aging of the world's population, which is boosting demand for innovative healthcare solutions.

At the Biophotonics Executive Forum during Photonics West 2017, we noted that a combination of pricing pressure and currency effects had caused a global revenue contraction across many of the top public healthcare companies during 2015: At Novartis, for instance, unfavorable currency movement negatively impacted revenues by about 9% and at Johnson and Johnson international sales fell about 13% because of a massive currency drag. As a result of the contraction, total photonics revenues reported in US$ for this segment in 2015 fell to $77 billion.

Since then however, currency markets have stabilized somewhat, and the general economic climate has remained positive, with the result that biophotonics-related market activity has grown steadily. Industry examples include global healthcare leader Abbott – which announced organic year-over-year revenue growth of 7.3%

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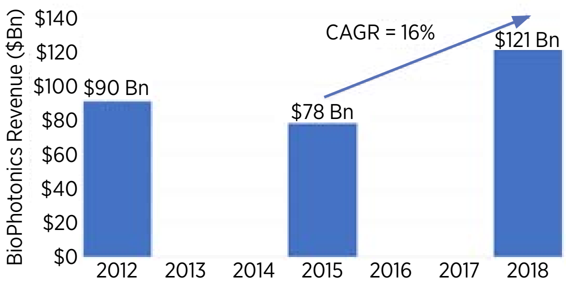
Revenue growth year to year



DON'T MISS THESE EVENTS.

SATURDAY
BIOS EXPO
10 AM - 5 PM, Hall D/E
HEALTHCARE KEYNOTE: Engineering the Future of Health
1:30-2:30 PM, Industry Stage, Hall D/E Exhibit Level
BIOS HOT TOPICS
7 – 9:30 PM, Rm 206/214, So. Hall, Level 2

SUNDAY
AR/VR/MR OPTICAL DESIGN CHALLENGE PRESENTATIONS
8:10 – 10:10 AM, Rm 2007, Level 2 Moscone West
BIOS EXPO
10 AM - 4 PM, Hall D/E
NEUROTECHNOLOGIES PLENARY
3:30 – 5:30 PM, Rm 206/214, So. Hall, Level 2
AR/VR/MR AWARDS RECEPTION
6 PM, Rm 2003, Level 2 Moscone West
BIOS PLENARY
7 – 9:30 PM, Rm 206/214, So. Hall, Level 2

MONDAY
OPTO PLENARY
8 – 10:05 AM, Rm 207/215, So. Level 2
AR/VR PANEL: What is the Potential Market for the AR, VR Industry?
11:50 AM - 12:30 PM, Rm 2003, Level 2 Moscone West
LASE PLENARY
3:30 – 5:40 PM, Rm 207/215, So. Level 2
EQUITY, DIVERSITY, AND INCLUSION PRESENTATION AND RECEPTION
5 - 6:30 PM, InterContinental Hotel, InterContinental Ballroom B, 5th Fl.

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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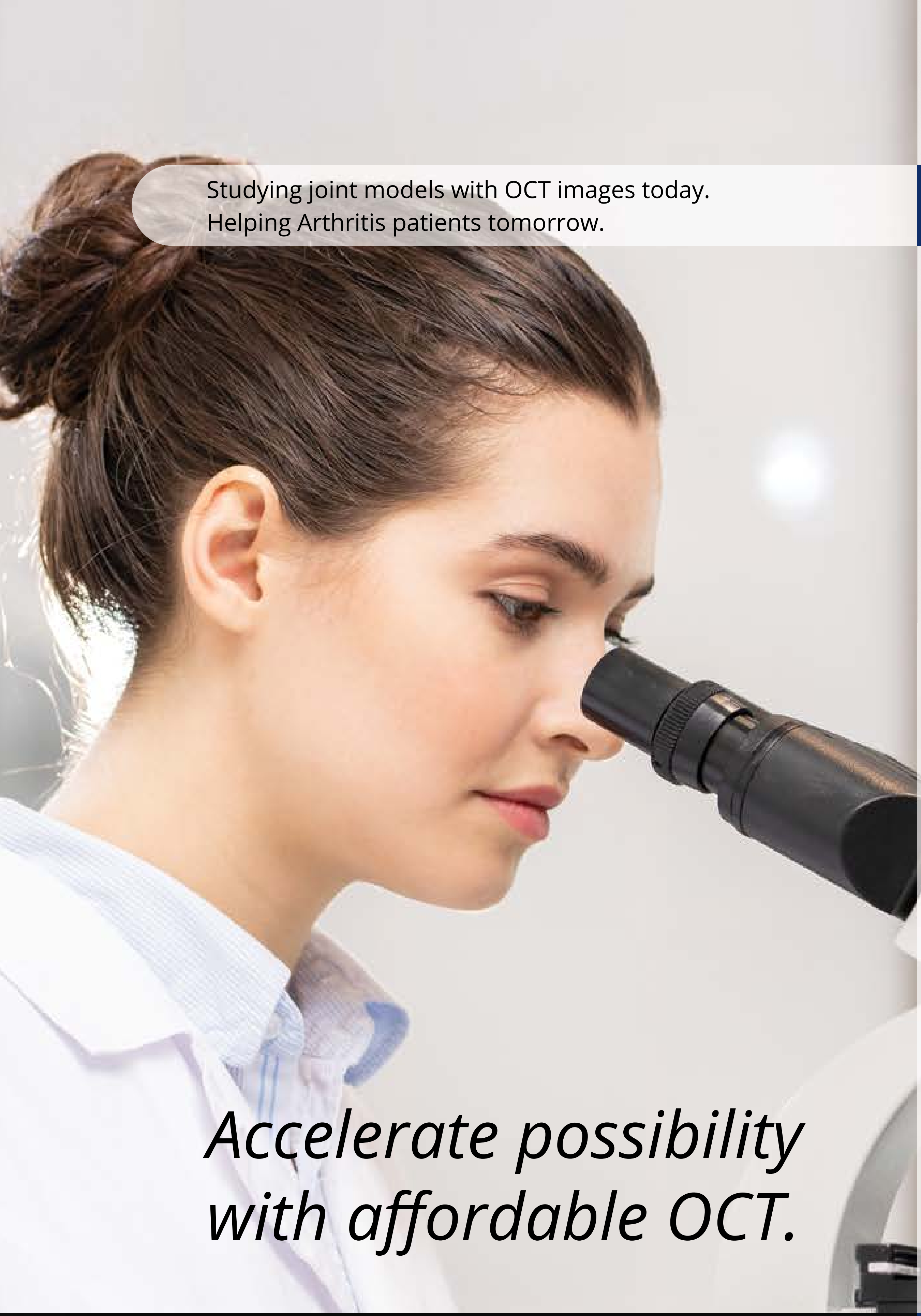
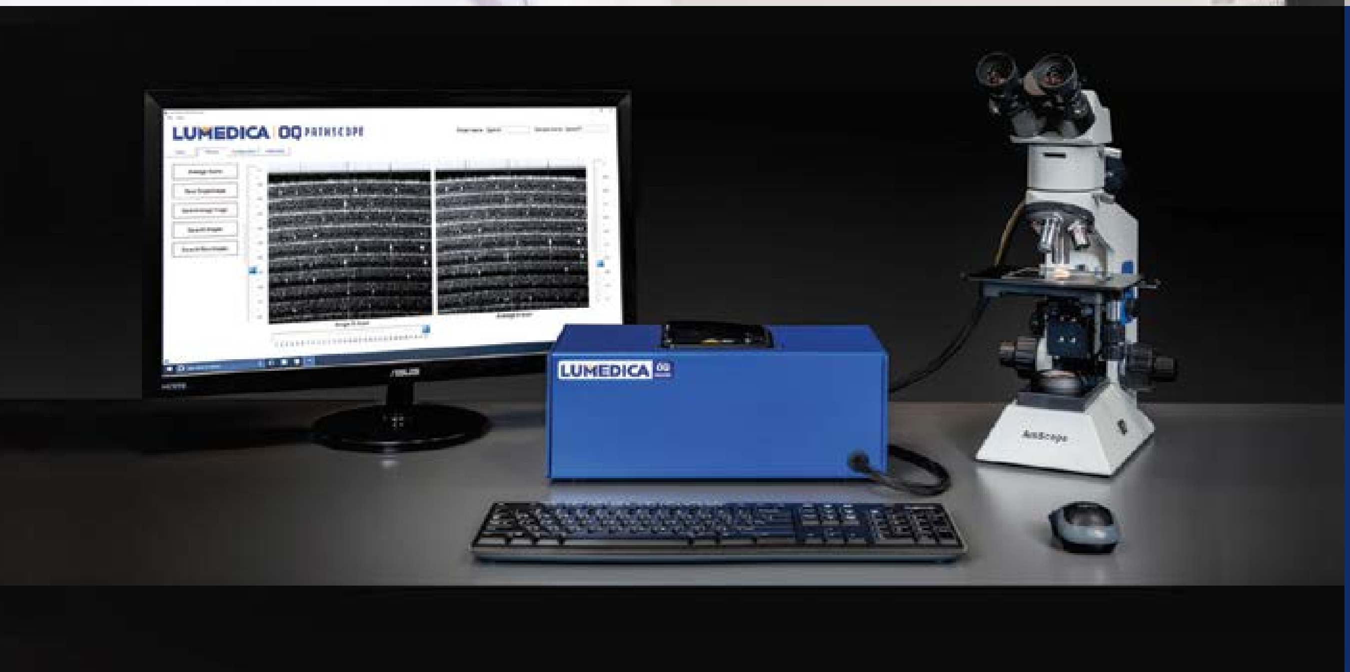

Studying joint models with OCT images today.
Helping Arthritis patients tomorrow.
Accelerate possibility
with affordable OCT.


LUMEDICA
LUMEDICA

BiOS community converges on San Francisco

This city is home to a multitude of biophotonics specialist companies, so besides seeing the latest and meeting the greatest, SPIE is sure you will feel very welcome here.

On behalf of the entire SPIE staff and the BiOS organizing committee, welcome to the most exciting weekend in biophotonics! With over 1300 biotechnology companies in the Bay Area, San Francisco is a fitting place to gather. I hope your travels here were uneventful, and you've arrived ready to learn, network, and enjoy the company of your colleagues from around the world. Together you are all working towards improving the human condition, either directly or indirectly, and your work matters.

This year BiOS will celebrate its 35th year, and has certainly grown since the original conference. BiOS started in 1985 as one conference with 17 papers. This year's meeting will feature 48 conferences and over 2200 oral and poster presentations. While this is an impressive evolution, it pales compared to the escalating impact photonics has had on health and medicine. Of course, this also has economic implications, and data SPIE will release this week shows industry revenues in biophotonics for 2018 grew to an impressive $121 billion globally, with signs for continued growth.

Whether its lasers in dentistry and ophthalmology, wearable health monitors and trackers, or improved imaging, diagnostics, and treatment photonics continues to drive improvements in our health. From imaging inside cells to identifying cancerous tumors earlier, or using mobile phones to test for malaria and imaging neurons to unlock the secrets of the human brain, the work presented in the conference rooms is genuinely inspiring and also reassuring as I get older.

The BiOS Expo continues to grow and features 220 companies whose technology enables many of the breakthroughs discussed this week. Walking the floor and talking with the companies about their new products is always enlightening and offers a glimpse into what may be possible when coupled with a talented research team or a daring post-doc.

Saturday night kicks off the plenary program with the always popular BiOS Hot Topics presentations featuring some of the most cutting-edge research in biophotonics. We will also honor a pioneer in biomedical imaging when we award the Britton Chance Biomedical Optics Award to Steven Jacques on Saturday night. On Sunday, in addition to the Neurotechnologies Plenary session highlighting brain research, is 2014 Nobel Laureate and imaging innovator Eric Betzig. Don't miss the other Photonics West plenaries on Monday and Tuesday, which feature talks on varied topics such as next-generation computing, VCSELs, nanomedicine, attosecond science, and the future of fiber technologies.

Kent Rochford. Credit: SPIE

Starting on Sunday in Moscone West is our SPIE AR/VR/MR event. This co-located symposium grew from the popular events held at Photonics West in 2018 and 2019. Your Photonics West technical badge also gives you access to this exciting event, so don't miss the opportunity to hear the latest from industry leaders and try on the latest hardware. Early applications of this technology in medicine are quite impressive, and teamed with an innovative biomedical engineer the possibilities are endless.

The week offers many networking events, panels, workshops, and technical forums – there is something for everyone. In addition, there are many after-hours events held in conjunction with Photonics West. Make the most all the week has to offer, and be sure to make some new connections and learn from those around you. Have fun, but please remain professional and treat each other with respect. Diversity of thought fuels innovation and SPIE is committed to be welcoming and open to all and free of harassment of any kind. SPIE staff are here to help you make the most of your week, if you have any questions or concerns, please let us know. We are easy to spot; we're the ones with name badges, a smile, and a look of awe at the work you do.

KENT ROCHFORD

BiOS Hot Topics continued from page 01

community," adds Drexler. "In this way I can give back for what I gratefully received over the last 20 years." After an introduction from the new chairs, the 2020 SPIE-Franz Hillenkamp Postdoctoral Fellowship in Problem-Driven Biophotonics and Biomedical Optics will be presented to Fernando Zvietcovich, a PhD candidate at the University of Rochester. The annual award supports interdisciplinary problem-driven research and provides opportunities for translating new technologies into clinical practice for improving human health.

The Britton Chance Biomedical Award will then be presented to Steven Jacques, an affiliate professor in the University of Washington's Department of Bioengineering, who will give a short talk. Presented each year for outstanding lifetime contributions through development of innovative technologies that have facilitated advancements in biology or medicine, this year's award honors Jacques' pioneering work in the field of biomedical optics. "Working in the biomedical optics and biophotonics community has been a lucky pleasure," says Jacques. "People in this group are especially supportive and interactive, and I feel lucky to be spending my career in this community." Jacques will teach a course in tissue optics on Sunday, February 2, at 1:30 pm.

Fingers on the PULSE: Muyinatu Bell (far left) and members of the PULSE Lab on the day of one of their first *in vivo* experiments.

With one hand poised on the buzzer, long-time facilitator and timekeeper Sergio Fantini of Tufts University will open the quickfire, 10-minute Hot Topics presentations, which-will cover new developments in biomedical optics, such as computational microscopy, multiscale quantitative phase imaging, photoacoustic imaging, photodynamic therapy, and nanomedicine.

Let the talks begin

James Fujimoto of MIT will discuss the path of optical coherence tomography (OCT) from its early research stages to current clinical practice. One of the co-developers of OCT, Fujimoto notes that within the relatively short span of 25 years OCT has grown to have a tremendous positive impact on society. This growth is due in large part to a global ecosystem consisting of sustained government funding, academic/scientific research infrastructure, and continuous innovation.

Laura Waller, head of the Computational Imaging Lab at UC Berkeley, describes computational imaging as the joint design of imaging system hardware and software. She will discuss new microscopes that use computational imaging to enable 3D fluorescence and phase measurement using simple hardware and advanced image reconstruction algorithms that are based on large-scale nonlinear non-convex optimization. Waller will further discuss engineering of data capture for computational microscopes in an invited presentation, "3D computational phase microscopy with multiple-scattering samples," on Tuesday, February 4, at 1:45 pm.

Physics professor Sarah Bohndiek is a junior group leader at the Cancer Research UK Cambridge Institute. Cancer screening and surveillance, she notes, often rely on white light endoscopy, where images are relayed outside of the body for review and identification of suspicious areas of tissue, which leads to cancer miss rates of up to 60%. Bohndiek will teach an introductory course on biomedical image analysis Monday, February 3, at 8:30 am.

Quantitative phase imaging (QPI) is gaining attention due to its ability to study unlabeled cells and tissues. However, as Gabriel Popescu, professor of electrical and computer engineering at the University of Illinois points out, QPI lacks specificity. Popescu will present a new microscopy concept, phase imaging with computational specificity (PICS), where the process of retrieving computational specificity is performed in the imaging system, in real-time. He will also teach a course on Fourier optics on Wednesday, February 5, at 8:30 am.

Muyinatu Bell, a professor of biomedical engineering at Johns Hopkins University and director of its Photoacoustic

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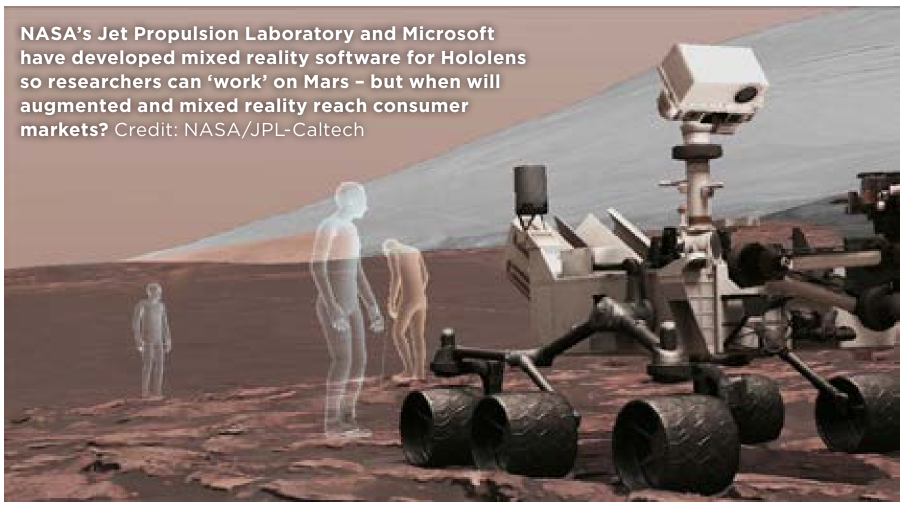
AR, VR, MR 2020: the future now arriving

From Microsoft and Magic Leap to Facebook and Google, the wonderful worlds of extended reality have collided at this year's new standalone event.

Thales InertiaCam.



NASA's Jet Propulsion Laboratory and Microsoft have developed mixed reality software for Hololens so researchers can 'work' on Mars – but when will augmented and mixed reality reach consumer markets? Credit: NASA/JPL-Caltech

When Sergey Brin wore a prototype of Google Glass to a retinal disease charity event in San Francisco in April 2012, the augmented reality headset prompted wonder and dread. Swiftly adopted by many, the first users found the smart glasses fun, more than functional. And while most onlookers expressed curiosity, some felt their privacy violated and labelled the wearers 'glassholes'.

Years later, the headset has, for now, found its niche in enterprise applications. But love it or loathe it, it's difficult to deny that Google Glass' early foray into the wonderful world of extended reality kick-started today's burgeoning industry.

"We've had Palmer Luckey, the 19-year old that put together the Oculus Rift VR headset with duct tape and sold his company to Facebook for $2 billion, and we've got Magic Leap, a recent MR start-up that's worth more than $7 billion," highlights Bernard Kress, Principal Optical Architect on Microsoft's Hololens MR Project, and also instrumental to the design of Google Glass. "The investment in augmented and virtual reality since the Google Glass days has been just amazing, and this has generated a lot of excitement."

And while this industry excitement was palpable at last year's SPIE AR, VR, MR conference – with its 2500 visitors – expect an even bigger buzz this year with 5000 anticipated attendees. As Kress puts it: "We've now graduated from Photonics West and have a fully-fledged conference."

The 2020 show comprises a technical program that looks at how researchers are enhancing the AR, VR and MR experience in Head-Mounted Displays. Kress and Christophe Peroz, Principal Scientist at Magic Leap, chair the Sunday Conference, 'Optical Architectures for Displays and Sensing in Augmented, Virtual, and Mixed Reality' with sessions including technology trends, visual comfort and sensors.

This is followed by more than 40 industry-invited keynotes across Monday and Tuesday. Microsoft, Magic Leap, Facebook, Google and more will provide insight into the latest product developments. As Kress emphasises: "These are industry talks, not technical talks, as this is really what people are looking for. More start-ups are choosing the event to introduce new products – this is very exciting."

Amongst a raft of activities, the AR, VR, MR Expo will showcase the latest XR gear with hands-on demonstrations featuring, for example, new sensors, displays technologies and diffractive holography. And this year's Optical Design Challenge Awards will reveal how students are solving key industry challenges from the size and weight of display engines to improving vision comfort.

Importantly, the keynotes are supported by three panel sessions, with the first led by Tom Emrich, AR Thought Leader from 8th Wall. He will ask 'What is the Potential Market for the AR, VR Industry?', a multi-billion dollar question the answer to which still eludes the community but one that Kress hopes will shed light on consumer use-cases.

"The first Google Glass targeted the consumer but was re-packaged for enterprise markets while HoloLens found real success with enterprise use-cases," says Kress. "Yet venture capitalists and the community still want something to replace the smartphone."

"Everyone in the field is thinking of ways to develop a headset in the form-factor of regular glasses and Apple has at least a thousand people working on this, but I don't see a use-case yet so we're responding with Tom Emrich's panel," he adds.

The second panel session from former Apple and Microsoft Director, Svetlana Samoilova, will ask 'How do we build the AR, VR World with Hardware?' As Kress highlights, this will look at the necessary HMD building blocks and will examine how these should be developed with a system architecture in mind.

In the final session, Magic Leap co-founder, Brian Schowengerdt, will examine the state-of-play of the bright and mighty micro-LED. "We see so much money floating into this display technology so we've invited start-ups to answer the questions; where are we today and how long until we can use the technology?" says Kress.

Participating companies include Sweden-based glō, Aledia, France, Plessey of the UK, Lumiode and Mojo Vision, both from the US, Oculus-owned InfiniLED and JadeDisplay, China. As Kress emphasizes: "We wanted the people that are actually getting the VC funds and dropping the technology on the panel. Everyone wants to know when can they can get micro-LEDs in volume to work them into their headsets – including Microsoft."

Hardware challenges

Micro-LED displays aside, AR, VR, MR communities are also keen to explore the industry's choice of optical engine, which for now remains an open question. Kress is watching developments in Liquid Crystal on Silicon (LCoS) and Digital Light Projector (DLP) microdisplays, and also highlights how Hololens 2 made the bold move to use MEMS laser scanners. Meanwhile other architectures from the likes of Holoeye, Himax and Vivid-Q, are even more daring, developing true holographic display systems.

At the same time, improvements are still required in all optical building blocks to optimise performance and bring down costs, especially for augmented reality. Here, the holy grail is to make an AR headset that looks and feels like sunglasses, but can also overlay additional information and images without causing eyestrain.

One key optical building block, the optical combiner, is crucial to overlaying virtual content onto a real scene without blocking the user's view, which is no mean feat. As Dr Phil Greenhalgh, Chief Technical Officer of UK-based WaveOptics points out: "[Designers] have to present a computer-generated image that's pin-sharp and has accurate colour with a wide field of view right in the wearer's central vision without the light engine getting in the way and obscuring the real world."

"But then we also have to do this with a minimal amount of power while competing with a massive dynamic range of brightness from the real world," he adds. "Sum all of that together and everyone in this field will agree that it's very hard."

Yet despite the difficulties, WaveOptics recently received a hefty $39 million in venture capital funds. Given this, Greenhalgh is taking part in the Photonics West 'Fireside Chat' with Evan Nisselson from early-stage venture fund, LDV Capital, answering questions on his company's success.

And crucially for the AR world, WaveOptics is amongst a handful of companies successfully manufacturing optical waveguide combiners for use in AR head-mounted and near-eye displays. Other companies include Finland-based Dispelix, Lumus, Israel, LetinAR, South Korea, as well as Vuzix and Digilens, both of the US.

Here, the waveguide couples the virtual image from the light engine – typically located in the arms or at the top of a headset – into a glass substrate. This image is then transported through the substrate via total internal reflectance and coupled back out towards the viewing area or eye box.

Right now, the alternative technology, freeform optics, is used by the likes of Google Glass and Nreal of China. But as Greenhalgh points out, diffractive waveguide optics promise huge savings in space and weight compared to bulkier freeform optics. And while optical waveguide combiners are still challenging to

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Bio-inspired tracking: This hybrid visual-inertial system from Thales Visionix provides path integration data – conveying a sense of motion into a sense of location with landmark perception – to assist GPS-based tracking.

AR, VR, MR 2020

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manufacture, Greenhalgh reckons WaveOptics can design a prototype waveguide from scratch in just three weeks.

"Waveguide optical combiners are already used in Hololens 2 and Magic Leap One... and Microsoft and Magic Leap are the only two organisations that have gone public with their technology here," says the CTO. "Freeform optics provide you with great quality, but I believe that waveguides are the only way to achieve mass adoption of AR headsets at a price point that will enable the consumer market."

Best of sensors

In addition to light engines and optical combiners, sensors – from depth mapping to head tracking, gaze tracking and gesture sensors – are critical to the XR experience. As Kress puts it: "You can have the best display in the world but if your sensors aren't up to the task, then the experience will be a joke."

Kress and colleagues will be addressing the challenges in a series of workshops and courses from Sunday through to Thursday at SPIE VR,AR,MR. But as the Hololens Optical Architect highlights, developing low-latency sensors is critical as data needs to be rendered in real time to produce a convincingly smooth and responsive AR experience. "When you move your head, your display has to be compensated," he says. "The motion-to-photon latency needs to be less than 10 milliseconds – any greater and you'll be uncomfortable and nauseous."

Microsoft's Hololens has achieved success in enterprise applications – could it reach consumer markets soon? Credit: Hoshinim/Onetech

With this in mind, Microsoft built a custom chip holographic processing unit for Hololens to swiftly process data from sensors and handle tasks such as spatial mapping and gesture recognition."We're down to 9 ms with Hololens 2 and hope to be close to 5 ms with next versions – but much work still needs to be done to reduce that motion-to-photon latency."

Jim Melzer, Technical Director for Advanced Projects at Thales Visionix, is also no stranger to the issues around sensors. As he puts it: "For good augmented reality you really need good tracking that can figure out where you're looking at any given point – this is tough and not so many people are talking about it right now."

Melzer's interests lie in visual and auditory perception, and recently he has turned to invertebrate vision and animal navigation for inspiration, as reflected in his talk, "Birds do it. Bees do it. A bioinspired look at wayfinding and navigation tools for augmented reality."

As part of this, Melzer and Thales colleagues have developed an operational visual and digital motion tracking system that will track the user, as he or she walks around indoors, without GPS. Melzer reckons the system could be invaluable to emergency services in life-and-death situations.

"Our next step is to develop this to also track where the user is looking – we're working on this right now and it's at an early protocol stage," he says. "Integrating this into a headset is about two years out."

Melzer is also running the course, 'Head-Mounted Display Requirements and Designs for Augmented Reality Applications' at this year's SPIE VR,AR,MR alongside colleague Michael Browne from SA Photonics, US. Here, he intends to examine what's important to AR – from field-of-view to color and lumen requirements – with an emphasis on what the user wants.

"You really need to understand the human user and what they are doing in order to be successful in this industry," he says. "And that's the emphasis of the class."

Vision Scientist, Professor Marty Banks from the University of California at Berkeley strongly agrees. As one of this year's keynote speakers and also presenting at the conference, Banks's research delves deeply into visual space perception and user comfort.

For example, Banks has spent much time exploring the eye-focusing problem – the vergence-accommodation (V-A) conflict – that plagues XR. "This is getting so much attention as you don't want to make the viewer uncomfortable and decrease their visual performance," he says.

Banks points to today's varifocal and multi-focal approaches, designed to solve this problem by using a focus-adjustable lens between the eye and the display screen. These varifocal and multifocal displays generate content either continuously or at discrete focal planes according to where the person is thought to be looking.

According to Banks, these approaches can work in the short-term, but as he points out, accurately tracking where the user is looking, and at what depth,

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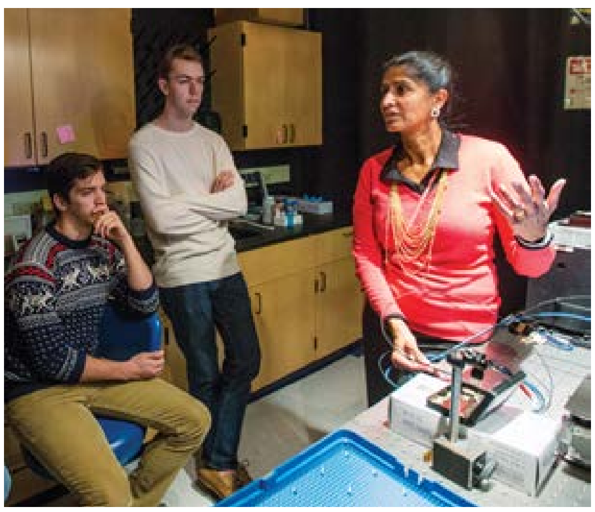
A track record of 'lightbulb moments'

From bowel inflammation to breast tumors, future SPIE President, Professor Anita Mahadevan-Jansen, has developed tool after tool to diagnose disease.

What drew you to photonics?
Growing up in India, I'd always wanted to go into medicine but missed the required grades by one point. I didn't know what to do next but I was really good at physics, so pursued an undergraduate degree in physics and mathematics at the University of Bombay-Mumbai with an attitude of not wanting to be there. Then I met Professor S. B. Patel, my Nuclear and Laser Physics Professor and lifelong mentor, who suggested that I should consider bringing physics and medicine together. He introduced me to biomedical engineering and optics, and turned my professional life around.

When did you first encounter spectroscopy?
I moved to the University of Texas-Austin to do a PhD and found Professor Rebecca Richards-Kortum. She introduced me to optical spectroscopy and its application for the diagnosis of cervical pre-cancer. While I started with fluorescence spectroscopy, I quickly became convinced this might not be the answer to solve this problem, and switched to Raman Spectroscopy. I soon discovered that signals from the optical fibers interfered with tissue measurements, so designed a novel probe that could filter these spurious signals and detect tissue. Each measurement took 90 seconds instead of today's two seconds, but building a system that could collect Raman signals *in vivo* was the highlight of my PhD and convinced me to continue this area of research.

At Vanderbilt you translate optical technologies into diagnostic tools – tell us more.
I develop all kinds of spectroscopies and imaging but what I do is different to many people – my research is problem-based and I focus on medical problems. We need people to develop new light-based technologies such as photoacoustics or optical coherence tomography but we also need people to match the problem to the solution. My approach is to understand the problem and find the best technique to solve it.



Professor Anita Mahadevan-Jansen with students. Photo credit: Vanderbilt University.

Examples of your problem-led approach?
Just over a decade ago, a third year surgical resident [at Vanderbilt] explained that finding the parathyroid glands, an organ that regulates the calcium in your body, during neck surgeries is difficult, and asked if there was a light-based solution. We discovered that there is a very strong near-infrared auto-fluorescence signal in parathyroid tissues compared to all other tissues in the neck. This discovery led to the development of the 'PTeye', an approach to help the surgeons confirm the identity of the parathyroid gland during surgery. At the time, most researchers were looking at disease detection using light but we were focused on finding an organ. PTeye is now FDA-approved and is one example of something that I always hoped to accomplish – to take something from the bench all the way to patient care.

You have used Raman spectroscopy to assess breast cancer margins and detect inflammatory bowel disease, early throat cancers and more. Will we see FDA-approved devices soon?
With the parathyroid glands, the fluorescence signal is so clear and doesn't require a lot of fancy processing – this made a huge difference to patient-numbers in trials and allowed us to get PTeye through FDA quickly. But with Raman spectroscopy you are looking at subtle changes in signals, and need to use multivariate statistics using data from many more patients, so approval takes longer. However, it is a powerful technique and for the right application, the right solution. For example, we're using the technique to evaluate the cervix as it re-models during pregnancy to predict the risk of pre-term labor and birth.

Your research on infrared neural stimulation (INS) is a little different – why do this?
This is one project where my husband, Dr Duco Jansen, and I work together. We were sharing a bottle of wine with a neurosurgeon friend, when we wondered if it would be possible to stimulate neural activity. The next day, we went to the lab and applied Vanderbilt's Free Electron Laser (FEL) to a frog sciatic nerve. Low and behold, for every pulse, we saw a twitch that we could record. We've since applied this to the peripheral and central nervous system of sea slugs, rodents, primates and humans and even single cells.

Will we see INS in clinics soon?
We have demonstrated the safe use of INS in cerebral palsy patients. These patients have an uncontrollable tremor – to help this, a few rootlets can be cut using electrical stimulation, but deciding which rootlets to cut is an educated guess. However, with INS we see which muscle group is innervated by that rootlet, and can accurately decide which to cut. We can also use the method for monitoring nerves during, say, cancer surgery, and hope to trial this on patients in a couple of years.

This is your 28th Photonics West. Can you explain why this conference is so important?
I attended my first Photonics West as a 2nd year PhD student in 1992. The conference showed me the breadth and depth of what light can do, and the networking was invaluable. I have since attended every meeting except one, and my husband is also a biophotonics researcher so we come to this conference together each year. Even when I had my daughter, we were at the conference 3.5 weeks later with her in tow. In fact, my daughter had attended ten shows by the time she was ten years old. This was in an era when people didn't bring their kids

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the business of photonics

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product focus

Photonics West is the premier photonics and laser event. With more than 1,250 companies, this exhibition continues to be the flagship event to find the latest products, tools, and applications for your research or business needs.

SPIE. PHOTONICS WEST BIOS

The Moscone Center, Moscone North and South
San Francisco, California, United States

1st - 6th February 2020

Welcome to the optics.org Product Focus which we have published specifically for Photonics West 2020 in partnership with SPIE and the Photonics West BiOS Show Daily.

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

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

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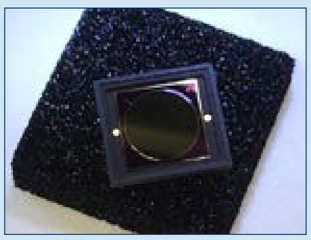

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I can see clearly now: AI smartens up OCT medical imaging

Ophthalmology and intravascular diagnosis are now using neural networks to better analyze optical data.

AI enables home OCT devices; now being commercialized by Visotec.
Image credit: Visotec

To help life-saving procedures to insert stents that keep open coronary arteries through which blood supplies our hearts with oxygen, medicine is increasingly adopting optical coherence tomography (OCT). Using intravascular OCT tools that illuminate tissues with lasers and collect reflections to build 3D images, surgeons can look into tissue surfaces to guide their decisions.

"Decisions are taken on the timescale of minutes," comments Gijs van Soest from Erasmus University Medical Center, in Rotterdam, the Netherlands. In this context, an OCT acquisition typically produces a few hundred frames that show geometries of atherosclerotic lesions that impede blood flow in an artery. "You basically look how big the free area is for the blood to flow through," van Soest explains. "But if you want to detect more pathological features, you have to have a human operator scrolling through all those hundreds of frames. It's just too labor intensive." The process could take half an hour, far too long during a surgical procedure, he explains.

And even when these large data sets are used for diagnosis outside of surgical settings, manual processing is often split amongst multiple hospitals, which can introduce errors. van Soest's Erasmus MC colleague Shengnan Liu adds that artificial intelligence (AI) techniques could help speed up the process, and improve reproducibility.

Yet this is just one of many instances where pairing AI and OCT shows great promise. The most common medical OCT application is ophthalmology, for which Somayyeh Soltanian-Zadeh from Duke University, US, is developing AI techniques. Soltanian-Zadeh explains that the most relevant AI form is usually a convolutional neural network (CNN). CNNs are stacks of convolutional layers that process a signal, she says. The convolution process applies a filter, such as a mask in the shape that one wishes to identify, to the signal.

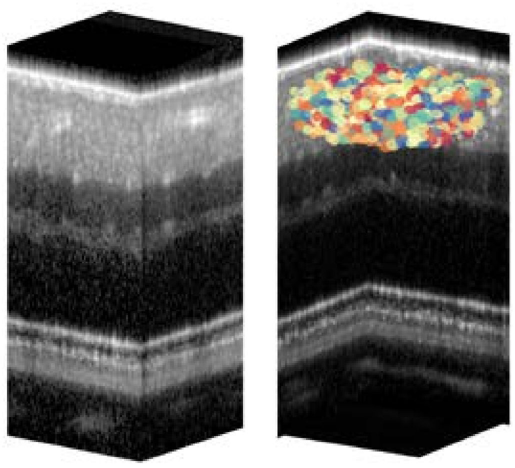
"Usually the filter is much smaller than your signal and you have to shift it across your signal," Soltanian-Zadeh says. An example is finding the character 'a' in a body of text. Convolution would move a filter shaped like the character 'a' around over the text, counting each time the filter and the text matched. Rather than being provided with filters, a neural network learns to create a set of filters to solve a task.

Building on such techniques, deep learning can supersede traditional machine learning and is relatively fast once trained, Soltanian-Zadeh adds. "In different fields, they are getting the best results compared to any other method," she says. "We are able to achieve human-level counting of ganglion cells from Adaptive Optics OCT (AO-OCT)."

Weak supervision's strength

Soltanian-Zadeh and her colleagues in Sina Farsiu's Duke team exploit volumetric data produced by AO-OCT. On Saturday February 1st, in session four of Ophthalmic Technologies XXX, as part of Photonics West, she is presenting her results on using a CNN with a weak supervision approach. An expert ophthalmologist manually localizes each cell in a volume, providing labels to train the network. The Duke team's goal is to then apply the CNN to tasks other than cell localization, which is where the weak supervision comes in. "Weak supervision is about leveraging granular input from human experts to solve a more complicated task," Soltanian-Zadeh explains. "This approach is useful because it bypasses the more time-consuming and extensive expert labelling required."

Soltanian-Zadeh uses this deep learning approach for automatic processing of AO-OCT data. "Our research focuses on the accurate quantification of ganglion cells of different shapes and sizes in the retina," she says. Adaptive optics corrects for distortions in the signal caused by light travelling through the tissue in order to achieve higher resolution OCT. Applying their deep learning approach to data acquired by this technique, the Duke team have been able to not only quantify the cell density, but also to locate each cell, by "segmenting" which pixels belong to each individual cell.



A Duke University team can identify and 'segment' individual ganglion cells in adaptive optics (AO)-OCT volumes using AI from a human retina (left), with ganglion cells identified with AI (right).
Different colors denote different cells. Image credit: Somayyeh Soltanian-Zadeh/Duke University

The Duke team is using this approach in collaboration with two other institutions that use AO-OCT imaging systems, specifically the US Food and Drug Administration (FDA) and Indiana University. "We are providing them with our code and they are using them for clinical and long-term studies," Soltanian-Zadeh explains. "From what I have seen, we are the first to use weak supervision for this specific type of data," she says.

Yali Jia from Oregon Health and Science University, US, notes that one area where OCT has been used extensively in ophthalmology is in diagnosing retinal diseases. "However, OCT quantitative biomarkers cannot be easily accepted due to the limitation of segmentation on low quality scans," she says. "Deep learning is the perfect tool to improve the robustness of segmentation of OCT biomarkers. On the other hand, deep learning has shown the promise of classifying retinal diseases using fundus photography." As OCT reveals more pathological information than other imaging methods, Jia believes AI-aided disease classification using OCT isn't far off.

Jia's team is therefore also presenting its work using such approaches in diagnosis of "wet" and other neovascular forms of age-related macular degeneration (AMD) at Ophthalmic Technologies XXX, in session two. AMD is the leading cause of severe, irreversible vision loss in individuals over 50 years old in Western societies. Wet AMD is characterised by choroidal neovascularization (CNV), the creation of new blood vessels in the eye's choroid layer. Identifying CNV is therefore essential for accurately identifying wet AMD, Jia explains. Her team therefore uses CNNs for automated diagnosis and quantification of CNV in projection-resolved optical coherence tomographic angiography (PR-OCTA).

Compared to conventional OCTA, PR-OCTA produces fewer artefacts and can visualize CNV both in cross-sectional and forward-facing views at the outer retinal slab. "However, CNV identification and segmentation remains difficult even with PR-OCTA due to the presence of residual artefacts," Jia notes. "Conventional image processing cannot classify CNV

continued on page 15

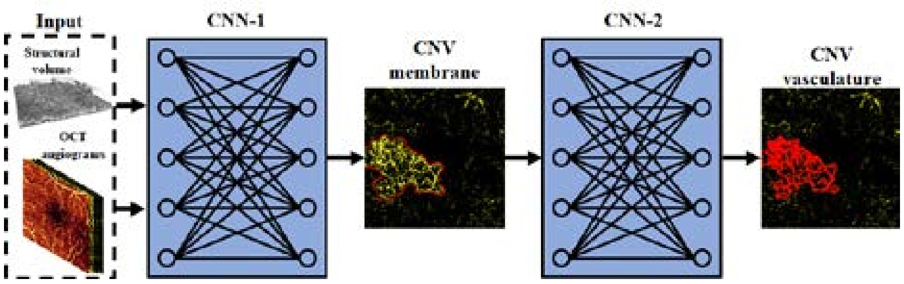
Artificial intelligence continued from page 13

and non-CNV scans, because they always segment CNV, regardless of whether it actually exists in an input scan. They can be easily fooled by background noise. Deep learning will intelligently recognize the target we are looking for.”

Commercializing AI in AMD

Her team therefore developed a fully automated CNV diagnosis and segmentation algorithm using CNNs. Jia explains that her team's algorithm incorporates two CNNs, one for CNV membrane identification and segmentation and the other for pixel-wise vessel segmentation. To train the CNNs, they exploited a clinical data set, including both scans with and without CNV, and scans of eyes with different pathologies. They didn't exclude any scans due to image quality. In testing, all CNV cases were diagnosed, and 95% of non-CNV controls were also not incorrectly diagnosed with CNV.

“By enabling fully automated categorization and segmentation, the proposed algorithm should offer benefits for CNV diagnosis, visualization and monitoring,” Jia says. She emphasises that the work is still only early-stage, and that OCT angiography itself is still pretty young. Nevertheless Jia believes that “this approach will be explored by other groups and be commercialized very soon. I am closely working with OCT instrument makers and always share the technologies to them,” she says. “Most of them have been successfully commercialized.”



Yali Jia's tem is developing a fully automated choroidal neovascularization (CNV) diagnosis and segmentation algorithm for age-related macular degeneration using convolutional neural networks to analyse OCT images. Image credit: Oregon Health and Science University

Neural networks

OCT imaging requires high levels of user expertise to obtain information relevant to surgeons or neurologists, says Gereon Hüttmann from the University of Lübeck, Germany. This is a barrier to the exploitation of OCT's potential to be a useful technology. Neural networks help with this in that “you can basically implement the knowledge and experience of an expert without having to employ one,” adds Hüttmann. Yet researchers face challenges delivering this, in particular in producing high-quality labelled data so that it can train the neural networks what to look for. “Of course, you have to train all the networks with data which were annotated or interpreted already by an expert,” Hüttmann says.

To do this, Hüttmann has teamed up with experts in AI from the University of Lübeck's Institute of Medical Informatics (IMI). In this work, the IMI is using a three-dimensional fully convolutional network, adapted from an approach developed by Olaf Ronneberger at the University of Freiburg, Germany called u-net. “We put reconstructed OCT volumes into u-net,” explains the IMI's Timo Kepp. “We trained it to segment pigment epithelial detachment structures and retinal thickness – both biomarkers for disease progression in AMD. After this we performed a shape refinement with an auto-encoder to correct for artefacts introduced by segmentation errors or motion. This auto-encoder learns the shape of the retina and that can compensate for errors.” The deep learning approach will appear in a poster at Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XXIV on Monday, February 3. Hüttmann's broader OCT work appears in several talks at Photonics West.

The Lübeck researchers exploit deep learning to develop an OCT imager for use at home that is smaller and more affordable than standard imagers. Patients can take an OCT themselves which can then be used in the treatment of AMD, Hüttmann explains. These devices can be used every day but generate a large amount of three-dimensional data that must be analysed to track disease progression, which AI can be used to do. The Lübeck team is also expanding beyond 3D segmentation, into 4D analysis, tracking changes over time.

A spin-out company named Visotec GmbH is commercializing the technology. Hüttmann and colleagues are also looking at a cloud-computing approach, so that people can upload the images from anywhere to be analyzed. Their research is “a way away from application,” Hüttmann admits. “But if we show we can generate clinically relevant data and that deep learning can do its job, then the product isn't far away from implementation.”

Deep learning has helped to develop an OCT imager for use at home that is smaller and more affordable than standard imagers. Image credit: Gereon Hüttmann/University of Lübeck

U-net biomedical image segmentation also comes into the Erasmus MC team's intravascular OCT system. “We start with an annotated data set, which has labels applied to the image,” says van Soest. “And we train the network on those images to automatically identify those labels. We use a relatively small sampling of small size images which simplifies the training process and attempt to utilise these efficiently by applying a transformation, generating images which can be used to enlarge the data set,” adds Liu. “We have attained quite good results using only 200 images from 20 patients.” They will present this work in the first session at Diagnostic and Therapeutic Applications of Light in Cardiology 2020 on Saturday, February 1.

Getting smarter

The Erasmus MC researchers have not yet tested the neural network “in a real-time practical setting” van Soest adds, so getting clinical validation is important. “The next step is to really perform clinical studies where we relate the analysis of this software package to real world outcomes, or we can retrospectively test this inpatient data that we already have on file.”

Machine learning technologies can facilitate image processing to distinguish healthy and unhealthy vascular tissue, says van Soest. AI recognises healthy tissue that is consistent in appearance, he explains, and marks anything else as unhealthy. Their approach then analyses those areas using optical attenuation measurements. Unstable atherosclerotic plaques that could give rise to potentially fatal disease outcomes have higher degrees of optical attenuation than stable plaques or healthy tissue, Liu says.

The approach cannot yet fully diagnose OCT images of atherosclerotic plaques, Liu adds, because they are very heterogenous. “We identify whether something is healthy or diseased, and that's something that the network does relatively well,” she says. “And then the diseased parts, we analyse by other methods.”

‘Not a fan of AI’

The Erasmus MC researchers see a trend emerging towards toolboxes for different tasks in AI for OCT image analysis “that require less of a computer science background,” Liu says. She adds that the amount of labelled data available to train neural networks with is growing, and that standards are getting more attention.

Yet Jia warns against relying on such techniques too much. “I am not a real fan of AI,” she says. “AI is not always powerful, and we may need to know our study goals before we try to use it. I just use it when I know it would be really helpful. I have accumulated many OCT angiography data, and also have been exploring this for quite a few years using non-AI tools. With extensive knowledge and background, we can think about how to let AI assist our work. Otherwise, I think it's very risky to apply AI everywhere.”

Hüttmann, by contrast, stresses that OCT imagers are still very expensive, and the images complicated to interpret. “A lot of fields need high-performance, low cost OCT and we're seeing this coming in now,” he says. “Cheaper approaches such as full-field OCT and integrated chip OCT are being developed. Deep learning has the potential to facilitate interpretation of OCT images, removing the need for the images to be sent to a specialist. These two factors combined with higher resolutions will open a lot of applications for OCT. At the moment OCT is like a smartphone without apps – despite the underlying power of the technology, without a user interface it is useless.”

Soltanian-Zadeh similarly makes a comparison to smart phones. “In my experience deep learning/AI in medical imaging fields often lags behind machine learning in the broader community, which incorporates images taken from cell phones and cameras,” she says. “I think the medical imaging field is catching up with the new trends that are being developed in machine learning.”

ANDY EXTANCE

Anita Mahadevan-Jansen

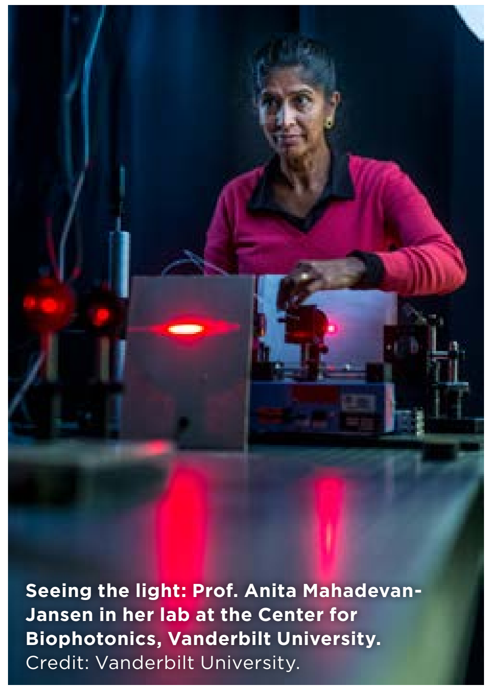
continued from page 09

to conferences but SPIE was supportive and helped us handle that work-life balance. Photonics West really brought both parts of my world together and holds a very special place in my heart.

This year you will serve as VP of SPIE and become President in 2022 – what are your hopes?
My research allows me to identify and understand a problem and bring the right solution to it – I'm hoping to bring that skill to the SPIE community. I want to listen to our members and help develop solutions and help them make connections. I would like to provide a global voice and showcase the benefits of being part of SPIE so more people can take advantage of its resources. I will of course, continue my efforts in bringing equity, diversity and inclusion to all aspects of SPIE and the optics and photonics community.

Advice to other researchers?
Interdisciplinarity is directly responsible for my success, but so is making connections with people and accepting help. When I arrived at Vanderbilt I was six months pregnant so spent the first few months at home. The then Department Chair, Professor Tom Harris, liked what I did, so said 'whenever you want to start, you can come in and I will support you'. If it wasn't for mentors like him and Dr Patel who guided me along the way, it would have been difficult to achieve everything that I have done. Seek the mentors and role models – SPIE is a huge resource here. Don't feel bad about asking for help – people often feel they have to achieve everything alone – I don't think that's necessary. This meeting is the perfect place to make connections that will last a lifetime.

REBECCA POOL



Seeing the light: Prof. Anita Mahadevan-Jansen in her lab at the Center for Biophotonics, Vanderbilt University. Credit: Vanderbilt University.

Multimodalities, translational biophotonics and the future trajectories of OCT

Wolfgang Drexler on optical coherence tomography, his work at the Center for Medical Physics and Biomedical Engineering at the Medical University of Vienna, and his new role as co-chair of BiOS at SPIE Photonics West.

"Who needs OCT? It's useless. No one needs this in ophthalmology. We have ultrasound, and that's good enough." This was the greeting Wolfgang Drexler received from colleagues in the early 1990s, when he was one of the first master's students in the lab of optical coherence tomography pioneer Adolf Friedrich Fercher. "There was very little perspective and appreciation regarding OCT at that time," says Drexler who has been attending SPIE Photonics West since 1996 and who, alongside SPIE Fellow Jennifer Barton is now co-chairing the BiOS conference at that symposium.

Thirty years later, he notes, BiOS, in conjunction with OPTO and LASE, offers a welcome and comprehensive perspective of the breadth of spectrometry available in both industry and academia. "BiOS is the largest meeting in the biomedical photonics field; it's the meeting I send all my students to," says Drexler. "You start with BiOS' clinically oriented weekend, and then, during the week, you translate into the more engineering, more science-driven sessions. It's great particularly for biomedical and optical engineering students to get a sense of the rich opportunities available to them whether they're pursuing PhDs or have business ambitions." The focus on translational science and medicine highlighted by BiOS suits Drexler to a proverbial T. Growing up, he was always curious about how things worked. "My parents would go nuts because I took everything apart, whether it was an alarm-clock or an electronic device: I was always curious to look inside and to understand how things work." At the same time, the young Drexler got interested in his grandfather's camera as well as books on human biology. Then there was the miniature railway system. "I thought I wanted to study medicine," Drexler grins. "But here was this railway with its circuits, motors and signals and speed, so I decided to study electrical engineering."

Quite quickly, a growing interest in lasers guided him toward medical engineering. "Semiconductor lasers were starting to become attractive — back then it was $2,000 a laser. I was fascinated by lasers and laser light. In my studies, I went from spectroscopy to material processing, and I ended up in a seminar giving a talk about laser welding in cardiovascular surgery." It was after that seminar that Fercher approached Drexler, offering him a place on the master's program at the University of Vienna. "I said, 'Yes, I'd like to work on laser welding and cardiology,' but Fercher said, 'No, this would be for some kind of interferometric method that does diagnosis.'" And the rest, as they say, is history.

A post-doctoral fellowship at the Massachusetts Institute of Technology with another OCT pioneer, James Fujimoto — where Drexler devised and built the first ultrahigh-resolution OCT unit — was followed by professorships and research positions in Austria and Britain. Now, as the director of the Center for Medical Physics and Biomedical Engineering at the Medical University of Vienna, Drexler is exactly where he always wanted to be, in a highly personalized niche that straddles medicine, biology, life science, physics, engineering, software, and electronics.

Expensive toys: Wolfgang Drexler, a co-chair of BiOS at SPIE Photonics West 2020.

There are six OCT groups and 160 scientists within the Center; every team working across the medical and engineering spectrum to discover or enhance the newest opportunities that might address the most critical healthcare issues. One example, notes Drexler, is mind-control prosthesis. "We do a lot of functional stimulation of the spinal cord for paralyzed people," he says. "Using surgery and biomedical engineering, you can connect these protheses to the neural network, so that you can interface once again with the control you had before. In partially-paralyzed people, you can ideally stimulate the spinal cord so that they can be assisted to walk again."

The Center also includes work in hybrid nuclear medicine as well as radiologic imaging, functional MRI, MR spectroscopy, image guided therapy, nuclear medicine, ultrasound, X-rays – a broad spectrum. It receives funding for additive manufacturing technologies such as 3D printing. A future medical application development that's being worked on: the capability to print skin transplants and bones.

OCT: an impressive trajectory

As for growth areas in OCT, from Drexler's knowledgeable perch, the future is brighter than ever. Cardiology is one area that continues to be nicely developed — "there is a fifth or sixth generation of a commercial system checking stent placement and overgrowth"— and OCT's impact on gastro-intestinal issues is also of interest. And then there's the proliferating miniaturization of OCT. "Electronics are miniaturized; we can miniaturize optics too – and put them on a chip. You can really package them into really small things, like a handheld probe, or incorporate them into an existing system that would be accessible for low-resource areas. At one point, we'll probably have a small capsule that you swallow and it's so cheap that it won't matter when it leaves the body again. OCT is very established in the $50,000 to $100,000 range in a lot of fields, but there isn't really a system yet that is handheld, one that we could use for oral cancer, for skin, for ophthalmology, for whatever. The challenge is you have to make it cost effective but still pass the threshold for diagnostics of significance, right? This is an area where I think there is a big, big future for OCT opportunities."

Multimodality, according to Drexler, is another growing area. It's not CT alone, it's not MRI alone: "You get the atomic information, you get molecular information, so you get the best of both worlds," Drexler explains. "The same is happening in optical imaging: you use a technology that is like a GPS that pre-screens the organ — it's very close to OCT, it's faster and microscopic — and then you spot the suspicious lesions that you observe, any kind of subcellular, metabolic or molecular issues. This is where all this Raman and photoacoustics and optical microcopy come into the picture."

Interactivity: a key component

One of the reasons, indeed, that Drexler took up his current role in Austria is that the Center is a part of a hugely interactive infrastructure. "We're sitting in one of the largest university hospitals in Europe. It's like working in a technical university, but we are also part of a university hospital with 24,000 rooms and 46 clinics and centers, which, for a scientist, is wonderful.

Being able to share this work at a conference such as BiOS is even better. Without organizations such as SPIE, notes Drexler, such meetings wouldn't exist. "I'm in a lucky situation where I've never had to actually work in my life. I always tell my kids: the toys just became more expensive. As a scientist, you shoot laser-light into an eye and you're curious to see what's happened. With an SPIE conference, you enable people to have a wider interest in what's going on in their field. And his co-chair role is just one of the ways Drexler considers that he can give something back, in the same setting where he's benefited for so many years. "It's on a different level now than it was 20 or 30 years ago – better perspective, more exhibitors, much more translational techniques and information." He shakes his head. "This is so high level compared to then."

And that level just keeps on rising. As Drexler notes, the more-than 50 conferences at BiOS this year will offer a wealth of timely topics. "BiOS 2020 will cover the exciting and widening spectrum of activities in the field of biophotonics, including the growing use of artificial intelligence, and significant trends towards cost-effective solutions for point-of-care diagnosis – from miniaturization to multimodal optical imaging – which are similar to the trends in radiologic and nuclear medicine.

"Biophotonics as a field continues to significantly improve in many areas, including as lasers and imaging technology and therapeutic procedures that are commonly used in clinical routine: look at the advances we are seeing in fluorescence detectors and techniques used for cancer diagnosis and treatment. I am also very pleased that, in addition to the main Photonics West exhibit comprising nearly 1,400 companies, the BiOS expo will showcase 230 companies."

DANEET STEFFENS

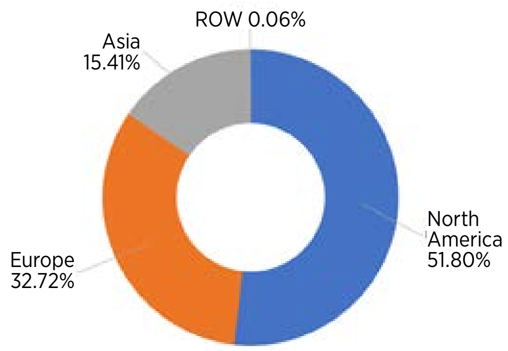
Biophotonics revenues continued from page 01

for 2018 with an expectation that similar gains would occur in 2019—and Danaher Corporation, which encompasses brands in diagnostics and life sciences. Danaher reported a 7% increase in all revenues for the same period.

As sales revenues have grown since 2015 so too has the number of companies in the marketplace. The 2015 industry analysis was based on 279 biophotonics-related companies employing 300,000 persons worldwide. In the interim, 126 firms have been acquired, merged, or otherwise left the industry while 229 companies have entered, so the 2018 analysis covers 382 companies based in 29 countries with total global biophotonics employment of 390,000. Besides organic growth in core biophotonics arenas, the new entrants encompass several different markets including in-vitro diagnostics, point-of-care, and food safety.

In terms of the geographical distribution of revenues, companies headquartered in North America dominate the market for biophotonics, a situation that seems likely to continue for the immediate future. These companies account for about half of the total, with European companies at about one third and Asian firms around 15% [see Chart 2 below]. It should be noted however that all revenues are reported as originating at the company headquarters location since it is generally not possible to accurately assess the geographical source of a given company's sales.

The abiding need for innovative healthcare solutions will continue to propel growth in the biophotonics industry, a trend that is also evident in the research pipeline. Paper submissions at the SPIE Biomedical Optics Conference exceeded 2500 for the first time in 2019 and continue to climb, having done so consistently for at least the past decade. Research growth areas (in terms of paper submissions) include biomedical spectroscopy and imaging, clinical technologies and systems, and the relatively new field of neurophotonics. Other elements of the biophotonics rebound include the use of artificial and virtual realities in therapy, diagnostics, and training; the implementation of artificial intelligence in medical imaging; and novel sensing technologies integrated with smart phones to name just a few.



Geographical Distribution of Revenues by Company Headquarters

STEVE ANDERSON

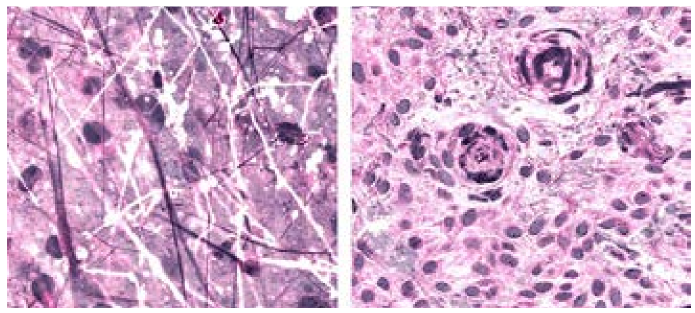
(*)BIOPHOTONICS

Biophotonics – the study of the interaction of light with biological matter, where "light" includes all forms of radiant energy whose quantum unit is the photon – is an enabling technology, whose principles are used in scientific research, and form the basis of applications of light in biology, life sciences, and medicine.

To estimate the size of the global biophotonics industry, we segmented the market and analyzed revenue data for companies active in those respective areas. Multiple relevant sources were reviewed in order to compile a current list of companies active in biophotonics. We assigned a "biophotonics factor" to each company, to account for biophotonics-related revenues.

Key biophotonics market segments include Biochips, Biosensors, Digital Pathology, Endoscopy Devices, Flow Cytometry, Genomic Sequencing Technologies for Medicine, Biological Imaging, In Vitro Diagnostic (IVD) Tests, Medical Lasers, Microscopy, Point of Care Diagnostic Testing, Food Safety, Food Q&A.

STEVE ANDERSON



The combination of advanced optical imaging with artificial intelligence can produce accurate, real-time intraoperative diagnosis of brain tumors. Translation of such innovations into the clinical marketplace will drive continued growth of the biophotonics industry. Stimulated Raman histologic images of diffuse astrocytoma and meningioma. Image courtesy of Dr. Daniel Orringer

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and Ultrasonic Systems Engineering (PULSE) Laboratory, will describe her team's novel light-delivery systems that attach to surgical tools to deliver light to surgical sites. She and her team have also developed acoustic beamforming algorithms that improve image quality using state-of-the-art deep learning methods applied directly to raw sensor data. These light delivery and acoustic beamforming methods hold promise for robotic tracking tasks, visualization and visual servoing of surgical tool tips.

Ewa Goldys is SHARP Professor at the Graduate School of Biomedical Engineering at the University of New South Wales and deputy director of the Australian Research Council Centre of Excellence in Nanoscale Biophotonics. Her research focuses on ultrasensitive optical characterization in the life sciences, label-free non-invasive high content cellular imaging, and theranostics.

Bo Huang, professor of pharmaceutical chemistry at UC San Francisco and investigator at Chan Zuckerberg Biohub, and his team are developing new fluorescent labeling methods and microscopy techniques to systematically map the subcellular localization, temporal dynamics, and activity profiles of proteins. Huang will present a paper on eSPIM on Saturday, February 1, at 8:30 am.

High doses of radiation are very effective against tumors, notes Shawn Chen of the National Institutes of Health/National Institute of Biomedical Imaging and Bioengineering. Chen will highlight the use of nanomaterials to convert x-rays to optical luminescence, which triggers photosensitizers to generate reactive oxygen species for combined radiotherapy and x-ray induced photodynamic therapy.

Current cell-sorting techniques require fluorescent tags to be added to key proteins that distinguish cell types. Cells are sorted by automated instruments that detect the presence of fluorescence. Keisuke Goda, a professor of chemistry at the University of Tokyo, and his colleagues have developed a new machine-intelligence technology called "intelligent image-activated cell sorting" that uses imaging to refine the fluorescent-sorting process. Goda's team has demonstrated the ability to make machine-based scientific discoveries in biological, pharmaceutical, and medical sciences.

KAREN THOMAS

AR, VR, MR 2020 continued from page 07

remains problematic.

With these issues in mind, he and colleagues are pioneering numerous new technologies, including an algorithm called ChromaBlur that compensates for the eye's chromatic aberration. This can be coupled with focus-adjustable lenses and gaze tracking to minimise the effects of the V-A conflict in headsets.

However, for the Vision Scientist, the long-term answer to the V-A conflict lies in the much-awaited light-field display, which could provide many views of a scene to each eye resulting in more natural focus information.

Banks discusses a route forward in his talk, 'How many views are required for an effective light-field display?' But as he highlights: "There are difficult computational and optical challenges and nobody has produced a satisfactory display yet."

"The companies involved are very secretive," he adds. "It's clear that Facebook Reality Labs is working on it, and while other companies talk about it, the words 'light-field display' have been used very loosely."

Banks reckons light field displays won't reach the market for at least another five years, so what can we expect in the meantime? WaveOptics' Greenhalgh is confident that the next 18 months will bring AR head mounted displays with a larger field of view for enterprise applications, but also expects to see smaller form-factor smart glasses with a relatively narrow field of view and more limited functionality.

He also highlights how his company is 'in talks' with UK-based real-time generated holography software developer, Vivid Q, on how to couple light-field holograms into waveguides, although admits this will be 'quite a challenge'.

Meanwhile Melzer is looking forward to shortly seeing waveguides being used with micro-LED displays. "I think this is a year or two out but its going to be key as much less silicon will be used and this is going to drive costs way down, which is very exciting."

And for Kress, the excitement will continue. "This field is evolving so fast and every year we have to adapt to a new trend or technology."

"Investors are pouring money in and we are seeing new markets all the time," he adds. "New use-cases are popping up everywhere, and hopefully we'll see this in the consumer market soon."

REBECCA POOL