EPIC Members Event Report

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Lasers & Photonics Marketplace Seminar 2015

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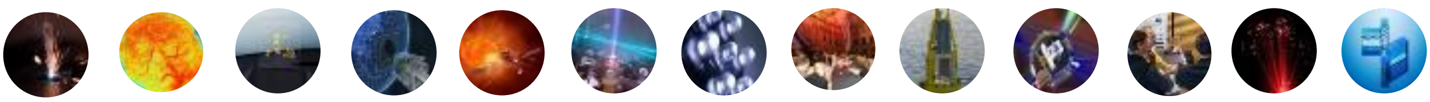
About the EPIC Members Event Reports

Initiated by the founder of EPIC Dr. Thomas Pearsall in 2003, these reports are prepared by members of EPIC to the benefit of the wider community. If you did not have a chance to attend the event but would like to know some key highlight, this report is for you. Emphasis is placed on exploring technical and business opportunities for the members of EPIC.



1. Welcome and introduction, by Conard Holton

Conard Holton has 25 years of science and technology editing and writing experience. He was formerly a staff member and consultant for government agencies such as the New York State Energy Research and Development Authority and the International Atomic Energy Agency, and engineering companies such as Bechtel. He joined Laser Focus World in 1997 as senior editor, becoming editor in chief of WDM Solutions, which he founded in 1999. In 2003 he joined Vision Systems Design as editor in chief, while continuing as contributing editor at Laser Focus World. Conard became editor in chief of Laser Focus World in August 2011. He received his B.A. from the University of Pennsylvania, with additional studies at the Colorado School of Mines and Medill School of Journalism at Northwestern University.

As Chairman of the Seminar, Conard briefly introduced the Seminar program and its schedule. Conard also noted that Laser Focus World was also celebrating its 50th anniversary. The Seminar was attended by approximately 150 people.

2. Keynote: The ultrafast future, by Ursula Keller

Prof. Dr. Ursula Keller is the Director of the National Center of Competence in Research for Molecular Ultrafast Science and Technology (MUST) and heads the Keller Group at ETH Zurich. She was a co-founder and board member of Time-Bandwidth Products (acquired by JDSU in 2014) and GigaTera, a venture capital funded telecom company (acquired by Time-Bandwidth). Previously she was a Member of Technical Staff at AT&T Bell Laboratories, and a visiting professor at the University of California, Berkeley and the Lund Institute of Technologies. She invented and demonstrated the first passively mode-locked diode-pumped solid-state laser in 1992 and solved a 25-year-old challenge. Her research interests are exploring and pushing the frontiers in ultrafast science and technology, including attosecond science. She received her Physics Diploma from ETH Zurich and PhD in Applied Physics from Stanford University. In 2013, the Laser Institute of America gave Prof. Keller the Arthur L. Schawlow Award, which recognizes individuals who have made distinguished contributions to applications of lasers in science, industry, or education.

Ursula started by reviewing her career since her early work at Stanford with David Bloom and subsequently AT&T Bell Labs. Her invention of the SESAM in 1992 led to her return to ETH Zurich in 1993. Ursula is interested in pushing the limits of laser technology, especially in power scaling of high repetition frequency ultrafast lasers. Her interest in SESAM devices continues to date, as they continue to offer a simple and effective way to passively mode-lock DPSS lasers when designed appropriately. More recently, SESAM-driven picosecond DPSS lasers are becoming important tools for micromachining applications, further driving their development and commercial deployment.

Ursula questioned herself if there was any other type of saturable absorber that could be used to similar effects with advantages, so that significant power scaling could be implemented. The broader question is what are the key technologies now that look interesting to consider? Considering this question, Ursula first focused her attention on Graphene, as it is a very exciting topic. Different types of Graphene saturable absorber mirrors were built, with recovery times in the picosecond domain, but Graphene mirrors damage easily. The Graphene layer is held to the substrate by van der Walls forces and heat conductivity to the substrate is imperfect, leading to easy damage when we try to saturate the absorber. The saturation of the nonlinear mirror is difficult – it requires high fluences and even then is imperfect, thus inducing significant losses in the laser cavity. Much progress must be achieved with Graphene mirrors before they can compete with SESAM devices in real world lasers.

Looking at power scaling, the ultrafast laser market has been dominated by Ti:Saphire lasers with 1W power being typical. The challenge now is to move to tens of W and even kW lasers, at MHz pulse repetition frequencies. Ti:Saphire is inappropriate for such scaling. One of the most promising technologies is DPSS based, but current laser configurations are still complex. Ursula sees as state of the art laser geometries for pushing the average power, fiber-chirp-pulsed-amplification (CPA), INNOSLAB and thin disks. Unfortunately CPA-type systems are complex and expensive.

As an attempt to push the output power of ultrafast laser oscillator's, Ursula's group is already at 242W with 580 fs pulses, 80µJ pulse energy and 66 MW peak power. This is a convenient pulse energy for many real world applications. The chosen laser configuration used a thin disk geometry of the type that TRUMPF has already been commercializing. The output pulses are very clean - they are soliton pulses - and this approach allows kW level outputs. Special dispersion mirrors with negative dispersion must be used to avoid optical damage.

Although the pulse width range 500fs – 1ps is ideal for industrial applications, it is not sufficient for scientific applications, for which much shorter high power ultrafast pulses would be desirable. A range of external compression schemes were tested. The most promising technology for external pulse compression without an observable limit seems to be Kagome hollow core PCFs and they are beginning to be commercially available. A 60cm long fiber with 30µm mode diameter can compress high power laser pulses at 80% efficiently and such results were demonstrated.

GHz lasers operating in the range 1-100 GHz at 1W – 10W level, are desirable for a number of different applications, including clock generation and distribution. Frequency combs and multiphoton imaging are also interesting applications. Even user interfaces as required for automatic face recognition could benefit from GHz lasers. The current technology of choice for that application is VCSELs. The Ti:Saphire laser still produces the shorter and high power pulses, and other lasers cannot yet match that performance. However, DPSS based on novel Yb:CALGO materials are developing fast and are beginning to approach the performance of Ti:Saphire lasers.

A recent promising development relates to optically-pumped VECSEL lasers, similar to VCSELs but based on an external cavity design. The power is scaled by changing the mode size on the semiconductor chip that is providing the gain, and an output power of 20W has been achieved at 43% efficiency. The laser is diode pumped and heat is removed by mounting the semiconductor on a diamond heatsink. It should be noted that Coherent's approach is similar and their lasers have been performing well on the market. More recently, the electrically pumped VCSEL, or NECSEL, using a ring electrode (such as what Novalux introduced years ago) is exhibiting promising results. To ensure a TEM00 mode, we need to introduce an electrical current spreading layer, and thus power scaling seems to be more difficult and less efficient than with the optically pumped equivalent.

Ursula also mentioned an alternative design that uses a tapered amplifier. However, a tapered amplifier seems unpractical in most circumstances as it efficiently guides any optical feedback into the laser, thus destroying it with ease.

Semiconductor lasers, thus, seem to provide several promising paths to develop and deploy short pulse, high average power and high pulse repetition frequency lasers. SESAM continues to be the best material to achieve passive mode-locking, considering that Graphene still has engineering problems that severely limit its useability and carbon nanotubes are lossy. New Yb:CALGO doped materials offer excellent possibilities for the future. In the future, Ti;Saphire lasers will be replaced by DPSS lasers of various types.

3. Global Laser Markets: Insights and forecasts, by Allen Nogee

Allen Nogee is a Senior Analyst, Lasers & LED Lighting, at Strategies Unlimited and is responsible for tracking hardware trends in the laser and optical industries worldwide. Nogee has more than 20 years of experience in the electronics industry in hardware and software development in addition to semiconductor market analysis. Previously, Nogee was a research director and principal analyst at In-Stat, where he was the lead analyst in the wireless area tracking RF semiconductors and wireless technologies. He has also held design-engineering positions at MCI, GTE, and GE.

Allen started by paying tribute to Charles Townes, who passed away recently.

In 2014 was a pretty good year overall for lasers. Towards the end of 2014 Europe diminish the activity a bit, but overall the growth was 6.3%. Going into 2015, the expectation is that overall growth will exceed 6.0% with the total laser market size reaching or approaching 9.7B USD.

IPG, TRUMPF and GSI Group had record laser revenues in 2014.

For 2015, medical lasers should grow significantly in all areas – surgical, eye, skin… - with the possible exception of lasers for dental applications. Scientific lasers should also do well. Companies are reporting that they observe a larger growth in developing countries, likely related to the emerging middle class there. Oil and gas, as well as 3D printing, should provide healthy growth rates for laser manufacturers, albeit the numbers are still small.

Allen also made the interesting comment that revenue from consumer electronics in developing countries will overtake the equivalent revenue from developed countries. On materials processing, it was mentioned that over 75% of marking lasers now come from China, while manufacturers based in Europe and the US will be focusing on higher end lasers, more specialized materials processing or finer sensing applications.
CAPEX in telecom seems to be slowing and much of the growth comes from developing countries. China and India are large countries that need much infrastructure growth to support mobile communications, in particular.

Uplink/downlink by laser to/from satellites seems to be coming of age.

On fiber lasers, the future looks extremely promising. A number of new companies are entering the market with new types of products.

CO2 lasers have rather flat sales since 2007. Fiber lasers are absorbing more and more of the revenue, a trend especially evident since 2014.

The sensing market for lasers is growing.

A growing industry for fiber lasers is 3D printing.

In oil and gas, the industry currently absorbs about 25M USD in lasers, mostly for sensing applications. This area is growing, and now starts to include high power lasers to assist drilling by heating rock.

Metal processing using kW class fiber lasers grew by 17% in 2014 and is a large market.

Display and entertainment using lasers is proving to be a growing market for lasers. The majority of these lasers come from China.

Sensors are an interesting area for lasers: sensor encompass a variety of device types and applications, including fiber sensors, spectroscopy, flow cytometry and many others. In the last few years spectrometers are being made very small – even a chip MEM spectrometer exists now - and that will change the deployment of lasers in many sensing applications.

Lidar and self-driving cars could offer an interesting application area for lasers. Still a few years off, it will be large nevertheless.

Gesture recognition (user interface) could also offer a good opportunity for short pulse (to allow mm range special resolutions) high repetition frequency lasers (to allow movement tracking).

Quantum Cascade Lasers (QQL) have been around for over 20 years but they are too expensive to be deployed in large scale. Useful for trace gas analysis, including breadth analysis, they never took off in the market. A promising application is non-invasive glucose measurements. The mid-IR research group at Princeton is doing a lot of work in this area. Non-contact explosive detection would also be an ideal application area.

The military are the largest users of QQLs and use them for a number of applications. A number of large military contracts are up for final decision soon.

On R&D, it should be noted that R&D investment in Europe has been decreasing in recent years, while in China is growing fast.
High power fiber lasers with >30kW output power are now being used as direct energy weapons to shoot drones and smaller weapons.

Extreme-UV applications for photolithography will be an expanding area. Currently, extreme UV light is generated using large CO2 lasers to bombard targets, but this technology will evolve.

Saphire cutting by ultrafast lasers is promising for the future, for mobile device screens. However, Apple recently shut down its Arizona facility.

Ultrafast lasers will command a laser market of 295M USD in 2015, and this will be a growing area. It is still a very expensive technology, with significant consolidation happening.

For marking applications, fiber lasers are dropping in price 9-10% per year.

In the Q&A period, it was stated that fiber lasers will become a lot more flexible in terms of parameter space. They will replace gas and chemical lasers gradually. Solid state lasers are also going to displace other obscure lasers. Valentin Gapontsev mentioned that direct diode lasers do not offer any advantage over fiber lasers. Fiber laser electrical efficiency now approaches 50%.

4. Emerging biophotonics technologies and needs, by Gary Tearney

Dr. Gary Tearney is Professor of Pathology at Harvard Medical School, Mike and Sue Hazard Family MGH Research Scholar, an Affiliated Faculty member of the Harvard-MIT Division of Health Sciences and Technology, Fellow of the American College of Cardiologists, Fellow of the College of American Pathologists, and heads the Tearney Lab at the Wellman Center for Photomedicine at Massachusetts General Hospital. He earned his MD magna cum laude from Harvard Medical School and his PhD in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology. His research interests are focused on the development and clinical validation of non-invasive, high-resolution optical imaging methods for disease diagnosis.

Gary took the audience on a fascinating journey inside the human body to illustrate novel optical techniques that are enabling 1 µm special resolutions over entire organ sizes, say 50 cm. The ideal techniques would be non-invasive and allow confocal resolutions at small fields combined with OCT resolutions over large fields. The goal is to observe changes at both cellular and organ structure/architecture (functional) levels that would enable a more accurate diagnostics. In-vivo volume micro-imaging is the goal.

Gary described several types of medical conditions that start by abnormal changes at cell and organ levels, including coronary and oesophagus conditions. Current techniques are expensive, cumbersome, time consuming, requiring cutting of tissue samples, sample preparation, off-site observation and reporting. Also, you cannot do it with many types of tissues (brain, eye, arteries…). Random biopsy also can miss the cancer source.

The promise of "in-vivo microscopy" is to image the body at the microscopic level, and it uses light, mostly in the near-infrared due to increased depth penetration. From a pathologist standpoint, OCT gives images that are very similar to microscope images taken at low power. It is a cross-sectional technology, it penetrates about 2 mm into the tissue, it has a resolution of 10-20 µm and a field of view of about 5 mm. Confocal on the other had provides much higher resolutions that allow to see individual cells, but the field of view is typically 200 µm. This is similar to looking under a microscope at high power. In summary, confocal giver cellular resolution while OCT gives architectural resolution. Confocal is more difficult to implement as the light spot size must be small and rapidly scanned. Modern endoscopes can include the scanning element on the tip of the endoscope.

A variety of slides and video clips were presented to illustrate the two types of imaging techniques, applied to imaging in coronary and oesophagus medical conditions.

Gary then addressed the future through entire organ imaging with cellular resolution. This is called volume microscopy. The imaging technology must be must be much faster – say involve high speed scanning swept source or Fourier domain OCT. This allows in-vivo imaging at structural resolutions, enabling the visualization of coronary disease in living people. Next generation OCT also serves to tell on how not to place stents. By imaging the area at high resolution, the ideal artery position to place the stent can be determined and checked.

The entire oesophagus can be imaged at high resolutions to determine the exact area where a biopsy should be made – guided biopsy. This capability will greatly reduce random biopsies and instead sponsor precise biopsy.

Combining both imaging technologies – next generation OCT and confocal – allows entire organs to be imaged at cellular resolutions. A capsule-based approach can combine both techniques to allow this type of imaging to be made in-vivo. Progress in capsule making and application was reported. The capsule includes the necessary spinning optics for next generation OCT. The 3D image results are truly stunning. With more recent versions of the capsule, a bit heavier, the capsule was found to also be able to enter the small intestine and image important structural features.

A novel generation of the capsule includes confocal imaging technology and has enabled sections of 20 cm to be imaged at 1 µm resolution.

Extended reality could also be added to the imaging system, to provide an immersive imaging experience.

Areas of significance to support these applications would include new supercontinuum light sources, new cameras and new swept source lasers – much broader wavelengths (300 nm) and much higher speeds (MHz).

5. Panel: Industrial laser applications

This panel of experienced industrial laser system developers discussed the trends they see across numerous applications of industrial lasers, from aerospace and automotive, to medical devices and electronics. They discussed the pros and cons of different types of lasers, the changing requirements of end-users and potential new market opportunities.

- Silke Pflueger, General Manager, DirectPhotonics (Berlin, Germany)
- Mark Taggart, President, Laser Mechanisms (Novi, MI)
- Ronald Schaeffer, CEO, PhotoMachining (Pelham, NH)
- Marianna Forrest, President, LasAp (Troy, Michigan)

Much of the panel discussions revolved around lasers relevant to be incorporated into machines and applications for the automotive and aerospace industries, including the micromachining of parts. In general, the panel was unanimous in recognizing that lasers are having a huge impact in micromanufacturing, including automotive part manufacturing.

In addition, the cost of laser sources is coming down fast, as well as their total cost of ownership due to reduced operation and maintenance costs.

Although laser cutting has been growing fast, laser welding has evolved slower. Laser welding will be an area of growth. On the other had, a single laser capable of cutting and welding would be a great tool to advance the industry.

High speed trains are also bringing a number of opportunities for laser technologies into play, considering the possibility of manufacturing large flat panels.

At Apple, cutting-edge manufacturing technologies are being developed for novel and advanced industrial processes. At Google, cutting-edge Lidar technologies are being developed for driverless cars. These are interesting examples of industries incorporating in-house laser technologies into the manufacturing of their own products.

It was also mentioned that in most cases industry adoption of laser processes is slow and requires substantial application development.

The need to find qualified personnel to participate in enabling new applications is a limiting factor.

6. Additive Manufacturing: An investor's perspective, by John Dexheimer

John Dexheimer is President of LightWave Advisors, and has a record of success in helping leading edge technology growth firms. He has advised on over 100 completed company financings and mergers in photonics, software, communications, electronics, and materials. He is also a partner of First Analysis Private Equity Fund, a growth equity investor with a long record in private capital investing. Previously he led the IPO of Uniphase, subsequently managed the equity research and venture organization of CE Unterberg Towbin, and was in the software industry with GE, DRI, and Broadview International. He has a bachelor's degree from the University of Minnesota's Institute of Technology and an MBA from Harvard.

Note: Unfortunately it was not possible for me to take notes during this lunch talk.

7. Photonics: World markets - regional trends, by Tom Hausken

Tom Hausken is the Senior Engineering and Applications Advisor for the OSA and OIDA. For 13 years until 2012, Tom led market research and strategy consulting for lasers, image sensors, and a range of other photonic products at Strategies Unlimited. In the past, he was an analyst at OIDA and a telecom policy analyst at the U.S. Congressional Office of Technology Assessment. He also held R&D and production positions at Alcatel and Texas Instruments in photonics and electronics.

In a revealing regional analysis of global markets for photonics products, Dr. Hausken drew on his recent research to explore drivers and growth opportunities by geographical area, ranging from China and East Asia, to the U.S., Europe, and the Middle East. His analysis included aspects such as primary photonics industries, government policy, profitability, and the potential for market penetration by new competitors. The information provided serves as an introduction to the coming Strategies Unlimited Laser Market Report.

Tom clarified the investment in photonics in different regions of the world.

Of all the good made in the world, about 3-4% are photonics related. Tom then proceeded to decompose the photonics related goods by categories and regions. It should be noted that displays is a huge category in itself.

Japan, Korea, Taiwan and China are very large in photonics. US and Europe are very strong too, especially in higher precision parts.

In Europe, the Horizon 2020 program considers photonics as a key enabling technology, but in total money it is about what NSF alone funds every year in the US.

Photonics related component production in China is valued at about 30B USD, of which about 1/3 relates to displays. However, the added value will likely be small in most circumstances. Currently, a reasonable estimate for the photonics related companies in China could be 10,000, involving an employment of up to 1 million people.

National initiatives: In Europe, the total budget for public R&D spending is 145B EUR per year, most of which is subsidies to poorer countries and farmers. The Horizon 2020 related investment reaches about 11B EUR per year, with photonics accounting for about 100M EUR per year for the next 7 years. This is about what the NSF in the US spends in photonics per year, and excludes all military programs (700 M USD per year). The total in the US could reach 1.3B USD.

The US initiatives on Photonics will be a beacon for other regions to follow.

8. Lasers in China, by Qihuang Gong

Prof. Qihuang Gong is the Cheung Kong Professor of Physics at Peking University, where he is the Founding Director of the Institute of Modern Optics and Deputy Dean of the Physics School. In addition, Prof. Gong serves as Director of the State Key Laboratory for Mesoscopic Physics. His current research interests are in ultrafast optics, nonlinear optics, and mesoscopic optical devices for applications. He serves as the General Secretary and Vice President of the Chinese Optical Society (COS), and Executive Council Member and Director of the Commission on International Exchange of the Chinese Physical Society. In addition, he is the Member of Chinese Academy of Sciences, Fellow of OSA, and Fellow of IoP. He received both his BS and PhD from Peking University.

China is a large country with 34 provinces. Among them, there are highly developed regions and less developed regions. In total, there are 2,000 universities. The Shanghai Institute of Optics was founded in 1952. In total, there are about 23M undergraduate students and about 1.6M graduate students in China. Of these, about 330K students are graduate students in optics related areas.

Currently, China is merging the main R&D investment programs into 5, to facilitate program coordination, management, control and effectiveness.

Qihuang went through these aspects in some detail, offering a bird's eye view of China's potential in photonics related areas.

9. Photonics in the oil and gas industry, by Christopher Jones

Christopher Jones joined Halliburton with its acquisition of Westport Technology, an integrated rock/fluids exploration & production laboratory in 2001. Having overseen the Laserstrat geological LIBS analyzer and ARMIS TDL Gas Isotopic Spectroscopy development, he joined the Halliburton Formation Evaluation technology research department in 2007. He currently manages the Fluid ID, Pressure Testing and Sampling Technology Group and oversees an optics team, reservoir fluids interpretation team, and chemometrics team. Chris Jones specialties include optical spectroscopy and optical methods, chemometrics/statistics including pattern recognition, compositional analysis techniques, and petroleum geochemistry. He received his BS from the University of South Carolina in Chemistry and an MS in Physical Chemistry from the University of Houston, with additional graduate hours from the University of Houston in Geochemistry and Sedimentary environments.

The future prospects for applications of photonics technologies used by the oil & gas industries look good.

A few key ideas:

- Easy oil does not exist anymore. As such, any technology that helps improve the prospects of oil extraction and characterization will be increasingly important.
- Major oil companies will do anything necessary to extract oil from the ground in a more efficient manner.
- R&D expenses cannot be cut, at the expense of a major technology slowdown later on.

A few key problems that can be solved though photonics:

- Pipeline measurements
- Flow assurance
- Reservoir production monitoring

These are relevant issues, as there are currently 2 million miles of pipelines installed in the world.

10. Executive panel: Drivers of global laser markets

With global markets constantly changing and new applications and customers appearing, we again bring together senior executives from several of the leading laser companies in the world to provide their perspectives on current markets, views on different technologies and opinions about future challenges and opportunities for manufacturers and integrators of lasers and photonics products.

- Armin Renneisen, Managing Director, Rofin-Sinar Laser rofin Member of EPIC
- Martin Seifert, President, Nufern
- Trevor Ness, Senior Vice President Global Sales and Marketing, IPG Photonics
- David Allen, Senior Vice President and General Manager, Lasers Group, Newport

This panel carried out a very interesting discussion. In general, the industry mood is upbeat and positive, with the general perception that laser technology is maturing rapidly while new technology literally comes to light.

Lasers are now tools to solve industry problems, and the trend is to reduce cost per part by moving from nanosecond to picosecond to femtosecond. But the application window is short, as new devices must be tested and validated within that window to be able to grab a significant business opportunity.

We are observing western manufacturers moving to China as well as Chinese manufacturers move to the US and Europe. In general, westerns manufacturers still have an advantage in lasers optimized precision processes. But China is evolving rapidly, in part fuelled by large R&D investment programs in photonics related areas, coupled to the availability of local talent.

Fiber lasers continue to grab the attention, as their efficiency now reaches 55%, including scanning and beam delivery. It was stated by Valentin Gapontsev that diode lasers do not offer any advantage relative to fiber lasers.

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