

THE

# LASER USER

ISSUE 81  
SUMMER 2016

**AILU**

IN THIS ISSUE:

*Maritime laser welding*

*High speed cladding*

*Aluminium alloy cutting*

*Hollow core fibre delivery*

*Marking results database*

*Laser-generated particles*



**TRANSPORT  
APPLICATIONS:  
MARINE, AEROSPACE AND  
AUTOMOTIVE MARKETS**

**Editor:** Dave MacLellan  
**Sub-Editor:** Catherine Rose

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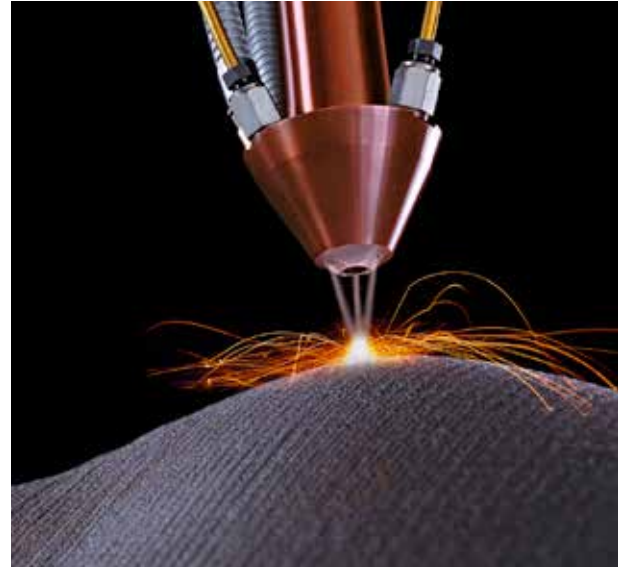
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The Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members. The Editor reserves the right to edit any submissions for space and other considerations.

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Cover image:

The DepositionLine from TRUMPF uses a specially designed processing optic with a powder nozzle for its laser deposition welding process.

Image courtesy of TRUMPF

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**Elected until 2018**

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**Elected until 2017**

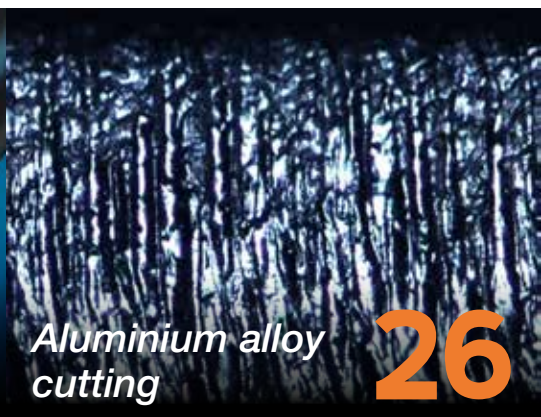
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 Mark Millar (Essex Laser)  
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Past presidents and founder members are also able to attend committee meetings. Anyone wishing to join the AILU Steering Committee please contact the Executive Director.

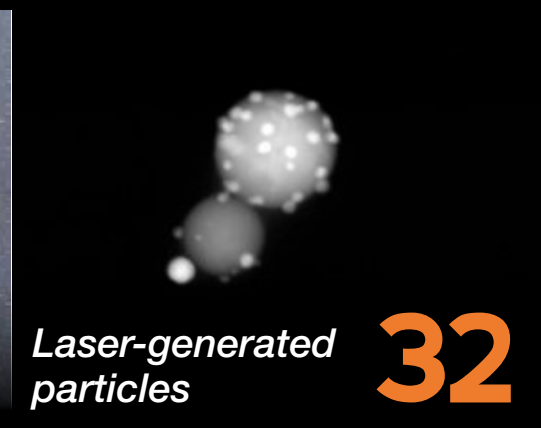
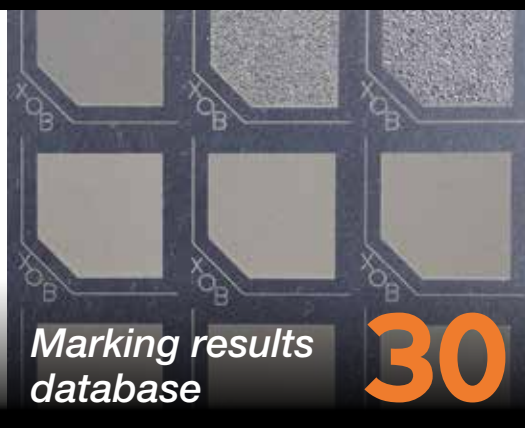
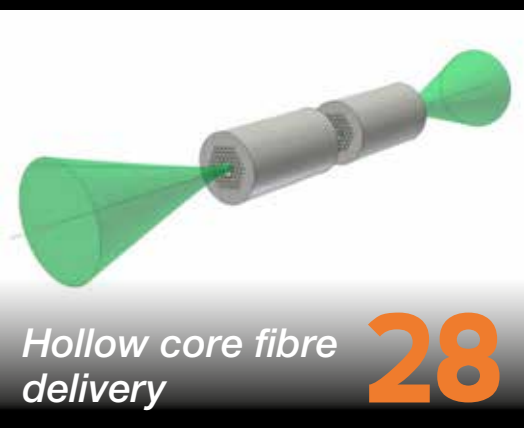
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## FIRST WORD

As an island nation, the UK was a front-runner in the shipbuilding industry, and I really enjoyed our Maritime Industry workshop and the tour of Cammell Laird shipyard in Birkenhead where the first all-welded metal ship was built in 1920. It was inspiring to see the issues and challenges faced by this industry and the applications (especially cleaning, additive manufacturing and welding/cladding) where lasers could improve the current process in terms of consistency, weight and waste reduction.

AILU, with UK headquarters, is nonetheless a global Association. During the next 2 years we aim to expand our membership with more overseas members. We welcome recent members Tamari Industry (Japan) and HiLASE (Czech Republic) and we are working closer with sister-organisations LIA (USA) and JLPS (Japan) to share our know-how and content wider. We live in a very small world and the interconnectedness of our laser community is something we are keen to enhance. No matter what happens to the European Union after the UK completes negotiations around an exit agreement (Brexit), I feel sure the international trade in laser sources and systems and the academic collaboration with partners inside and outside of Europe must surely continue to expand. We are investigating holding AILU events outside the UK, a movement to enhance the global networking of our members and create a strongly-linked global community that co-operates and communicates better and better.

We are starting to line up speakers for the ILAS in March next year (22-23 March, is it in your diary?), and the website [ilas2017.co.uk](http://ilas2017.co.uk) is the best place to find the latest details as they are published. Our intention is to build on three pillars (thanks Stan Wilford for the suggestion):

**INVITATION:** People respond to personal invitation, so start inviting today!

**INNOVATION:** Tell us about your new and innovative applications.

**INDUSTRY:** How can your application be adopted by industrial manufacturers?



**Dave MacLellan**

**AILU Executive Director**

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## PRESIDENT'S MESSAGE

Welcome all to our latest edition of "The Laser User". Well as I promised in my last President's Message, no matter what the result on 23rd June, AILU will still be here for our members and the broader Laser Processing Community – and here we are! There is, as you will all know too well, enormous change going on all around us, at political, economic and societal level. You will be pleased (at least I hope you will be) to know there has been no change at AILU and all the officers and staff are still in post! In fact at a time when there is talk of moving away from Europe, AILU is moving further towards it. We are starting to think how we might further engage with our European colleagues and friends and expand the reach of AILU. The intention here is to expand our membership beyond the UK whilst being cognisant of the need to provide support and knowledge exchange services for our European counterparts. Indeed we are not limiting ourselves to Europe but looking beyond also. A fine example of this is that AILU has recently been announced as the organisers and hosts of the Laser Precision Microfabrication (LPM) conference in

partnership with the Japan Laser Processing Society (LPS). This will be held in Edinburgh in 2018 and I must make public my thanks to both Duncan Hand and Lin Li for the excellent work they put in in securing this for us. On a different tack we also have Lin Li our vice-president serving as President of LIA (Laser Institute of America) what a perfect opportunity for collaboration across the water.

So, at a time when the world looks to be getting smaller and we in the UK more isolated, AILU are looking to expand and develop new connections and new opportunities.

I hope you enjoy this edition of our magazine and wish you all luck and good fortune in this new world that we find ourselves in.

**Ric Allott**

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## SHARP COMMENT

Referendum week in June was an interesting and busy time, not just for myself, but many others too. Of course the most significant and historic news was the referendum result itself. The result came at the end of a week of many varied activities as far as I was concerned. I have to say I woke that Friday morning, saw the BBC notification on my phone announcing the breaking news that we were to leave the EU, and could only feel disbelief. Yes I voted for staying in; I have benefited from having my pay funded by the EU and am aware of the volume of research that is funded by the EU. Liverpool itself has been transformed with the support of EU funds.

The country has taken an initial hit in terms of exchange rates and share prices plummeting, but just a month on, all is feeling like business as usual. Well, with the potential exception of applying for EU R&D funding. We are hearing numerous reports from a range of entities that European consortia writing Horizon 2020 proposals are very nervous of including UK partners. The official line is that it should be business as usual, but unofficially we are hearing that UK partners are being asked to leave bids under preparation (although my colleague Paul French has been told by Fraunhofer in Germany that they would not have any problems with UK partners). So definite uncertainty in this activity - perhaps the real risk with "Brexit" is the short term uncertainty that has the risk of doing some lasting damage.

A good place to do international business had been underway in Liverpool a few weeks prior

to the referendum. The International Festival of Business 2016 (IFB 2016), followed on from a very successful IFB 2015. Several impressive international business deals were announced during the period, but there were some reports of poor interest. I suspect that some tweaking will be required for the next IFB, already planned for 2018. At the beginning of the referendum week, I was involved in a day-long event for our own Sensor City joint venture with the University of Liverpool and this was well attended.

LJMU were heavily involved in preparations for the AILU Maritime meeting in June (see reviews on pages 6 and 7). We had the chance to hear first-hand from a couple of well-informed naval architects that there would be interest in laser processes, but this was also tempered to some degree by working practices that relied heavily on portable equipment being taken to the point of work, and the generally one-off, bespoke nature of the contracts and work required. I still feel there should be a role for lasers in this, but this most probably also requires a significant change in business models. The workshop generated a lot of discussion and I believe this can provide a new type of AILU event, working in partnership with other regional and sectoral trade bodies to deliver focused workshops to identify relevant laser opportunities.

**Martin Sharp**

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**ILAS 2017**  
5th UK Industrial Laser Symposium

**AILU**

# INDUSTRIAL LASER APPLICATIONS SYMOSIUM

## 22-23 MARCH 2017

**BELTON WOODS HOTEL, BELTON, GRANTHAM, UK**



### 50 YEARS OF LASER CUTTING

2017 marks the 50th anniversary of the first gas assisted laser cutting demonstration which was carried out in May 1967, by Peter Houldcroft (of TWI) and Arthur Sullivan, using a 300 W slow-flow CO<sub>2</sub> laser. In recognition of the 50th anniversary, Paul Hilton (TWI) will recap on the history and look at how far the technology has come in the 50 years since it all started. But ILAS is not all about laser cutting!

### SESSIONS AT ILAS 2017 WILL INCLUDE:

- Additive manufacturing
- Surface engineering – Including hardening
- Micro & macro laser welding
- Precision micro-fabrication (fine cutting, micro-machining, 3D etching)
- Repair & remanufacturing
- Sources & beam delivery
- Ultra-short pulse applications
- Drilling
- Marking & ablation
- Macro metal cutting
- Non-metals cutting
- Laser cleaning

### INVITATION

You are invited to attend the ILAS, but we also would like you to invite your international connections, partners and colleagues to take advantage of the ILAS experience. Evidence shows that a personal invitation from a colleague or friend will carry far more weight than an advert or an email from the Association. In 2015 we had 210 delegates and the feedback was excellent – we are building ILAS 2017 around target of 250 delegates.

### INNOVATION

Laser applications are evolving every year with innovative ideas even in some of the most routine applications (think how much progress has been made in laser cutting). ILAS 2017 is an opportunity to share the innovative developments in applications that could bring laser processing enhancements to the market place – whether you are a research institute, manufacturer, job shop or end-user, the shared know-how can bring forward improvements and productivity in laser manufacturing.

### INDUSTRIALISATION

Adopting innovative and efficient applications can enable industrial organisations to improve competitiveness. What do you have in your recent experience which is industry-ready and waiting to be applied in real-world applications? One of the greatest strengths AILU has is the mixture of delegates from all around the laser community. ILAS will help you to pick up ideas ready to apply or share your ideas with the industries ready and willing to apply them.



### VENUE

The Belton Woods Hotel is set in 495 acres of countryside, 2 miles from Grantham in Lincolnshire. This 4-star hotel is an ideal conference venue which will enhance the ILAS experience with excellent food, beautiful scenery and first class facilities. With 3 golf courses, a health spa and swimming pool as well as a range of outdoor facilities, the hotel is ideally suited to networking and building business connections in a relaxing environment.



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## AILU BREAKFAST WORKSHOP: LASER APPLICATIONS IN THE MARITIME INDUSTRY

22 JUNE 2016 MARITIME KNOWLEDGE HUB, BIRKENHEAD

The event was held in the newly refurbished Maritime Knowledge Hub, hosted by Mersey Maritime Limited in their excellent facilities at Lairdside in Birkenhead. This event was different in that it was targeted at one specific market and held in the morning only as a half day event with a networking breakfast to start the day.

Chris Shirling-Rooke, Mersey Maritime CEO, welcomed the 30 delegates and introduced the Northern Powerhouse and the maritime industry locally, and Dave MacLellan from AILU gave a brief overview of the laser applications with the most potential for use in the maritime sector.

Presenting on behalf of Maritime industry end users Cammell Laird, were Naval Architects Nicholas Mansell and John Barnard, who gave an insight into the challenges faced in ship repair and ship building especially the need for equipment to be hand-held and/or portable and safe to use in a shipyard environment. After their talk (see summary on the facing page), there was a lively question and answer session between the presenters and the audience discussing potential solutions to maritime problems. There is an opportunity for new applications and new technology to be applied and this was an ideal occasion to make introductions.

Paul French from Liverpool John Moores University gave an overview of surface texturing and included some fascinating information about ongoing work on anti-fouling surfaces to reduce the adhesion of biological matter on undersea surfaces – inspired by some natural patterns taken from shark skin and whale skin.



### Networking breakfast

Ioannis Metsios from Powerlase gave an overview of the advantages of laser cleaning for removal of paint from ship's hulls and superstructures. Laser ablation creates much less toxic waste compared to blasting or solvent-based removal processes. Progress is being made towards a target of 1m<sup>2</sup>/min as laser power increases.

Nic Blundell from MTC described the applications of high power fibre laser welding, comparing it to other processes including hybrid arc laser welding and highlighted the results possible with laser cladding by wire or powder feed (see his article on pages 22 and 23).

Ali Khan from TWI then delivered the final presentation highlighting the work carried out at TWI over the past decades in high power laser welding of stiffened structural panels and presented work on cladding for shaft repair and building of parts by 3D manipulation to perform additive manufacturing and repair. Finally the work on decommissioning by laser cutting and

underwater cutting were described showing the capability of laser cutting where access is difficult and conditions are extreme.

Following the presentations there was an opportunity for delegates to either visit the Cammell Laird ship yard or the Mersey Maritime ship simulator. John Eldridge led a fascinating tour of the ship yard and gave a flavour for the technologies used and skills required to build and repair ships. Cammell Laird has an interesting history since it opened in 1828, especially in 2003 when it came close to being demolished and redeveloped as luxury apartments. With many successful contracts completed, work is underway to build the new RRS Sir David Attenborough, due to enter service in 2019.

Both tours were scored very highly with delegates and the event feedback was all very positive with most delegates indicating that they had made 4 or 5 new contacts on average and had found opportunities to explore new business further. Hopefully this workshop will be the catalyst for more collaboration between the laser community and the supply chain for the maritime industry.

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Event speakers (left to right): Dave MacLellan (AILU), John Barnard (Cammell Laird), Nick Mansell (Cammell Laird), Chris Shirling-Rooke (Mersey Maritime), Ioannis Metsios (Powerlase), Nic Blundell (MTC), Paul French (LJMU), Ali Khan (TWI), Martin Sharp (LJMU)

## MARITIME WORKSHOP REVIEWED BY PRESENTER NICK MANSELL, CAMMELL LAIRD



RRS Sir David Attenborough (image courtesy Cammell Laird)

On 22 June 2016 AILU visited the Maritime Knowledge Hub in Birkenhead. Formerly an industrial heartland, the area has seen large declines since the 1980s, but now new investments like Peel's new container port 'L2', supported by the might of historic names such as Cammell Laird Shiprepairers and Shipbuilders Ltd, promise to bring jobs and technology back to the area over the coming years.



Rust removal (image courtesy General Lasertronics)

Following the award of a contract for the design and build of the polar research vessel RRS Sir David Attenborough in November 2015, the Cammell Laird team are currently investigating how industrial lasers can be utilised within the shipyard to drive performance improvements. Project Managers John Barnard and Nick Mansell laid down the gauntlet to AILU

delegates, describing current barriers to laser use in shipbuilding and repair activities and sharing some interesting ideas for potential future applications.

A number of laser applications were of particular interest to the Cammell Laird team, including recent developments in paint and rust removal tooling. John and Nick noted that such applications could provide good alternatives to conventional tooling, reducing noise and sparks associated with grinding as well as the extensive clean up and environmental impact encountered with shot blasting. Manufacturers have noted that lasers can currently remove around 3 m<sup>2</sup> of paint per hour, but were targeting 60 m<sup>2</sup> by the end of next year, making the process comparable to existing blasting processes. It was also noted that paint and rust removal around small areas such as around weld seams was as important as tackling large areas such as the side of a ships hull and so small, portable, lightweight machinery was the focus of many of our discussions.

Significant opportunities also exist for the shipyard to utilise lasers to project complex shapes onto plates in horizontal and vertical planes. The Cammell Laird team highlighted instances where using lasers to project a CAD drawing onto a floor or bulkhead would be especially useful, leading to a reduction in setting up time at the beginning on new manufacturing

projects. These opportunities are amplified by the nature of the core activities carried out by the shipyard which span newbuild and repair style work.

The team emphasised the one-of-a-kind nature of typical manufacturing jobs which meant that new tooling had to be highly adaptable. Nick noted that "Adaptability has been the key to our success over the past 15 years and will continue to drive our progression in the future. This is why we are so keen to understand current industrial capabilities and work with organisations such as AILU to describe our upcoming needs. The opportunities presented by the new Maritime Knowledge Hub in Birkenhead are huge, especially given the influx of new vessels we are expecting to see with the new L2 development".

Steel cutting for the RRS Sir David Attenborough is set to begin this summer and will be delivered 18 months later. During this period the company will continue to support the Ministry of Defence and Royal Fleet Auxiliary, whilst delivering a first class service to local shipping operators and offshore organisations. Cammell Laird is also a major player in the full spectrum of the UK's nuclear renaissance as it brings offsite manufacturing technology of large complex structural modules to a sector that demands the highest standards of engineering standards and quality. When discussing the growth of the company, John said "The company is in its next phase of evolution having delivered over 11,000 tonnes of flight deck modules for the Queen Elizabeth Class Carriers and two commercial ferries in 2014. The future for the company is bright, illustrated by the award of the RRS Sir David Attenborough which provides the shipyard with the opportunity to showcase to the world the first class workmanship that is delivered by the men and women of Merseyside and their partners throughout the UK and Europe".

**Nick Mansell**

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Tour group at Cammell Laird



## UK ORGANISATIONS TAKE LEAD IN INNOVATIVE LASER WELDING R&D PROJECT

Aerospace company Hutchinson AeroTech (sister company to AILU member Hutchinson Engineering) has announced that a project to accelerate academic research in laser welding of titanium in order to bring it to industrial maturity for the aerospace sector, has been funded by Innovate UK.

The project consortium, led by Hutchinson AeroTech, has been awarded over £1.1 million and brings together AILU members TWI, MTC, and IPG Photonics with the Northern Ireland Technology Centre at Queen's University Belfast, Leonardo Helicopters and TISICS.

With a strong collaborative effort, the partners will work together to develop and demonstrate industrial welding of structural titanium to

ensure that the UK is at the forefront of the aerospace industry. The total project value is almost £1.5 million.

Mark Hutchinson, managing director of Hutchinson AeroTech, comments; "Eventually, this new capability will replace more traditional assembly techniques on existing and newly designed aerospace parts. Our aim at completion of this project is to be in a prime position to use new developments in robotic laser welding from the project to implement cost savings firstly within the aerospace sector and subsequently to a wider range of industries in the future. The significant benefits that this project will offer include a reduction in manual labour, lead times, component

weight and energy consumption. This will have an exceptional impact on the future of laser welding in the UK aerospace sector."

John Laughlin of Innovate UK, said, "Laser welding is emerging as the process of choice since it can produce low distortion welds of good quality and properties at significantly faster speeds than other welding processes. We are delighted that this funding will allow the consortium to form and with their expertise we will add real value to the future of the aerospace sector."

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*L to R: Ray Durman, Operations Director, TISICS Ltd, Dr Chris Allen, Principal Project Leader, TWI Ltd, Adrian Smith, Project Manager, Leonardo Helicopters, Dr Andrew Silcox, Technical Specialist, The MTC, Dr Adrian Murphy, Director Research – Aerospace & Manufacturing, QUB, Helen Lucas, Monitoring Officer on behalf of Innovate UK, Mark Thompson, Director of Sales & Service, IPG Photonics (UK) and Dominic McDonnell, Financial Director, Hutchinson Group.*

### MKS INSTRUMENTS ACQUIRES NEWPORT

Earlier this year MKS Instruments completed the acquisition of Newport Corporation, the parent company of Ophir-Spiricon, LLC. MKS is a publicly traded technology leader in vacuum measurement and control, power and plasma, data analytics, and automation and control.

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### NEW PRESIDENT AT WALL COLMONOY

Wall Colmonoy is pleased to announce that Nicholas W. Clark has been appointed to the position of President. In March 2012 Nicholas started with Wall Colmonoy Limited (UK) as a Process Engineer rising to Deputy Managing Director. In October 2014, he returned to the US as a Director.

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### RENISHAW OPENS AM SOLUTIONS CENTRE, INDIA

Renishaw has opened a new Additive Manufacturing Solutions Centre in Pune, India. The new facility will provide a secure development environment in which customers can expand their knowledge and confidence using AM technology.

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### ROFIN EXPANDS FIBRE LASER PRODUCTION

Due to the increasing success in the market, ROFIN expands its fibre laser production by an additional assembly line at the company's factory in Hamburg. With the creation of additional production capacities, ROFIN now reacts to the increasing demands in the segment of low-power fibre lasers.

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### HAMAMATSU INCREASES CAPACITY IN JAPAN

Hamamatsu Photonics K.K. has announced the construction of a new building at its Shingai factory to increase manufacturing capacity of opto-semiconductor components. The new building will be used for post-processing steps (assembly and inspection).

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### TRUMPF INVESTS 30 MILLION EUROS

TRUMPF has invested nearly 30 million euros in new development and production facilities for solid-state lasers. The new production facility in Schramberg, Germany, will offer 12,000 square meters of additional floor space, enlarging the total available production area to nearly twice its current size.

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[www.uk.trumpf.com](http://www.uk.trumpf.com)

## POWERLASE WINS BEST COMPANY AWARD

Powerlase Photonics was invited to compete with other Photonics SMEs at the European Photonics Venture Forum 2016 in Eindhoven, Netherlands. Powerlase is proud to report that it won the Best Company Award as judged against a range of investment criteria, giving independent acknowledgement of Powerlase's strong position and strategy for growth.

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## HAMAMATSU'S JOINT RESEARCH DISCOVERY

The Graduate School for the Creation of New Photonics Industries, Toyota Motor Corporation and Hamamatsu Photonics K.K. have announced the discovery of a new efficient heating mechanism for fusion fuel by irradiating opposed two beams in three steps (total: six beams) with lasers installed opposite each other with fusion fuel between them. This achievement shows that a compact device has a potential to make fusion fuel compressed, heated and ignited with less number of lasers than large scale laser fusion fuel facilities, which advances the practical use of laser fusion.

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## BYSTRONIC OPEN HOUSE SUCCESS

Bystronic UK welcomed more than 80 visitors to its latest Open House, held at the company's Coventry headquarters and technical centre from 12th - 14th July. During the week of the event, orders were placed for three laser cutting machines, indicating that UK manufacturing still has a positive outlook post-Brexit.

Bystronic's latest fibre laser machine was on show, the ByStar Fiber, which is aimed at users who want to rely exclusively on fibre laser technology and use it to process thick as well as thin sheet - from stainless steel, through aluminium and mild steel, to non-ferrous metals such as copper and brass.



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## OPTICS

### SCANLAB CAMERA AUTOMATES ALIGNMENT

SCANLAB AG offers an intelligent monitoring and calibration system for laser processing applications requiring strict dimensional tolerances. The easy-to-use SCANalign image processing solution augments scan systems via ultra-precise calibration of the entire image field. By enabling automatic process alignment and visual quality control of laser processing results, SCANalign prevents rejects and cuts costs.



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### NEWPORT INTRODUCES NEW OPTICAL PEDESTALS

Newport Corporation is introducing the PX series of forkless pedestals and posts, the most space-saving option for stable mounting of optical components. Forkless optical mounting posts and pedestals have a unique internal slotted base allowing them to be directly mounted to optical tables or breadboards without a clamping fork. This patent-pending feature can provide up to 66% of space savings compared to standard pedestals while still providing positional flexibility and excellent long-term stability.



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## SCANNERS

### LASER SCANNING SYSTEMS FROM ELUXI

A comprehensive selection of ARGES scan heads with 2-8 axes for a broad range of applications in the field of industrial laser material processing are available from ELUXI. Customer-specific scan modules and laser scan systems are tailor made for a wide variety of custom applications. The remote welding ELEPHANT (pictured) has 3D scan-heads for robot-assisted applications.



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[www.eluxi.co.uk](http://www.eluxi.co.uk)

### NEW RAYLASE SCAN HEAD CONTROL CARD

RAYLASE is simplifying and accelerating the development of laser systems with its new SP-ICE-3 universal control card. It controls 2-axis and 3-axis deflection units as well as all standard laser sources. Furthermore, it offers speed-dependent and position-dependent control for a consistently high processing quality.



**Harnesh Singh**  
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[www.raylase.de](http://www.raylase.de)

## SOFTWARE

### COHERENT'S NEW LASER MEASUREMENT APP

Coherent's new LabMax-Pro Mobile App enables operation of the company's laser power and energy sensors using a tablet computer, thus delivering an improved user interface and enhanced ease-of-use.

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PRODUCT NEWS

POSITIONING

**PHYSIK INSTRUMENTE'S COMPACT LINEAR STAGE**

With the U-521, PI (Physik Instrumente) has added a compact linear stage to its portfolio with dimensions of 35 x 35 x 15 mm, that allows perfect integration even when space is limited. It reaches maximum velocities up to 200 mm/s with a dynamic start-stop behaviour and is suitable for travel ranges up to 18 mm.



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[www.physikinstrumente.com](http://www.physikinstrumente.com)

**NEW PLATFORMS FROM AEROTECH**

**FiberMaxHP photonics alignment platform:** a second-generation 3-6 axis photonics alignment platform.

**High-dynamic linear piezo nano-positioning stages:** the QNPHD stages provide the benefits of both a stage and actuator in one compact package.

**QNP2-100-XYA piezo stages:** combine sub-nanometer resolution, high dynamics, and exceptional geometric performance.

**Microscope-objective piezo nanopositioner:** enables microscope objective and optics positioning at high-speeds with nanometer-level performance.



QF-46 piezo nanopositioning stage

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SOURCES

**INNOLAS LASER SPEEDS UP CUTTING PROCESS**

Speeding up free-form cutting processes of printed circuit boards (PCBs) can be an extremely challenging task. The use of CO<sub>2</sub> lasers causes charring and unwanted conductive residues. Using 355 nm UV lasers prevents charring but the low penetration depth requires high laser pulse energies, giving low cutting speeds, expensive system pricing and poor laser lifetime. Going to high rep-rate, short pulse 532 nm lasers, the use of InnoLas Photonics' BLIZZ lasers enables up to 30 mm/ sec high speed PCB cutting processes with impressive cutting quality, laser performance and reliability.



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Micromachining Shouldn't be a Giant Task

Linear Stages

- Models with travels from 50 mm to 1.5 m
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- Low cost; high performance
- Ball-screw or linear-motor-driven models



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VascuLathe® DS

Integrated Servo/ Scanner Systems

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- Laser firing based on real-time scanner/servo position



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X, XY, and Z Piezo Nanopositioners and Piezo Controls

- Resolution to 0.02 nm
- Linearity to 0.007%
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- Travels to 600 µm



Q-Series



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Dedicated to the Science of Motion

**SAFETY**

**CONTAINMENT SOLUTIONS FROM LASER COMPONENTS**

Even lasers with comparatively low power levels require efficient protection, but this does not have to mean bulky and expensive laser safety barriers. LASER COMPONENTS offers a new and cost efficient material, offering sufficient protection for power levels of up to 100W/cm<sup>2</sup> for 100s (test parameters: 1064nm, 2.82mm beam diameter). The material is offered in custom sizing and multiple formats including wall- or ceiling-mounted curtains, window shades and free standing barriers.

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**LASERMET'S LASER CASTLE INSTALLED**

Lasermet Inc. completed the installation of a Laser Castle laser safety cabin at the Composite Prototyping Centre, New York State. The 26ft wide, 18ft deep and 11ft high enclosure included laser interlock control, LED sign, HD CCTV system and automatic doors.

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**FUME EXTRACTION**

**BOFA'S 2ND GENERATION EXTRACTION UNIT**

With the introduction of iQ-based extraction units in 2012, users were able to monitor real time filter performance and access system data to support fast and effective filter replacement and system maintenance. iQ2 second generation combines iQ reliability with a range of new and highly advanced feature enhancements, adding significantly to the list of seller and user benefits.



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## Laser Safety



Viewing Windows  
Curtains & Barriers



Roller Blinds  
Enclosures  
Beam Dumps  
Eyewear  
Warning Signs



LaserBee Software




T: 01829773155  
 E: [info@laserphysics.co.uk](mailto:info@laserphysics.co.uk)  
[www.laserphysics.co.uk](http://www.laserphysics.co.uk)

**LASER CASTLE**

Laser Safety Cabins



Failsafe Interlocked Solution  
 Options include:-

-  Auto-doors
-  Guillotine doors
-  Turntables



**laser jailer**  
 active laser guarding system

Turns multi-kW laser off in 50ms if the beam strikes the wall.  
 Can be retrofitted to existing cabin or walls



LED Warning Signs

**glaser jailer**  
 active laser safety window

Active Filter Windows



**I-extract**  
 laser fume extraction

Fume Extraction



**lasermet**  
 laser safety solutions

01202 770740  
[sales@lasermet.com](mailto:sales@lasermet.com) [www.lasermet.com](http://www.lasermet.com)

British Manufacturers of Lasers Safety Systems since 1987

EUROBLECH IMTS FABTECH  
 Hanover Chicago Las Vegas  
 Hall 12, Stand H26  
 Booth N-6200 Booth N1126  
 Laser Safety Training at NPL  
 on 29<sup>th</sup> Sept

PRODUCT NEWS

BEAM DELIVERY

THE 'ALL-IN-LIGHT' PACKAGE FROM PRECITEC

With the new 'All-In-Light' package, Precitec offers an attractive solution for the complete optical chain – from the laser and the laser light fibre to the cutting head. This package is made possible by a strategic cooperation with TRUMPF. It makes the disc laser technology, proven and appreciated in the industrial environment, available for manufacturers of flatbed and tube cutting machines.

"This cooperation enables us, on the one hand, to offer the complete optical chain for laser cutting from a single source and, on the other hand, to advance new developments even more specifically in order to provide the customer with a perfectly coordinated, optimal package" explains the CEO of Precitec, Dr. Thilo Wersborg.



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II-VI HIGHYAG OFFERS CONSULTING SERVICES

II-VI HIGHYAG complements its portfolio with application-specific consulting services. Collaboratively with its customers, II-VI HIGHYAG's application engineers develop optimal systems and process set-ups for mission-critical laser applications that require a high degree of customisation to meet performance and reliability requirements. Areas of expertise include laser welding, laser soldering, laser brazing and laser cutting.



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SCANLAB PRODUCTS ARE COUNTERFEIT-PROOF

SCANLAB AG labels its products using the latest security technology so that users are protected from poor quality copies. This counterfeit-proofing guarantees system authenticity for customers, and the 'engineered and manufactured in Germany' quality attribute. Every scan head and galvanometer scanner shipped now bears individually coded brand-protection security labels to ensure each system's uniqueness, genuineness and traceability.

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SYSTEMS

TRUMPF'S ENTRY LEVEL WELDING SYSTEM

Laser welding is becoming a hot topic as, for a relatively modest investment, it presents job shops with a great opportunity to differentiate themselves and make good money in the process.

To make the decision to adopt the technology even easier, TRUMPF has introduced its compact, TruLaser Robot 5020 Basic Edition with TruDiode laser which can reduce the initial outlay by up to 20%. And where a laser network is used, reductions of up to 50% are possible. The entry level system TruLaser Robot 5020 Basic Edition from TRUMPF has a compact footprint and includes everything a manufacturer needs to perform automated deep penetration and heat conduction welding in mild steel, stainless steel and aluminium up to four millimetres thick.

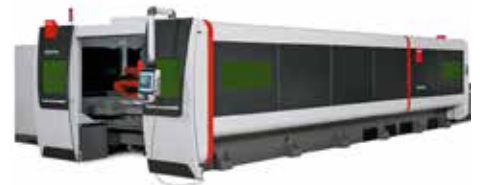


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BYSTRONIC SYSTEM CAN CUT LARGER SHEET

Bystronic, has extended its BySprint Fiber range of fibre laser cutting machines to include a larger model, designated 6520. It allows metal sheet measuring up to 6.5 metres by 2 metres to be processed, whereas the other two machines in the range have maximum table capacities of 4 metres by 2 metres and 3 metres by 1.5 metres respectively.

As with the smaller BySprint Fiber machines, the larger 6520 model can be equipped with a 3, 4 or 6 kW fibre laser source. There is no compromise on speed, maximum simultaneous positioning of the axes being the same at 140 m/min.



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PRIMA POWER'S NEW DUAL WORKSTATION

Prima Power Laserdyne has introduced the new Dual Workstation LASERDYNE 606D multi-axis laser processing system – The Power of 2™. This new innovative system features two completely independent 3D laser processing work stations in a single structure.

The 606D is ideally suited for operations with relatively high volume applications of precision 3D laser cutting, welding, and drilling and those operations where set-up and part changeover are critical. In both cases the system appeals to those who are concerned about obtaining the greatest throughput per unit area of factory floor space.



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## MARKING

## ROFIN PROVIDES ADDED OPTIONS WITH EASYMARK

With the EasyMark, ROFIN offers an extremely compact tabletop laser marking system, which is also suitable for engraving and cutting of thin metal. The range of application covers single part production with manual part loading as well as automated manufacturing of small to medium lot sizes.



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## COMPACT LASER MARKER FROM INNOLAS

Due to the ongoing miniaturisation in electronic and medical manufacturing, ID codes often become too small for CO<sub>2</sub> or fibre laser marking. InnoLas Photonics' compact Air Mark laser marking modules provide a drop-in upgrade for production equipment. The all-in-one design contains not only the laser and all necessary electronics, but also beam expander, scanner, pointing laser and scan lens in a small, air-cooled housing.



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## TLM DISTRIBUTES FOBA LASER MARKING SYSTEMS

Reliability, consistency and traceability are often mandatory attributes for components being supplied into industry. FOBA's laser systems generate the alpha-numeric codes necessary to guarantee reliable identification and traceability. FOBA systems are available from TLM Laser, UK.

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## CASE STUDIES

## CONCEPT LASER PRINTS CONCEPT CAR PARTS

The EDAG concept car, named "Light Cocoon", is a compact sports car with design inspired by nature and constructed using additive manufacturing, covered with an outer skin made from weatherproof textile material.

The nodes of the space-frame are 3D printed in metal and combined with intelligently processed steel profiles. Thanks to additive manufacturing, the nodes can be configured to be highly flexible and multifunctional so that, for example, different versions of a vehicle can be produced "on demand" without any additional tooling, equipment and start-up costs.

The nodes were manufactured on an X line 1000R machine from Concept Laser which has the appropriate build envelope for such projects and operates with a 1kW laser. The spaceframe body of the concept car combines the advantages of 3D printing, namely flexibility and design for lightweight construction, with the efficiency of proven conventional profile designs. The technology used in this novel product design is available from ES Technology, the local supplier for UK and Ireland of systems solutions by Concept Laser.



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## EOS AIDS MANUFACTURE OF CIRCUIT BOARDS

The German firm, Beta LAYOUT GmbH, manufactures prototypes for printed circuit boards (PCBs) and 3D mechatronic integrated devices (MIDs). To speed prototype production and reduce costs, it has installed an additive manufacturing system from EOS.

The ever-shorter life cycle of many devices poses additional challenges, as injection moulding costs too much for prototype manufacture. For this reason, Beta LAYOUT wanted a less expensive alternative and installed an EOS FORMIGA P 110 additive manufacturing system to produce circuit carriers for evaluation.

The innovative process starts with building the boards layer-by-layer from glass-filled polyamide (PA 3200 GF). They are then coated with a special finish containing an additive.

## RENISHAW DELIVERS AM MOUNTAIN BIKE FRAME

A collaboration of cutting edge technology and companies, anthropometry, and years of experience has led to the unveiling of the new Robot Bike Co. R160 mountain bike frame – designed and manufactured in the UK with partner companies Altair, HiETA Technologies and Renishaw, using metal additive manufacturing.

A great design freedom has been achieved through the development of a unique construction using titanium lugs, proprietary carbon fibre components and tubing and a double lap joint bonding concept.

Through the experience of the partner companies, each frame can be tailored to a customer's individual measurements or specifications, with the added benefit that the frame can be constantly improved as new technologies emerge, as the production process is not constrained by a mould.



Titanium lugs produced using AM

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Subsequent LDS (laser direct structuring) activates the finish by triggering a physical-chemical reaction that creates metallic spores while simultaneously roughening the surface.

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# HOW CAN PILOTS PROTECT THEIR VISION FROM LASER STRIKES?

Last week I decided to invest £65 in a new laser pointer from an online retailer, with free shipping direct from Hong Kong. The specification was 'blue laser', less than 5 mW power and came with a number of patterns and safety glasses. According to the instructions 'this laser pointer can be used for presentation, teaching indicator, children amusement and more'. I can vouch this could be used for 'more' but certainly not 'children amusement'.

After unpacking the laser and charging the batteries the first action was to measure the output. The initial reading showed nearly 2 W at 445 nm and the beam managed to drill a hole immediately through the safety glasses supplied with the laser.

There is a worrying trend for laser pointers to be sold with incorrect information on the label. Last year we tested several green laser pointers for a technical review paper; the laser pointer specifications ranged from 5 mW to 100 mW at 532 nm. All emitted far more power than the label indicated when the batteries were fully charge. However, even more disturbing was the fact that most of the models gave off a significant and dangerous amount of near-infrared (both 808 nm and 1064 nm).

The pointers obviously had not been fitted with any type of blocking filter and the suppliers have scant regard for the safety of users (and bystanders). The user may think they are protected by wearing typical orange 532 nm blocking eyewear when in fact dangerous amounts of radiation are entering their eyes.

These lasers, which are readily available online to the general public, pose problems to police



*ST Laserstrike light-weight titanium aviator laser protection glasses*

helicopter pilots, civil aviation pilots operating near built up areas and in fact anyone working in the emergency services or security.

Brinell Vision has been developing and manufacturing advanced filters for visible lasers since the company started six years ago, and our filters are now used in a wide range of fields from medical microscopes, range finders, astronomy, space qualified sensors and defence.

On the back of our experience we set out several years ago to develop eyewear which could be utilised in real 'non-lab' working environments; this meant providing protection for multiple visible wavelengths while maintaining maximum light transmission, colour balance and user comfort for the wearer. The work led us into the development of our own special lens material and incorporation of customised absorbing dyes to allow production of a light weight lens which is able to accept complex laser coating.

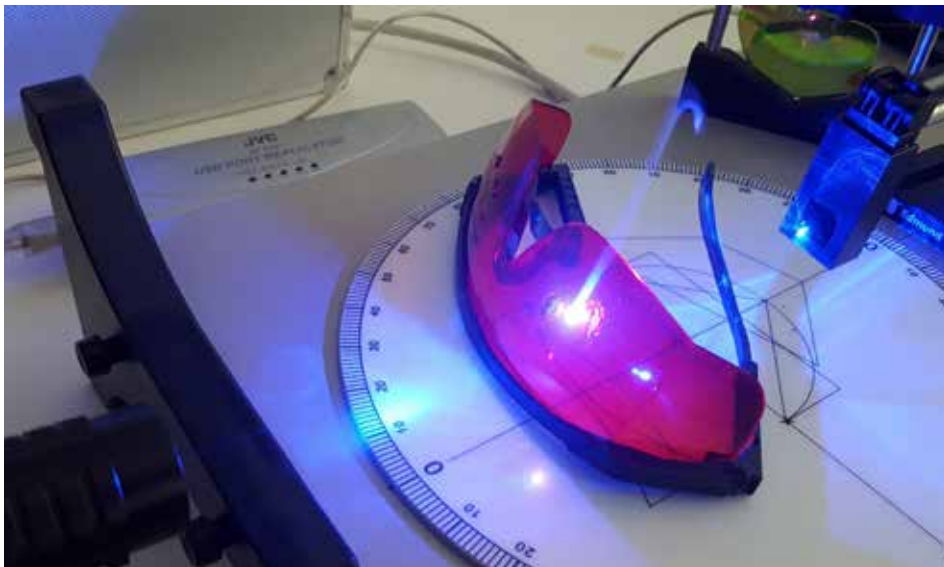
Our project brought us together with Optimum RX Lens Specialists in Lancashire (a manufacturer and supplier of prescription lenses and frames) and Sierra Tango in Florida (an aviation project consultancy). In April this year we agreed to form a new company, ST Laserstrike with offices in the UK and USA, which would focus on the supply of laser-strike eyewear. Our manufacturing base in the UK supports some of the most sophisticated equipment in freeform lens generation, lens coating and glazing.

The new company will be offering personalised eyewear for pilots or emergency services; this includes a range of special single-vision and varifocal lenses optimised for the environment in which the user has to operate. As an example, pilots with instrumentation above and below the cockpit screen required near-field vision at the top and bottom of the lens along with our specialised aviation frames ideal for wearing beneath HUD, headphones and visor.

ST Laserstrike brings together expertise in aviation safety, advanced optical prescription lens manufacturing and laser protection solutions to create the only company dedicated to offering a comprehensive laser-strike solution for pilots and emergency services worldwide.

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[www.stlaserstrike.com](http://www.stlaserstrike.com)



*Laser damage to laser protection goggles: a concern for those wearing glasses which have not been through EN207 laser stability testing*

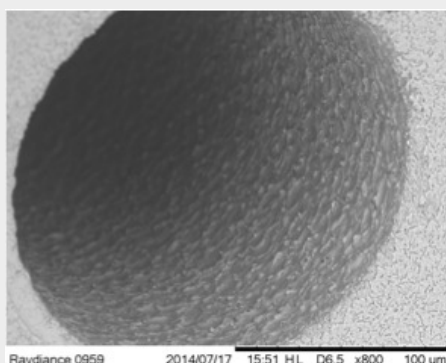
## ULTRAFAST LASERS ENABLE GREENER AUTOMOBILES

**Governments throughout the world are adopting more stringent automobile emissions standards to lower air pollution and reduce air quality-related health concerns. For example, in the European Union, adoption of the EU6 standard for exhaust emissions (including particulates) started in 2014, and will be completed by 2017. In response, automotive manufacturers are developing novel designs and manufacturing technologies to yield cleaner, greener engines.**

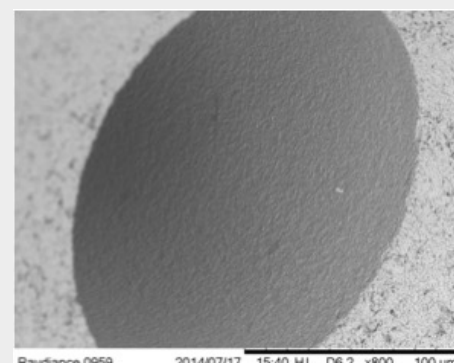
For gasoline direct injection (GDI) engines, the fuel injection system has a significant impact on the mixture formation and its homogeneity. This, in turn, impacts particulate emissions. Researchers at Delphi Automotive have shown that innovative fuel injector nozzle hole shapes can improve mixture formation and combustion dynamics, and hence reduce particulate emissions.

Specifically, the investigation at Delphi Automotive showed that a nozzle configuration consisting of four tapered slots resulted in a long, planar fuel plume having a thin aspect ratio. This pattern exhibited substantially improved emissions characteristics over round holes, and shows the potential of novel shapes.

Unfortunately, Electrical Discharge Machining (EDM) cannot easily create non-round holes.



Raydiance 0959 2014/07/17 15:51 HL D6.5 x800 100 um



Raydiance 0959 2014/07/17 15:40 HL D6.2 x800 100 um

**Figure 1: The EDM drilled hole (left) shows greater surface roughness than the femtosecond drilled hole (right)**

In order to realise these geometries, Delphi employed a Raydiance (now Coherent) R-200 femtosecond laser. This acts as a superior alternative drilling tool that can enable precision machining of these slotted holes on a production basis (Figure 1).

The underlying reason that the ultrafast femtosecond laser produces superior results is that it removes material in a cold "athermal" process. This delivers a better surface finish and improved reliability over EDM, plus sub-micron resolution, no thermal damage to the material, and no recast debris. Delphi also notes that the femtosecond laser produces holes with sharp entrance and exit edges. This helps to atomise the fuel and produce a

consistent plume, all of which improve engine emission characteristics. The femtosecond laser also introduces less heat into the part and offers increased ablation efficiency as compared to picosecond (~10 ps) lasers, which are also currently used in production to drill high precision GDI holes.

The success of this study indicates that new nozzle hole shapes will almost certainly come in the future, and ultrafast lasers will enable their reliable production on an industrial scale.

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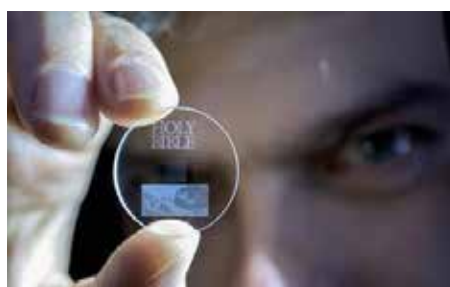
## ETERNAL 5D DATA STORAGE COULD RECORD THE HISTORY OF HUMANKIND

Scientists at the University of Southampton have made a major step forward in the development of digital data storage that is capable of surviving for billions of years.

Using nanostructured glass, scientists from the University's Optoelectronics Research Centre (ORC) have developed the recording and retrieval processes of five dimensional (5D) digital data by femtosecond laser writing.

The storage allows unprecedented properties including 360 TB/disc data capacity, thermal stability up to 1000°C and virtually unlimited lifetime at room temperature (13.8 billion years at 190°C) opening a new era of eternal data archiving. As a very stable and safe form of portable memory, the technology could be highly useful for organisations with big archives, such as national archives, museums and libraries, to preserve their information and records.

The technology was first experimentally demonstrated in 2013 when a 300 kb digital copy of a text file was successfully recorded in 5D. Now, major documents from human history such as Universal Declaration of Human Rights (UDHR), Newton's Opticks, Magna Carta and Kings James Bible, have been saved as digital copies that could out-survive the human race. A copy of the UDHR encoded to 5D data storage



**Eternal 5D data storage**

was recently presented to UNESCO by the ORC at the International Year of Light (IYL) closing ceremony in Mexico.

The documents were recorded using ultrafast laser, producing extremely short and intense pulses of light. The file is written in three layers of nanostructured dots separated by five microns.

The self-assembled nanostructures change the way light travels through glass, modifying polarisation of light that can then be read by combination of optical microscope and a polariser, similar to that found in Polaroid sunglasses.

Coined as the 'Superman memory crystal' - the glass memory has been compared to the "memory crystals" used in the Superman

films - the data is recorded via self-assembled nanostructures created in fused quartz. The information encoding is realised in five dimensions: the size and orientation in addition to the three dimensional position of these nanostructures.

Professor Peter Kazansky, from the ORC, says: "It is thrilling to think that we have created the technology to preserve documents and information and store it in space for future generations. This technology can secure the last evidence of our civilisation: all we've learnt will not be forgotten."

The team are now looking for industry partners to further develop and commercialise this ground-breaking new technology.

Source: <http://www.southampton.ac.uk/news/>

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# INNOVATION AT THE HEART OF ADVANCED ENGINEERING 2016

Advanced Engineering, the UK's largest annual engineering trade show, returns to Birmingham's NEC on 2 and 3 November 2016. The show, which has become the hub for the advanced engineering industry, brings together engineering professionals and decision-makers to witness the latest innovations and trends.

### Exhibitors

With over 80 per cent of the show floor already booked, Advanced Engineering 2016 is on target to have its largest ever exhibitor base. Visitors will have access to over 700 organisations, many of whom will be using the show to launch new products and services to the wider engineering market.

As well as show regulars, the show boasts a number of major first time exhibitors taking to the show floor this year. These include Pipex, Reichhold, Industore, BOC, North East Automotive Alliance, Hexcel Composites, Segura Systems, Senior Aerospace and CyberOptics.

### Open Conference

Advanced Engineering will host the most comprehensive Open Conference programme of its kind. This will provide those in attendance with access to the latest information, from industry trends and supply chain opportunities

to technical talks, case studies and the latest innovations.

Visitors are offered access to six conference forums, which span key industry sectors, such as aerospace, automotive, motorsport, marine and civil engineering. The conference forums include Automotive Engineering, Aerospace Engineering, Composites Engineering, Composites & Advanced Materials Engineering, Performance Metals Engineering and Enabling Innovation.

Throughout the two-day conference there will be a number of insightful and educational sessions from leading industry experts. Sessions confirmed so far include the likes of Jaguar Land Rover, Innovate UK, Magna International, SMMT, BOC, KTN, National Instruments, Womens Engineering Society and many more.

There will also be a series of engineering features live on the show floor, giving visitors unique access to the latest innovations. At the 2015 show these included the ARION1 Land Speed Bicycle, Vestas Sailrocket 2, the Facebook Aquila Solar Plane wing, and Tesla's Model S electric car.

### Show Support

Easyfairs, the organiser of Advanced

Engineering, reports that interest has never been stronger, with more than 80 show supporters on board, including the Institution of Mechanical Engineers (IMECHE) and the Manufacturer.

The IMECHE, the official show supporter, will be running two one-day technical conferences co-located with Advanced Engineering 2016, focusing on the aerospace and automotive sectors.

The Manufacturer will run its Smart Factory Expo in partnership with Advanced Engineering, as part of a series of events to examine Britain's response to Industry 4.0. The Manufacturer Live events include the two-day exhibition, The Manufacturer Top 100, The Manufacturer Annual Leaders Conference and The Manufacturer MX Awards.

Advanced Engineering will also run alongside Lab Innovations 2016, the UK's only event dedicated to laboratory professionals. Visitors will have the opportunity to access both shows with one badge.

For further information about Advanced Engineering 2016, please visit [www.advancedengineeringuk.com](http://www.advancedengineeringuk.com) or contact one of the Easyfairs team on +44 (0)20 8843 8800.

# ADVANCED ENGINEERING 2016

2 & 3 November, NEC, Birmingham

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## LASER PROCESSING RESEARCH CENTRE

**DIRECTOR: PROFESSOR LIN LI**

The Laser Processing Research Centre (LPRC) is part of the School of Mechanical, Aerospace and Civil Engineering at the University of Manchester.

Laser material processing is a multi-disciplinary subject, covering multi-physical processes such as thermal, mechanics, optical modelling in multi-scales. The team performs advanced modelling to support experimental works and to delve into the deep science of the process.

The centre has four research areas with each allocated to a dedicated team with specialist skills in the appropriate fields. These are:

- additive and shaping processes;
- cutting, drilling and welding; micro-nano processes;
- nano-photonics and meta-materials;
- computer simulation and modelling.

In addition to his role as Director of the LPRC, Lin Li is Vice President of ALLU and President of the Laser Institute of America.

There follows an introduction to recent research projects at The University of Manchester related to Laser Materials Processing.

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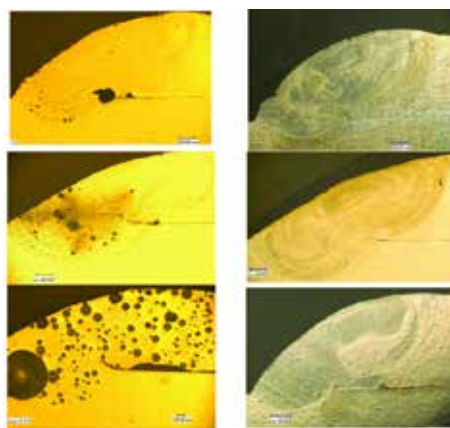
[www.mace.manchester.ac.uk](http://www.mace.manchester.ac.uk)

## NANO-MANUFACTURING

Research in this area is mainly on the laser and hybrid production of novel nanoparticles and nanowires for medical applications. This has resulted in a spin out company. Also research has been conducted in the area of developing nano-porous surface structures. Another area of research is laser modification of graphene.

## CLEANING FOR BETTER WELDING/JOINING

In collaboration with Jaguar and Land Rover, research has been conducted to understand the effects of introducing laser cleaning on laser welding performances in a number of aluminium alloys. The research has led to the practical implantation of the technology at Jaguar and Land Rover for the production of Land Rover Discovery cars.

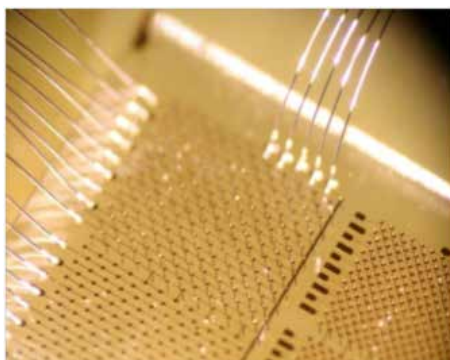


*Laser welded aluminium alloy without laser cleaning (left) and with laser cleaning*

## MICRO-FABRICATION

Laser drilling of small holes in diamond has resulted in the development of 3D sensors installed in CERN for particle collision experiments. In collaboration with Swiss Tech, water assisted fibre laser cutting of medical coronary stents was investigated.

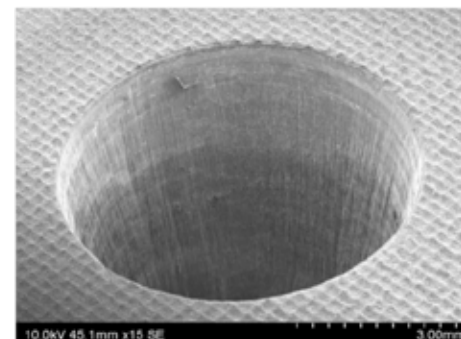
In collaboration with NHS Trust and Johnson & Johnson, laser texturing of coronary stents has been demonstrated for the first time for improved biocompatibility. Collaboration with Tsinghua University in China, another area of research has been focused on laser generation of controllable surface properties such as light control (covering wide spectrum), wettability through laser micro/nano surface texturing.



*Laser drilled diamond 3D sensor system*

## HIGH POWER PICOSECOND MACHINING

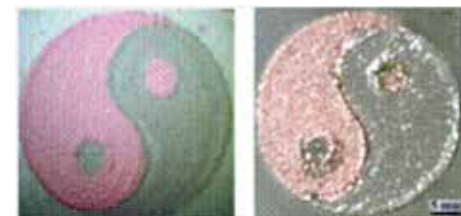
High quality "cold" machining of composite and metallic materials has been demonstrated using a high power ps laser.



*A 6 mm thick CFRP composite cut with a high power picosecond laser.*

## AM AND 3D PRINTING OF MULTIPLE MATERIALS

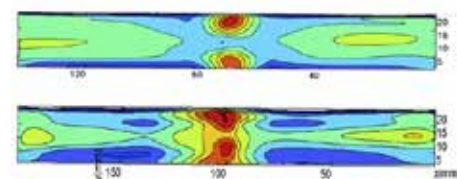
A number of on-going projects are investigating laser 3D printing of multiple material components (metal, ceramics and polymer) using modified selective laser melting (commonly known as powder bed) systems and hybrid SLM and LMD (blown powder) processes.



*Selective laser melting (or powder bed laser fusion) of multiple materials*

## NARROW GAP WELDING AND JOINING

The research forms part of the EPSRC NNUMAN (New Nuclear Manufacturing) programme grant for nuclear manufacturing, aiming to laser weld 130 mm thick ferritic steels. Also, in collaboration with Tata steel, research has been conducted to weld thick section high strength steels (S960, S700).



*Residual stresses of a laser narrow gap weld and an arc weld*

# LASER HARDENING: APPLICATIONS IN THE WORKPLACE

Laser hardening offers an excellent process for improving the mechanical properties of steels and cast irons. At LASE Ltd we offer laser hardening as one of our principal services.

### The laser hardening process

The laser hardening technique is relatively simple, a high power laser beam is traversed along the component surface. The surface temperature rises to a point where the microstructure is entirely transformed to Austenite. It is important to achieve an accurate and consistent surface temperature in order to ensure the surface is fully transformed without surface melting.

As the laser moves away, the heat dissipates into the substrate and natural quenching takes place. This quenching rate is so high that very hard Martensitic structures are produced. High power diode lasers are ideal for this application as we rely on a large beam with a uniform energy density to impart the necessary heat at an appropriate rate without causing melting.

### Laser hardening for piston ring grooves

LASE Ltd were approached to harden a batch of 130 pistons. These large cast iron pistons required hardening in the piston ring grooves. During service as the piston oscillates within the cylinder the hard piston ring can wear against the piston itself. This leads to a loss in performance and a reduced lifetime for the piston. Laser hardening the grooves to over 62HRC significantly reduces the wear rate prolonging the life of the piston, and therefore the engine.

### Other applications for laser hardening

Laser hardening is ideal for localised hardening on highly accurate components. The process offers no distortion compared with traditional hardening processes and is very fast too. This allows finish machined components to be hardened as the final step in the production process. Forming and stamping tools can benefit from this technology, as can gear components and prop shafts.

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## YORKSHIRE LASER TAKES A FIRM STAND ON WASTE

Yorkshire Laser and Fabrication (YLF), in Castleford has invested £10k to reduce waste and use of raw materials. YLF provides laser cutting and makes enclosures and brackets for companies in the oil and gas, telecommunications, lighting and automotive industries. YLF wanted to cut waste and boost profitability so adopted a series of measures that has helped it achieve ISO 14,001 environmental accreditation. Yorkshire Laser has also invested heavily in a new fabrication workshop which is environmentally cutting edge and employs energy efficient emergency lighting.

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## CARRS GO LARGE WITH NEW 6 KW DISK LASER

Carrs have entered the next stage of their capital spend on the latest TRUMPF 6 kW disk laser. The laser provides important backup for the 4 kW disk already installed and, being situated in different factories, allows the company to have crucial production cover for all their product lines. The YAG will weld 6 mm (and more depending on the joint) of steel and aluminium. Titanium can be welded up to 5 mm.



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## HUTCHINSON COMPANY IN ACCESSIBILITY PROJECT

Martin McGilligan, MCG Mobility has teamed up with H360, part of the Hutchinson Group, to invent a 'stand alone' adaptable wheelchair lift at a competitive price, offering greater accessibility to those who could not previously afford it.

Previously, 'all-in-one' wheelchairs that raise and lower the user have cost thousands of pounds, pricing many individuals out of the market. This invention, the ALTO, comprises a scissor lift mounted onto the users existing wheelchair, allowing the user to be raised and lowered, enhancing quality of life.



*Martin McGilligan (right), MCG Mobility with Ian Ferguson at H360 and Martin's sister, Leanne Crawley*

Ian Ferguson, Senior Design Engineer at H360, said: "The ALTO wheelchair lift is essentially a very compact small scissor lift that facilitates the attachment of various types of rigid wheelchairs. The basic design incorporates several, mostly tubular steel sub assemblies that make up the overall assembly. Aside from the standard flat bed laser cut parts we have the ability to utilise tube laser technology, which greatly enhanced the simplicity of both the design and the manufacturing process. Tubes that interlink through tabbing and slotting easily help maintain a consistent level of accuracy throughout the assembly and fabrication process."

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# BREXIT...



...the one word that has created so much drama and has proven to be so divisive. Whether you are bored to tears, raging with fury or still devastated over the referendum result, there is no denying this a hot topic which is still creating headlines and head-scratching throughout the UK. There is no doubt that uncertainty in the short to medium term will create pain to those of us involved in manufacturing, but possibly also create some opportunities. The biggest problem with uncertainty is reduced investment generally, which will have a direct knock-on effect to manufacturing. However those willing to take bigger risks could reap the rewards.

Politicians increasingly appear to be completely out of touch with the public. They do not seem to understand the daily struggles faced by many and often appear to be worlds apart. For example my bug bear is: why are we letting people continually set up "phoenix" companies that have a huge detrimental effect on small businesses? The people with the power to change this do not understand how damaging it is or the scale of the problem.

I believe that the recent cut in interest rate from 0.5% to 0.25% is a waste of time and shows that the Bank of England has serious concerns about the economy but nowhere to go. This lack of confidence fuels the fire of fear. The extra £20 banded about in the media as the amount an average mortgage holder will be better off is neither going to kick-start spending nor increase consumer confidence. Discouraging saving is also a short-term view, setting up a potentially bigger problem in the future. Perhaps the Government should ensure that multinationals pay a fair contribution of corporation tax. According to the National Audit Office, in 2006 more than 60% of Britain's 700 biggest companies paid less than £10m corporation tax, and 30% paid nothing. NOTHING!

Whenever the economy is in trouble the government turns to manufacturing to suddenly turn the taps on, work a bit harder and save

the day (the implication being that the rest of the time we sit around doing nothing!). What we really need is for Government to take a serious interest in manufacturing all the time, not just whenever there is a problem. It needs to show some level of consistency and realise manufacturing often requires huge investment. Constant moving of the goalposts by politicians is irritating and can be highly disruptive. This can be seen everywhere: targets for schools or the NHS; solar power subsidies; PHEV vehicle grants; the list is endless. The government has the opportunity to make a real difference and encourage technologies, fuels and investment etc. However this only works if investors are confident that the government will adhere to its policy decisions.

Of course Brexit has not actually happened...yet. The reaction of the economy to the referendum result is a forewarning, but hopefully the blow will have been lessened when Article 50 is implemented, so stay positive. The referendum vote has really made me, along with many others, wake up in terms of politics; this is one of the most positive things to have come out of it. Another positive is that there are always others less fortunate than ourselves; at least we do not have Trump running for Prime Minister. Plus the Olympics in Rio has given everyone reason to smile.

Yes we are in for a tough time and the EU will want to make an example of us, so brace yourselves for a bumpy ride, but remember we have one of the strongest economies to help weather this storm and the plucky Brit stiff-upper-lip mentality will endure. -We still need to know more before we can act, so hold your nerve and watch this space. Rant over.....and breathe.

**Mark Millar**

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# INTRODUCING JAPANESE FIBRE LASERS TO EUROPE



**AN INTERVIEW WITH  
SIMON RICHARDSON  
FIBRE OPTIC DIVISIONAL MANAGER, FUJIKURA EUROPE**

## **Q. Can you give us an overview of Fujikura and how the UK office fits in to the EU and global company?**

Fujikura was founded in Japan in 1885 and the first products were cotton-insulated wires which rapidly evolved to rubber-insulated wires.

New companies evolved in various sectors, but it was the power and communications activity which became our core business in the 1960s, predominantly based in the Sakura plant (Chiba, Japan),

where much of our current R&D takes place today.

The communications business moved into Optical Fibre in the 1970s, when Fujikura was a pioneer in the process for producing optical preforms and fibres. Naturally, this progressed to other special fibres and components including optical amplifiers, gratings, dispersion control and splicers.

Today Fujikura employs 55,000 and is active in power and communications, consumer electronics, automotive, materials and real estate, the European business being founded in the UK in 1988 to sell and support our Fusion Splicing business throughout Europe. Today we are the main conduit for all Fujikura's optical and electrical products.

### Q. You recently launched a new range of fibre lasers, what is the history of this product range?

The origins of our laser business really go back to the 1970s when we started making optical fibre. We naturally expanded our fibre production business and are currently one of the top 3 fibre producers in the world. We also developed a wide range of special fibres such as Polarisation Maintaining Fibres, Erbium Doped Fibres, Dispersion Compensating Fibres and the like. In addition we became one of the key optical fibre components suppliers in the 1990s when optical amplification and DWDM helped launch the rapid expansion of communications around the world. Of course, many of the optical components used in amplifiers such as couplers, gratings and active fibres, are what enabled the evolution of fibre lasers today.

“

*Not only are we fully vertically integrated, but we make the splicers that assemble the lasers.*

”

We first developed our fibre laser in the early 1990s and are currently a leading supplier of fibre lasers for the Japanese market. We currently offer ultra-stable pulsed fibre lasers primarily at high-end applications where performance and stability are key. We are also producing CW lasers which will be released in Europe late in 2017.

### Q. Vertical integration is important to be cost competitive, how vertically integrated is your company?

Fujikura is completely vertically integrated. We produce all of the optical fibres used with the laser of course, and have been a supplier of large core delivery fibres to the EU for many years now. We produce the active doped fibres, as well as the couplers and gratings within the laser cavity. We have over 70 patents on fibre-based laser technologies including techniques to prevent photo-darkening, to unique coupler and grating technology. We even produce the high end splicers that all of the other laser manufacturers use in order to manufacture and repair their own lasers...so not only are we fully vertically integrated, but we make the splicers that produce the lasers...does that make us 110% vertically integrated?

On the active side we acquired the Japanese high power laser diode manufacturer Opto-Energy back in 2010. The key processes for the (MOCVD) epitaxial growth of the diodes, as well as the AR coating and packaging, are all carried out in our Sakura plant, the same site that produces our fibres. We have 100% control of all production for every key item within our fibre lasers.

### Q. What benefits does your technology offer? How do you protect against back-reflection?

The key benefit that we offer for both our pulsed and CW lasers is extreme tolerance to high levels of back-reflected light. Some of our customers in Japan and Europe have used fibre lasers from our competitors on certain materials at high powers and the laser just cuts out. Of course, this is a

safety mechanism to prevent damage to the laser, but our laser is different. The internal optics provide complete stability even at normal incidence and at high power. Our laser does not shut down because it is protected at a fundamental optical level. Our customers can machine these materials with no problem. We have many technologies which facilitate this. We have a unique optical coupler which protects the laser diodes from reflected light, our pulsed laser cavity employs a Raman frequency shifter to isolate the seed laser. We have removed photo-darkening by utilising certain fibre dopants which remove this effect. We also have developed techniques to dramatically reduce the destabilising effects of Stimulated Raman Scattering from affecting the laser stability.

On the CW side, we have developed very high power pump diodes currently producing 18 W+ per chip. These are combined to give pump modules of more than 150 W with huge amounts of redundancy at low cost. In addition we have some optical designs in the pipeline which will dramatically increase the total power output per module.

### Q. How do you see the future in terms of growth and share in this crowded market?

Fujikura has a long term target to become a top 3 supplier of fibre lasers for the European market by 2020. We see many suppliers moving into the field of systems in order to move into profitability. This is not our goal at all, our business is lasers and it will stay that way. We do not want to compete with our customers in this market. Instead, we aim to use our expertise and strength in fibre technologies to improve efficiency and gradually grow market share working with a few key customers to start whilst we ramp up our support base. Our first product launch for Europe will be the pulsed lasers, followed by the CW lasers at the end of 2017. We also are not ruling out acquisitions or other partnerships in order to gain a wider footprint more quickly. However, Fujikura is a patient company and were looking for longer term stable growth rather than creating dramatic short term headlines.

“

*AILU has given us great access to my existing contacts as well as many new ones.*

”

### Q. How has AILU Membership been helpful to your company?

I personally first heard of AILU during my employment at ZED Instruments where I was involved with product development. I've been out of the laser market for 15 years so AILU has given us great access to my existing contacts as well as many new ones. We have attended many AILU events which have been extremely informative for both our UK staff and our colleagues from Japan. The networking opportunities are excellent and the general level of support has been a great help in helping us to establish ourselves in the UK and EU.

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# HIGH POWER WELDING FOR THE MARITIME SECTOR

NICHOLAS BLUNDELL

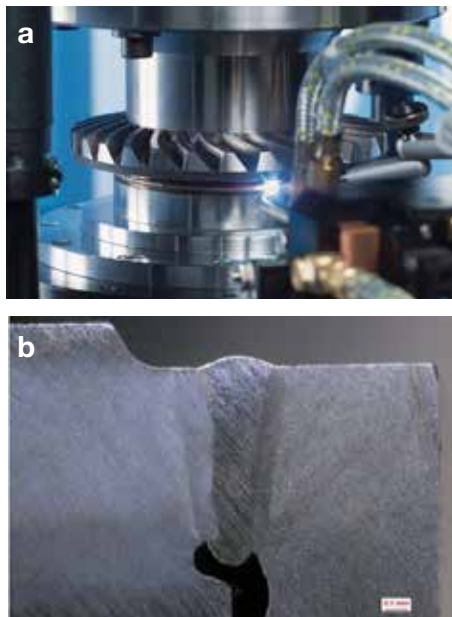
**There are multiple laser sources for high power welding (CO<sub>2</sub>, YAG, diode, disk, fibre), with many conflicting publications highlighting their suitability for specific applications. For many applications, high-power solid state laser sources provide an optimal solution in terms of energy consumption, process efficiency and integration, but much like laser cutting processes, there are other factors that influence welding beyond the simple 'horsepower' of the laser source we choose to use, and consequently rumours of the demise of the CO<sub>2</sub> laser appear greatly exaggerated.**

Within this article, fibre and disk lasers are considered together as fibre-delivered lasers. They are both high-brightness sources with near identical output wavelengths (as far as material interaction is concerned), and they are cost and efficiency equivalent.

Ship and ocean-structure building is dominated by steel with approximately 35 million tonnes consumed annually [1], compared with only 1.2 million tonnes of aluminium [2]. Aluminium is used exclusively for smaller vessels (currently the largest aluminium vessel, *LCS2 USS Independence*, has a displacement tonnage\* of 2307 t, compared to the bewildering 270,000 t of the *Prelude* floating gas production platform, still under construction). This sets the context for 'high power' laser welding within the maritime sector: multi-mm section steels require multi-kW power regimes.

The two most important parameters in any welding process are the two pieces of metal to be joined (this includes geometry and composition) – they define the type of process that can be applied, and largely, they define the parameters for that process. For example, when laser welding Titanium 6-4 sheet using the MTC laser cell, there is a balance between interaction time, energy input and the thermal properties of the material that limits the weld speed to less than 1m/min. Higher weld speeds result in unacceptable levels of porosity, and excessive input power results in porosity, material ejection and undesirable weld cap geometry. The cell is capable of delivering 20 kW, but the material limits the power.

\* A calculation of the weight of a vessel without crew, cargo, ballast or fuel.



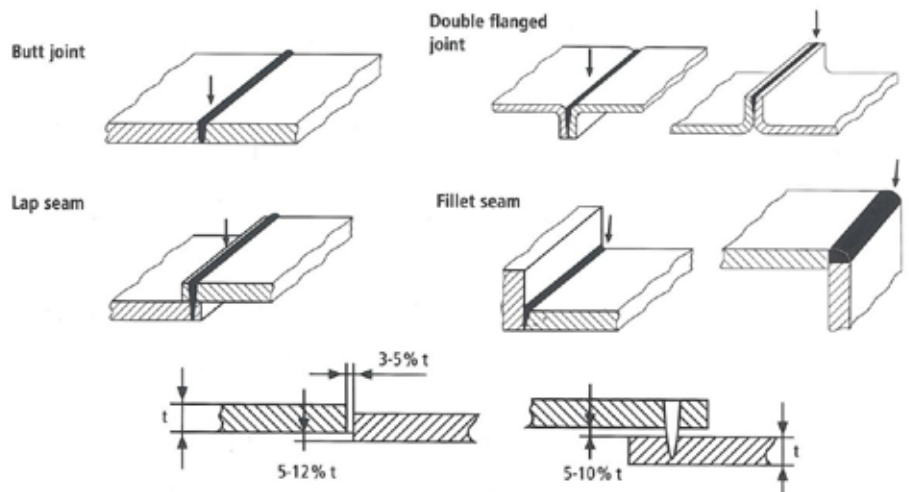
**Figure 1: Differential welding using a laser with a fibre delivered beam a) production application (copyright Emag [3]) and b) a typical resulting weld (copyright TRUMPF)**

Thin sheet steel can typically be laser welded at a maximum of 19 m/min before the onset of the awkwardly-titled 'humping' defect (the reason for resistance welding still dominating the canning industry). In aluminium, the onset of this defect occurs at approximately 200 m/min (hence the use of lasers to weld roll-formed spacer bar). This is true regardless of the output wavelength or available laser power: again, it is a factor of the material.

As a further example that welding is not necessarily about horsepower, the MTC laser cell can produce a single-pass weld in 20 mm S355 steel at 11 kW – it is however a weld susceptible to high levels of porosity and techniques must be employed to prevent catastrophic root drop-out. The process envelope is also very small – a power variation exceeding  $\pm 100$  W will negatively affect the welding process and the resulting weld. Process speed is likewise limited.

In contrast, there are multiple applications where CO<sub>2</sub> lasers are used to produce repeatable, high-integrity seams in thick sections plain carbon steels (up to 20 mm in some cases). One interesting example of this is the welding of differential crown-gears (see Figure 1). To achieve thinner weld seams (2-6 mm) fibre-delivered beams are preferred (low operating costs, simplified installation and set-up etc). CO<sub>2</sub> lasers are favoured for thicker section seams where an increased penetration depth per kW and a reduction of top surface disruption and spatter has proved the deciding factor. For many of these applications (whether thin or thicker section) an additional filler wire is applied to accommodate differing chemistries of the parent materials and to mitigate fit-up voids.

Figure 2 shows typical joint configurations and gap limits for laser welding. These rules apply to thinner sheet material (max. ~2 mm) but do not translate readily to the thicker sections associated with the maritime sector. Furthermore, the stringent edge requirements necessary for laser welding may not be achievable using the profiling and



**Figure 2: Typical laser welding joint configurations and gap limits**

edge preparation strategies currently available within the shipyard (the titanium and differential applications mentioned earlier feature machined interfaces). Further to this, a key factor influencing the performance of fillet joints is leg length and throat depth of the resulting weld and laser welding often produces an unacceptably small fillet. For certain applications the lack of fillet is a bonus, but for structural welds in steels, there is often insufficient fillet produced to support the static and dynamic campaign load requirements of the fabrication.

The addition of a separate filler material, as described for differential welding, can be used to accommodate a larger gap than would be acceptable with an autogenous weld. It also adds material to build a fillet. However, adding material also reduces penetration and can introduce lack-of-fusion defects within the weld. Hybrid Laser Arc Welding (HLAW) offers a solution to introducing additional material into fillet and butt seams and accommodating the typical edge-prepare variation expected in the maritime sector (see Figure 3).

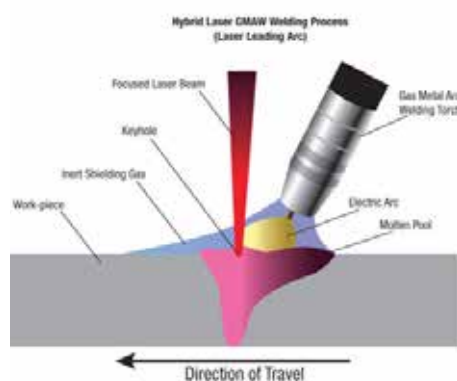


Figure 3: Hybrid welding schematic (copyright Lincoln Electric [4])

HLAW offers some potentially valuable solutions for a relatively small additional investment (compared to autogenous laser welding):

1. A higher process speed compared to conventional arc welding (up to 400% compared to Submerged Arc Welding and up to 1600% compared to MIG).
2. A lower overall heat input compared to arc welding, resulting in lower levels of distortion and associated rework.
3. A lower cooling rate than autogenous laser welding, resulting in a reduced peak weld hardness.
4. Increased tolerance to panel fit-up (the Hyblas project [5] proved gap capabilities up to 3 mm).
5. Acceptable fillet sizes produced.
6. A capability to produce a fillet on both sides, using a single-sided process if the resulting joint is of suitable geometry (see Figure 4).

20 mm AH 36  
 $v = 0.6 \text{ m/min}$   
 $P_{\text{Laser}} = 20 \text{ kW}$   
 $v_{\text{wire}} = 11.8 \text{ m/min}$   
 Wire:  $\varnothing 1.2 \text{ mm SG-MoNi}$   
 Laser leading  
 MAG trailing

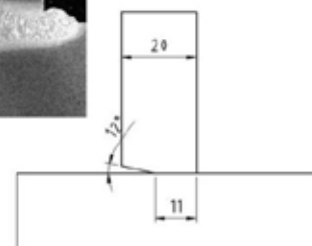
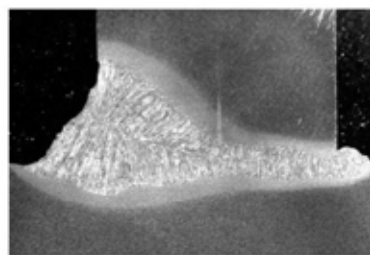


Figure 4: Single sided HLAW weld in 20mm AH36 steel [6]. Copyright European Communities

7. Smaller weld preparations required (square butt readily feasible).
8. Reduced consumable input (less weld preparation to refill).

Two key users of HLAW in the maritime sector are Meyer Werft (up to 450km of HLAW per vessel, producing deck and wall panels up to 25 m x 30 m) and Fincantieri (large area deck and wall panels). Interestingly, Meyer Werft use both fibre delivered and CO<sub>2</sub> laser sources for their hybrid welding requirements – the arc, it would seem, is a great leveller of wavelength. HLAW is being applied to aluminium by Seiweld Blechform for the manufacture of snow cannons and although not a maritime application, it does hint at potential future applications within the sector.

Any high-power laser welding application requires automation, and this has been factored in as the most significant cost of the potential manufacturing system. Robots are often heralded as 'low cost automation', but even a standard articulated arm robot may cost circa £100 k once integration costs are considered. Then there is the cost of the process to consider (laser source, processing tool, clamping etc.). Gantry systems are considered expensive in comparison to robots, and for small working envelopes they are. However a robot has a very limited working envelope and surprisingly poor dynamic performance at elevated motion speeds.

There are good reasons why most multi-axis laser cutting systems for metals are gantry systems. An external slide way can be added to a robot to increase its working envelope in one or two axis, but these cost significantly more than the original robot, and by the time the system is complete, there is a very high probability that a gantry will have been more cost effective.



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It has been argued that robots have a better reach capability than gantry type systems, however it is typically the process tool that limits access to the workpiece, not the device carrying the tool. The positive news however, is that whilst CO<sub>2</sub> beams are challenging to route via articulated arm robots, gantry systems are suitable for both free-space beam transmission and fibre delivery.

In summary, there are two key take home messages. Firstly, fibre-delivered lasers have their advantages and golden applications, as do CO<sub>2</sub> lasers. As yet, there is no 'one size fits all' solution for metal joining; simply increasing the horsepower of one type of laser source or the other does not necessarily negate the alternatives. Every application should be considered on a case-by-case basis. The most important business metric is the relevant unit of currency, and any application should be instigated only if it actually helps the end user make more money, either directly or indirectly (every problem has a solution, and every solution has a knock-on effect, positive or negative, somewhere else in the manufacturing chain).

Secondly, process speed, like laser power, is not the be-all and end-all: weld integrity must come first. And therein lies another discussion!

- [1] [http://bit.ly/issue81\\_blundell1](http://bit.ly/issue81_blundell1)
- [2] [http://bit.ly/issue81\\_blundell2](http://bit.ly/issue81_blundell2)
- [3] [http://bit.ly/issue81\\_blundell3](http://bit.ly/issue81_blundell3)
- [4] [http://bit.ly/issue81\\_blundell4](http://bit.ly/issue81_blundell4)
- [5] [http://bit.ly/issue81\\_blundell5](http://bit.ly/issue81_blundell5)
- [6] [http://bit.ly/issue81\\_blundell6a](http://bit.ly/issue81_blundell6a)

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# CAN HIGH SPEED LASER CLADDING REPLACE HARD CHROME PLATING?

MARKUS RUETERING AND OLEG RAYKIS

**Under the EU REACH regulation (Registration, Evaluation, Authorisation and restriction of Chemicals), industries are required to find an acceptable alternative for hard chrome plating of metal parts by a 'sunset date' of September 2017. One alternative, thermal spray, has already been tested and although it offers high flexibility, the quality of results is often not acceptable. A good alternative to hard chrome plating is the latest development of extreme high speed laser cladding, developed by Fraunhofer ILT (Aachen, Germany) using equipment manufactured by Laserline GmbH (Muelheim-Kaerlich, Germany).**

In power plants and other industrial manufacturing sites, metal parts often experience high levels of wear and tear, and heavy-duty processing can result in corrosion and abrasion. To counter this, and to extend the operational life span of metal components, especially those of high value, the entire surface of rotating parts, tubes and other functional components is covered with metal or ceramic layers. This increases the resistance of the parts against heat, humidity, aggressive chemical substances as well as metal debris and spatter. A commonly used process is hard chrome plating, a galvanic coating method in which the part is dipped into a chromium electrolyte and covered with a chrome layer. Sections not requiring coating are covered before dipping the component into the electrolyte bath.

## The need for new coating technologies

Although currently a successful technique, the future of hard chrome plating is uncertain; the commonly used chromium-trioxyde ( $\text{CrO}_3$ ) and hexavalent chromium ( $\text{Cr}^{6+}$ ) are carcinogenic and were identified by the EU commission in 2013 as Substances of Very High Concern (SVHC). Along with other chromium compounds, they have been listed in Annex XIV of the REACH regulation which tightly controls the use of these chemicals. These substances can only be used under a certification of compliance from the ECHA (European Chemicals Agency) after September 2017. Receiving this authorisation is a highly complex procedure; it must be proven and guaranteed that any SVHC can be and will be handled safely in terms of the intended use and that there are no alternatives. For the well-

established technique of hard chrome plating it is questionable whether these conditions can be fulfilled, particularly if  $\text{CrO}_3$  is used. Consequently industries using hard chrome plating are on high alert and have already lost a law suit with the European Court to further allow the use of chromium in general.

This raises serious issues for industries that use hard chrome plating in terms of identifying, and then establishing, alternative technologies. Companies relying on the use of chromium might risk their entire business model. A major problem is the limited amount of alternative, economical technologies available.

One alternative method currently used in industry is thermal spray, in which the additive material is applied as powder. The powder is melted by a burner and "fired" against the surface of the part to be coated by a hot gas jet. The molten material is attached to the surface by mechanical bonding. The main advantage of this is the high flexibility of the process, as the coating can be applied to a wide variety of different materials. The major disadvantage is the limited maximum mechanical stress-level. This is due to the mechanical bonding between the base material and the coated material, a bond much less resilient than that created by a galvanic process. Hence, coatings created by thermal spray are lost much faster. In addition, the process creates

a porous surface and material layer, which easily leads to cracking, and the latter often cannot be repaired by the initial process. This often results in a partially transmissive layer which is not comparable to hard chrome plated coatings. To get around the porosity in the range of 1-2% the thickness of coated layers is increased which has an impact on the cost of the process. It is believed that thermal spray will at best partially substitute electro plating.

## ANn alternative: ultra high speed laser cladding

A much better prognosis for the future is given to the powder-based cladding process where a laser is the heat source. During laser cladding, both the metal powder and the base material are melted creating a metallurgical bond as the two molten materials are joined together in a dilution zone. These metallurgical bonded layers last much longer than comparable thermal spray created coatings and can even enhance the known wear resistance of galvanic coated parts. Furthermore, laser cladding results in a dense layer, free of pores and cracks and offers several advantages. However, the success in industrial applications has been limited for two major reasons. Firstly, the layer thickness was limited to 0.5 mm or thicker which excluded its use in some applications where a much thinner layer is required (e.g. oil and gas, agricultural

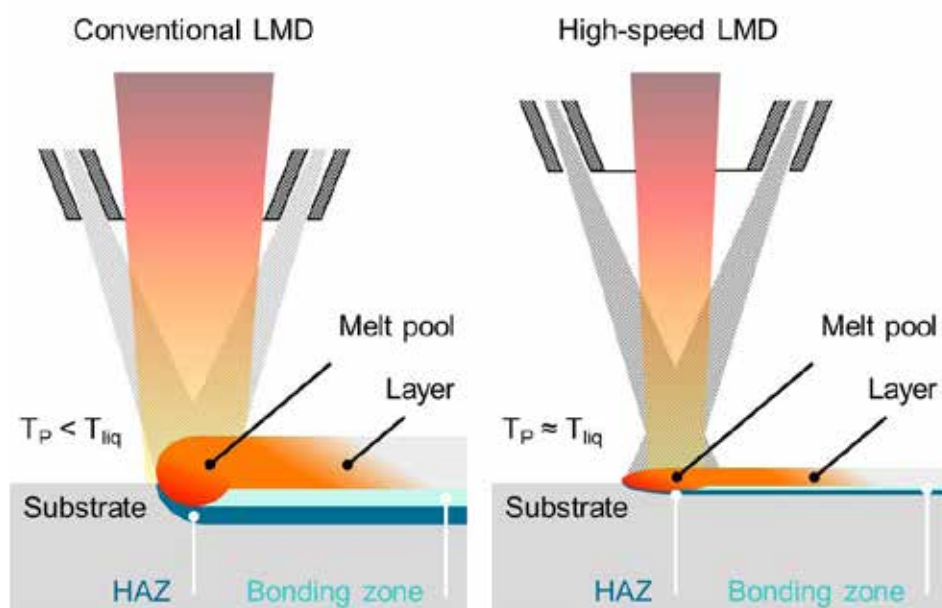


Figure 1: Schematic process principle of conventional LMD (left) and high-speed LMD (right) (source: Fraunhofer ILT)



Figure 2: Coating of a hydraulic plunger with ultra-high speed laser cladding (source: Fraunhofer ILT)

and power plant applications). Secondly the area treated was limited to 10 to 50 cm<sup>2</sup>/min which was the limitation for parts of sizes measured in meters rather than centimeters, due to the speed. However, for rotating applications this disadvantage has been eliminated by the Fraunhofer Institut für Lasertechnik (ILT).

In initial trials, which were conducted on a specifically upgraded lathe using a Laserline LDF 4000-8 (a diode laser with beam converter), it was shown that corrosion protective layers from a nickel-chromium alloy Inconel 625 could be applied extremely rapidly with a speed of up to 200 meters/minute. This helped to reduce the layer thickness to 20 µm and to increase the coated area to 500 cm<sup>2</sup>/min. The patented process of ultra-high speed laser cladding can achieve thicknesses between 10 and 250 µm.

The key to this success was increasing the intensity in the focal plane. Whereas standard laser cladding uses a spot size of 2-3 mm or greater, the new approach is based on a 1 mm spot size. Furthermore it was necessary to work on the positioning of the laser spot, powder supply and shielding gases.

Conventional laser cladding involves the initial melting of the base material and subsequent melting of the powder in this molten pool - they only meet in this plane. Ultra high speed laser cladding allows the powder particles to heat to a level close to melting point, increasing the speed of the bonding process and reducing the layer thickness. The two process principles are shown in Figure 1. The high temperature of the powder particles creates near-molten particles which only require a short contact with the molten pool of the base material to create the desired metallurgical bonding. This leads to the increase of speed as compared to melting the particles in the melt pool in the conventional technology. In conjunction the energy required for the melt pool in the base material is much lower. To apply the same amount of powder in some cases the necessary laser power can reach 20 kW whereas the high speed process only requires 2 to 4 kW of laser power. Thus the process is more economic based on this efficiency,

reducing both the capital investment costs and higher running costs. Finally the cladding process gives a non-porous coating with a very low surface roughness, which only requires a limited amount of treatment after coating.

This new high speed process provides an alternative option to hard chrome plating that outperforms thermal spray technology.

#### An alternative with a bright future

In early 2016 the first customer project took place based on this technology developed and patented by ILT, using lasers from Laserline GmbH (see Figures 2 and 3). As the global interest in this technique is very high, the partners are working on many more projects and

there will be more installations in the industry in the near future. As the process was initially developed for parts that can be coated while rotating, there are now ideas and approaches to establish more options for coating of parts of differing shapes. Laserline and ILT will engage in more development and apply the ultra-high speed laser cladding to more applications and purposes.

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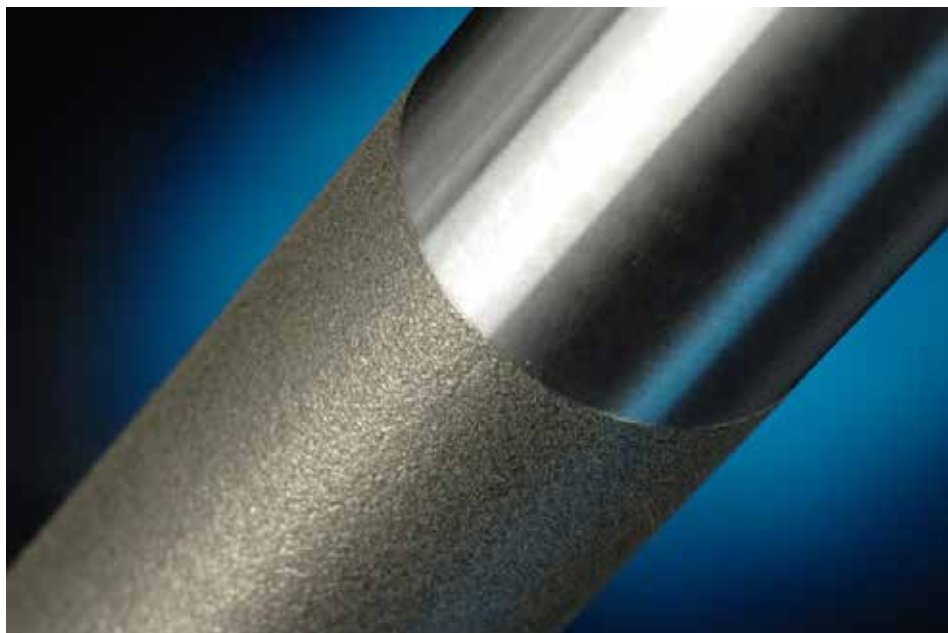


Figure 3: Hydraulic plunger coated by ultra-high speed laser cladding and reworked by laser (source: Fraunhofer ILT)



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# FIBRE LASERS MITIGATE CRACK FORMATION IN ALUMINIUM ALLOY

SÓNIA MECO ET AL.\*

**Aluminium AA2024 is widely used in the aerospace industry due to its high strength to weight ratio and good fatigue strength. Nowadays mechanical processes are used for cutting holes and profiles on the aluminium panels. Punching, routing and shaving are some examples of the methods used to machine aluminium panels. Since these processes occur at room temperature the microstructure and the mechanical properties of the material remain similar to the unprocessed material.**

The use of lasers could greatly increase the processing speed and boost the productivity of the cutting process. In comparison to mechanical processes, laser cutting offers many advantages. Some examples are small kerf width, no tool wear due to the non-contact nature of the process and the flexibility of the laser in terms of geometries that can be processed. However, AA2024 aluminium alloy is difficult to process using a thermal process due to its high susceptibility to hot-cracking, also known as solidification cracking. This happens due to the large solidification temperature range and the high thermal expansion coefficient of the aluminium. During solidification, the grains shrink and due to the absence of liquid molten metal between the grains it is easy for intergranular cracks to form. Concern regarding microcracking of aluminium during laser cutting is the main reason that prevents the broad implementation of this process in the aerospace industry.

In order to overcome this issue it is necessary to investigate the interaction of the laser with the AA2024 aluminium alloy. It is important to understand which parameters contribute most to the crack growth to be able to control the process and avoid cracking during cutting.

Various lasers under different conditions have been investigated for cutting AA2024 aluminium alloy but crack formation has not often been reported. High brightness fibre lasers enable small beam diameters and therefore, due to the higher power density, it is possible to use higher cutting speeds and potentially obtain smoother kerf edges and narrower cuts. Due to the short interaction time of the laser with the substrate, the heat affected zone should be very narrow when processing with small beam diameters and this could be beneficial when processing

AA2024 aluminium alloy. This article focuses on the quality and crack formation of 1.0 and 1.2 mm thick sheets of AA2024 aluminium alloy during cutting using a fibre laser.

## Experimental setup and methodology

A high brightness continuous wave fibre laser, manufactured by SPI Lasers, with maximum power of 3000 W and a beam diameter of 110  $\mu\text{m}$ , was used in this work. The laser beam was characterised using a Primes GmbH focus monitor system and the second moment method. The substrate was attached to X-Y linear stages and the cutting head to a Z linear stage.

In order to assess the effect of the laser parameters on the cut quality and crack formation, the aluminium sheets were cut with different power levels and processing speeds whilst all the other parameters were kept constant. Pure argon was used as assist gas with 10 bar of gas pressure. The gas nozzle of the cutting head had a 2 mm diameter orifice and a stand-off distance of 1 mm was used between the aluminium and the nozzle. The variable parameters are shown in Table 1. The maximum processing speed was determined for each value of laser power.

Material thickness (mm)	Laser power (W)	Processing speed (mm/s)
1.2	450 – 650	45 – 120
2.0	600 – 1200	25 – 115

**Table 1: Process parameters for laser cutting of 1.2 and 2.0 mm thick AA2024 aluminium alloy sheets**

After cutting, the microstructure and the quality of the kerf edge were analysed. The cutting quality was assessed by measuring the roughness of the kerf edge and the microstructure by metallographic analysis. Finally the results were compared to those reported in the literature and conclusions made regarding how beam diameter affects the cutting quality and whether it can mitigate crack formation in laser cutting.

## Result analysis and discussion

Roughness is an important factor in laser cutting because it not only affects the cutting quality, which may lead to post processing of the cut

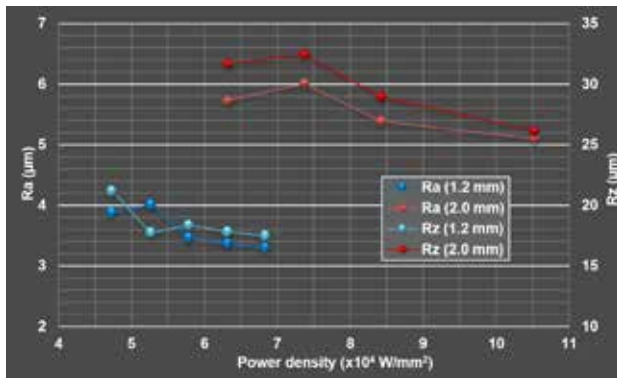


**Figure 1: Cut edge of the 1.2 mm thick AA2024 aluminium alloy processed using 68 kW/mm<sup>2</sup> of power density and a travel speed of 120 mm/s**

material, but it may also induce crack formation. Figure 1 shows the cutting edge of the 1.2 mm thick aluminium sheet cut with the fibre laser.

The roughness of the cutting edge was measured in terms of Ra and Rz as shown in Figure 2. Ra measures the average value of roughness along the distance measured, whereas Rz corresponds to the average of the biggest distances between peaks and troughs. It is clear that there is a significant deterioration in quality when the thickness of the material increases. However, the roughness tends to decrease when processing with higher levels of power density and travel speed, regardless of the thickness of the material. This is due to the reduction in the viscosity of the molten aluminium by the increment in the temperature at higher levels of power density. Thus, the molten metal is removed more easily. It was reported that cutting with a CO<sub>2</sub> laser source at 1 and 1.5 kW the Ra was above 10  $\mu\text{m}$  for a similar focal length.

The cross-section of the samples was analysed by optical and scanning electron microscopy. The optical micrograph in Figure 3a shows a dark layer, which is a recast layer, on the cut edge of the aluminium, from the top to the bottom surfaces. During fusion cutting the assist gas creates a pressure gradient between the top and bottom surfaces and blows the molten metal out of the kerf. If the metal is not removed quickly enough then it



**Figure 2: Roughness measured on the edge of the AA2024 aluminium alloy for different levels of power density, considering the laser beam constant and maximum speed. Ra: average value along the distance measured and Rz: average of the biggest distances between peaks and troughs**

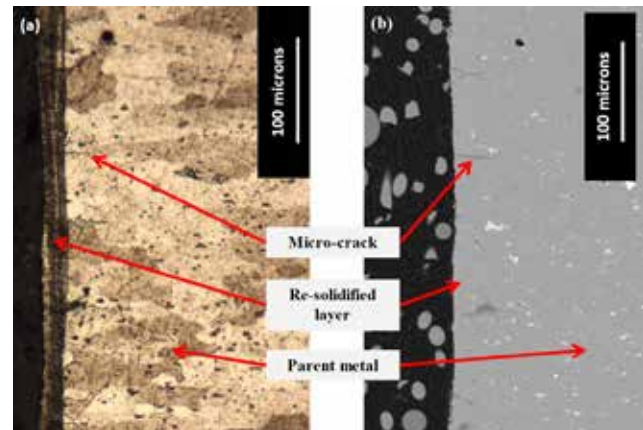
re-solidifies on the cutting edge and forms the recast layer. The layer thickness depends on the processing parameters in use: laser type, laser power, beam diameter, processing speed, gas type and pressure. The thickness of the recast layer formed on the cutting edge of the 1.2 and 2.0 mm thick sheets was less than 20 and 30  $\mu\text{m}$ , respectively. These results are significantly better than the ones reported using a  $\text{CO}_2$  laser with a large beam size in which the recast layer thickness varied in the range between 100 and 300  $\mu\text{m}$ . The size of the laser beam and the cutting speed in use determine the time that the material is exposed to the laser beam and the total energy transferred to the material. Therefore, as the speed increases less energy is transferred to the material and the smaller is the recast layer.

The chemical composition of the layer and the parent metal was analysed by SEM-EDS and it was found that both had similar composition, but slightly richer in Cu in the recast layer.

The presence of oxides and nitrides, which have very high melting temperature, was not detected on the recast layer, even though there are many reports saying that these cut products are always present on the cutting edge, even when cutting with argon. The absence of oxides and nitrogen in the recast layer is beneficial for subsequent processes such as welding or removal of the recast layer mechanically.

The microstructure of the material was not affected by the heat since the dimension of the grains remained constant. This can be explained by the short interaction time of the laser with the material due to the small laser beam and high processing speed used.

Figure 3a shows that the majority of the microcracks were developed at the grain boundaries. It is known that the lower melting points of the alloying components can cause cracking at the grain boundaries due to the segregation induced by the heat of the process. Stress concentrations are developed due to the re-solidification and creation of an uneven profile of the cutting edge, all this



**Figure 3: Cross-sectional view of the laser cut sample by (a) optical and (b) scanning electron microscopy (SEM)**

magnified by the very high cooling rates that are undergone during laser cutting.

The SEM micrograph in Figure 3b shows microcracks growing from the cutting edge towards the bulk metal (parent metal), regardless of the cutting conditions in all the samples analysed. The length of each microcrack is fairly stable in the range of 50  $\mu\text{m}$ , which means that they go across the recast layer and enter the parent material.

When reporting that cracking was overcome using a  $\text{CO}_2$  laser, in a larger scale than that analysed in this work, previous researchers attributed the results to the smooth cutting edge that was obtained with low values of roughness ( $R_a = 8 \mu\text{m}$ ), which is similar to that of this work ( $R_a = 5 \mu\text{m}$ ) [1]. In turn, this was accomplished at high values of power, about 2.5 kW, short interaction times with 50 mm/s of travel speed. They explained that the material becomes more fluid if more energy is delivered, thereby being easier to remove the molten material from the cutting front and achieve both better cutting edge quality and less stress concentration.

### Conclusions

In this article a fibre laser was used to assess the crack formation during laser cutting of AA2024. It was found that cracks originally formed at the cutting edge (recast layer) grew towards the parent metal along the grain boundaries. The length of the cracks was about 50  $\mu\text{m}$ , independent of the power density of the laser (power between 750 W and 1250 W and laser beam diameter of 110  $\mu\text{m}$ ). The recast layer was only 30  $\mu\text{m}$  thick whereas in the literature it was reported to be between 100 to 300  $\mu\text{m}$  when using a  $\text{CO}_2$  laser with a larger beam size.

In this work it was not possible to completely

prevent crack formation by using a fibre laser to cut AA2024 aluminium alloy but it was possible to reduce both the roughness of the kerf and the thickness of the recast layer. However the crack length is significantly reduced so a simple manufacturing step such as shaving could be used to easily remove the cracks and the recast layer.

Future investigations will include processing with even higher power densities and speeds which should produce an even better surface quality and shorter crack lengths. To reduce the interaction time further cutting with a short pulsed laser will be investigated. The combination of the very short pulse duration, high peak power and small beam diameter should be suitable to cut thin sections of AA2024 aluminium alloy by vaporisation of the aluminium, forming a very narrow kerf and recast layer and thus, eliminating or minimising the crack formation.

Further factors which affect the cutting quality, such as gas pressure and type, orifice diameter with respect to the kerf width and finally focus position should also be investigated. So far there is no agreement in terms of the values of these parameters to use to obtain the best quality. This is because these values are also dependent on the laser beam parameters and the material thickness in use. Beam diameter is often disregarded in other studies.

[1] A. Riveiro, F. Quintero, F. Lusquiños, R. Comesaña, and J. Pou (2010) Parametric investigation of  $\text{CO}_2$  laser cutting of 2024-T3 alloy. J. Mater. Process. Technol., vol. 210, no. 9, pp. 1138–1152

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# INDUSTRIAL FIBRE BEAM DELIVERY SYSTEM FOR ULTRAFAST LASERS

**BJÖRN WEDEL AND MAX FUNCK**

**Fibre optic beam delivery has been the key enabler for the wide industrial application of high power solid state cw lasers. Up until recently, fibre optic beam delivery could not be used with ultrafast lasers. Micro-structured hollow core fibres now make it possible to confine the laser light inside a small hollow core and transmit pico- and femtosecond pulses of high energy with excellent beam quality. Packaged into a rugged laser light cable this is likely the start of a new era in laser beam delivery (Figure 1).**



**Figure 1: Laser light cable for ultrafast application**

Ultrafast lasers are used for a growing number of applications as they allow processing of practically any kind of material at unrivalled precision. In order to get the optimum out of an ultrafast laser and establish the technology in industrial application, exact control of the pulse in time, space and shape is required. A key component in a laser processing system is the optical interface between the laser source and the application: the beam delivery system. Its main purpose is to simply transport the laser beam as efficiently as possible from laser source to the desired spot on the work piece. However, additional functionality is increasingly demanded to enhance the laser beam in shaping it spatially and temporally.

In the 1990s, the introduction of fibre-based beam delivery systems for continuous wave (cw) diode- and solid state lasers was a major breakthrough for industrial laser applications and become a de facto standard for cw applications up to multi kW laser power. The same impact can be expected if a fibre beam delivery in ultrafast applications can be realised.

## Beam delivery of ultrafast laser pulses

For the emerging class of ultrafast lasers with

pulse durations below a few picoseconds and pulse energies high enough for material processing, free-space beam delivery is employed today. These mirror-based systems can be very alignment-sensitive (in particular for longer distances) and may suffer from contamination with dust and particles. They also introduce a large number of optical components into the beam path, which are potential sources of beam degradation. Additionally, a stable and well engineered support structure is required and typically the laser source has to be located in close proximity to the application. Typically, this involves a lot of cost and effort in the overall system design.

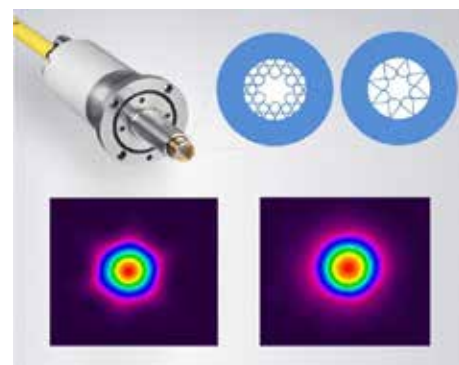
The lack of standardised beam delivery solutions hinders the wide application of ultrafast lasers in industrial applications. Adaptation of a new laser source requires additional alignment effort and significant cost. Fibre-based beam delivery systems are not appropriate, as classical fibres are no longer suitable. They suffer from dispersion making the pulses longer; exhibit insufficient damage threshold; and, for high energy pulses, nonlinear effects such as self-focusing, stimulated Brillouin scattering or Raman scattering take over and destroy the fibre material or the pulse profile. As a consequence, ultrafast pulses for industrial applications cannot be transmitted using conventional glass fibres.

## New fibres confine light in a hollow core

Micro-structured Hollow-Core Fibres (MHCF) (see Figures 2a and 2b) support light propagation mostly inside a hollow core (e.g. in gas or vacuum) enabling high power handling and drastically reduced nonlinear effects. Such fibres are an evolution of photonic crystal fibres, which were developed in the 1990s by Cregan et al. at Bath University [1]. Since then, other types of micro-structured fibres have been developed and their potential for high power ultrafast laser beam delivery have been demonstrated. These have a core size comparable to step-index fibres (for single mode operation) and confine the light inside an irregularity of the crystal like structure: the core. The core region of a single mode fibre can be much larger, as with step index fibres, allowing even higher damage thresholds. For this class of fibre more than 99% of the laser light can be guided inside the hollow core, improving greatly on maximum permissible laser pulse energy up to levels in the mJ regime well beyond many material processing applications. With proper integration into an industrial beam delivery



**Figure 2a: Beam propagation through a micro-structured hollow core fibre**



**Figure 2b: Different types of micro-structured hollow-core fibres (MHCF) and a characteristic near and far field mode profile showing high beam quality ( $M^2 \sim 1.3$ )**

system, ultrafast laser pulses with multi 100 W and multi 100  $\mu$ J can be reliably transmitted with excellent beam quality. A beam delivery system making use of these fibres greatly enhances industrial application by increasing robustness, separating laser source and application, distributing laser energy to multiple workstations and robot-based applications.

Due to the low dispersion in the order of a few ps/km/nm hollow core fibres are particularly suitable for ultra-short pulses down to the femtosecond regime. For wavelengths around 1  $\mu$ m attenuation values are between 30 and 70 dB/km or approximately 1% per meter are possible over a spectral range of 900-1100 nm.

## From hollow-core fibres to ultrafast laser fibre beam delivery systems

A fibre-based beam delivery system consists of a beam launching system, a laser light cable (LLK) with integrated fibre and a processing head. In order to match the output of the laser source to the fibre, a coupling unit – or beam launching system (BLS) – is required to adapt the size of the beam exiting the laser source and focus it to exactly the required spot size at the fibre



**Figure 3: Beam Launching System (BLS) to connect laser source and laser light cable together with laser light cable connector for ultrafast laser applications**

tip. This will maximise transmission efficiency and increase the beam quality exiting the fibre. Positioning needs to be accurate to a fraction of the spot size, typically in the few micron regime, putting a high demand on mechanical interfaces and stability. The optical system is diffraction-limited and (depending on the laser beam quality of the source) delivers a Gaussian intensity distribution at the focal position. However, fulfilling the requirements on mechanical stability and imaging quality is known state of the art technology for high power cw laser beam launching.

The optical fibre itself is well protected; a rugged outer conduit designed to withstand substantial bending in robot or gantry applications ensures reliable operation in daily industrial use. Mechanical stress needs to be kept to minimum and particles, dust or moisture should not enter the fibre as these will reduce the performance and may cause fibre damage. The connector design features a window to create a sealed environment and be far enough away to minimise laser damage to the coatings and bulk material of the window. The enclosed volume can be filled with clean air, or any other gas, and may be pressurised or vacuumised. The fibre itself is mechanically held into position with good thermal contact. Water cooling is optional to reduce thermal effects at higher power levels. A dedicated alignment of the fibre tip with respect to the connector interfaces guarantees high repeatability when changing laser light cables. Reconnecting the same cable requires virtually no realignment of the laser focus.

A flange type mounting supports high precision interfaces and is quickly connected, at the same time the o-ring seal offers a safe protection when used in typical industrial manufacturing conditions. In addition to the optical functionality, the laser light cable can feature security functions as used for high power laser light cables. The conduit will prevent laser light exit in case of fibre breakage. Also, fibre breakage and proper connection of cable and coupling unit are monitored according to industry standards.

#### Application to industrial ultrafast lasers

Performance evaluation of the fibre beam delivery with industrial ultrafast laser systems ranging from 3 to 200 W average power, 300 fs – 10 ps and pulse energies between 3 and 250  $\mu$ J reveals the full potential of the new technology. With proper coupling using a dedicated beam launching system the laser

light cable can operate over a very wide range of ultrafast laser parameters. Pulse durations in the femtosecond regime can be transmitted as well as average powers of multi-100 W and pulse energies of multi 100  $\mu$ J with typical transmission above 90% for a 3 m-5 m cable. Coupling efficiency is constant even for different power levels indicating negligible focus shift with respect to the fibre end face and enables applications with fast power modulation. Physical limitations are only reached for high pulse energies that can damage the fibre end face, cause overheating due to fibre losses at high average powers and pulse degradation due to nonlinear effects at high peak powers.

With optional water cooling and evacuation of the laser light cable connector, very high average powers and high peak powers can be handled as is illustrated in Figure 4, showing results from field evaluation. Given the correct beam launching, the beam quality delivered at the output of the laser light cable is also very high. An  $M^2$  of 1.3 is generally achieved. Figure 2b shows the near field and the far field image of the laser beam transmitted by a typical micro structured fibre. Both have  $M^2$  1.3 and very symmetric far field profiles.

Not only when laid out statically but also when moving the laser light cable dynamically (such as with a gantry or robot system) the beam parameters and the near field beam profile at the output of the fibre can be preserved. The near field pointing stability could be measured to 1 – 2%.

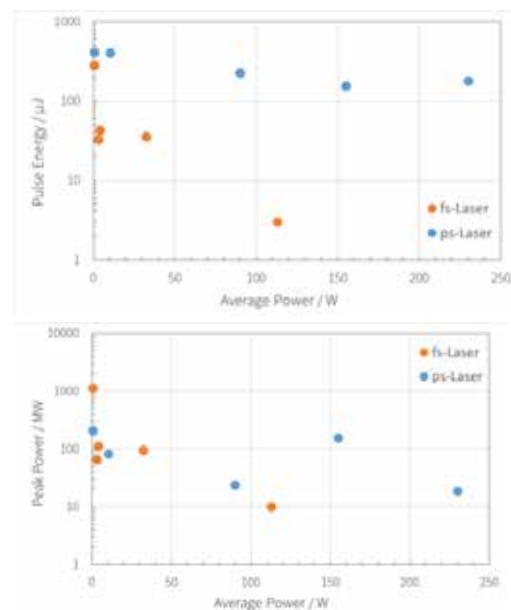
For the dynamically moved cable the preservation of linear or circular beam polarisation at the end of the beam delivery could be established with a polarisation extinction ratio of 25:1, which makes it suitable even for the majority of beam polarisation-sensitive micromachining applications.

#### Conclusion

Fibre based beam delivery systems have once paved the way for industrial application of diode and solid state lasers in material processing. For ultrafast lasers similar solutions are now



**Björn Wedel** is a Managing Director at Photonic Tools GmbH, Berlin, which he co-founded with Bernhard Lummer in 2013. Prior to that Björn founded HIGHYAG Lasertechnologie GmbH which he managed as CEO until June 2013.



**Figure 4: Results from field evaluation demonstrating high power and high pulse energy performance of fibre beam delivery**

available and have the potential to similarly impact the ultrafast laser applications. The biggest advantage will be a far simpler system integration facilitated by the laser light cable: enabling the laser to be dislocated from the application and the movement of the processing machine, there will not be a need for a heavy support structure and a delicate free space beam delivery system, a simpler exchange and service of components is an additional benefit. These technical advantages go along with major reduction of the total cost of ownership for the overall laser system installation.

Application results show that excellent beam quality, pulse duration and power of a laser can be preserved over distances of several meter long fibres integrated in a beam delivery system. Both transmission and beam quality are robust to mechanical loads thanks to a rugged design of interfaces. Bending and movement of the laser light cables within typical limits of bending diameters do not change power transmission and have virtually no effect on the location of the intensity profile. For ultrafast laser applications between 900 and 1100 nm wavelength a laser light cable can easily transmit hundreds of Watts average power and hundreds of  $\mu$ J pulse energy.

[1] R. F. Cregan et al. (1999) "Single-mode photonic band gap guidance of light in air," Science, vol. 285, no. 5433, pp. 1537–1539

**Max Funck is head of R&D at Photonic Tools**

**Contact: Björn Wedel**

[b.wedel@photonic-tools.de](mailto:b.wedel@photonic-tools.de)

# MARKING RESULTS DATABASE IMPROVES CONSISTENCY

## NEAL CROXFORD

**After the initial purchase cost of laser marking equipment, one of the major barriers to new users is the complexity of finding the correct parameters to get the mark required. Unlike conventional machining processes, where there are typically only two or three parameters to set and where these parameters are fairly well documented, the range of parameters in a laser marking process is vast, with very little selection guidance available.**

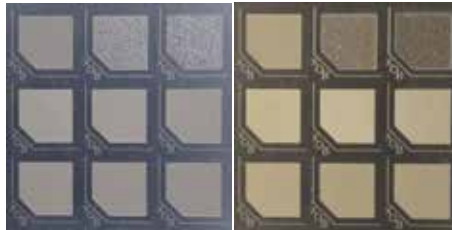
### The problem

A laser marker can have up to nine main parameters that need to be selected: wavelength; power; frequency; pulse duration; spot size; speed; fill separation; number of passes; and fill angle. To complicate matters further, a final 'clean-up' pass may be required at a different combination of all of these parameters.

The parameters of the part to be marked also have to be considered, such as: material; surface finish; size and shape, all which determine the depth of focus required by the process. Every material behaves differently when being laser marked; even seemingly similar materials can mark very differently due to small changes to their composition. Even when the perfect set of parameters has been determined, there is the question of how to record and archive the results for later use, or for another staff member to locate when they face a similar application.

Photographs taken under different lighting conditions or from different angles often look dissimilar and colours can alter when displayed on different PC monitors or tablet screens. How can the user compare a photo taken in unknown lighting with some real-world part? For example, Figure 1 shows two photographs of the same marking sample taken with the same camera at the same position but under two different lighting angles, one from the top and one from the side. The perception of texture and colour are very different on the two images.

The task for the new and inexperienced laser marker user is very daunting: how do you find the correct set of parameters for the mark you wish to achieve? The cost of the time taken to find an acceptable set of laser parameters can make the adoption of a laser marking process uneconomic.



*Figure 1: Two photos of the same sample under different lighting conditions*

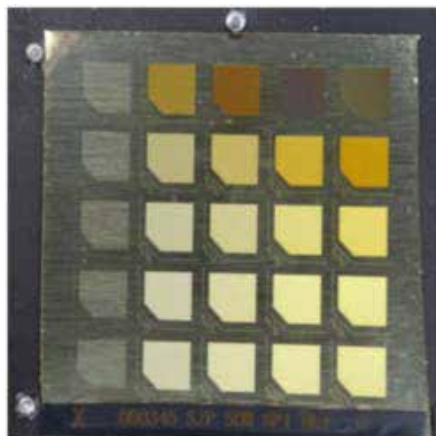
### The solution

As part of an InnovateUK-sponsored project DeBe Lasers, in association with SPI Lasers, has been developing a laser marking sample production, recording and information storage methodology to be used with a searchable database. The method of collecting and recording the data has been standardised and optimised with a pathway to semi-automatic sample creation, capture and entry into the database by multiple users.

### Creating the information

Firstly swatch samples are defined which indicate the range of colours and textures that can be achieved within certain bounds (see the brass sample in Figure 2). All swatches are the same size, 60x60 mm, which allows all commonly-used laser marker scan lenses to be included in the database. All the swatches contain a 5x5 array of swatch items, each of which is the result of a particular combination of laser marking parameters.

Two parameters to be varied are chosen, for example frequency versus laser power, so five different laser powers are marked at five



*Figure 2: Brass sample containing a 5x5 array of swatches*

different frequencies. At the start of the data acquisition these five frequencies and five laser powers will be equi-spaced between minimum and maximum, but as the database becomes populated, an automatic feature will identify where the parameters of intermediate items are required to fully describe the full range of the marking possibilities.

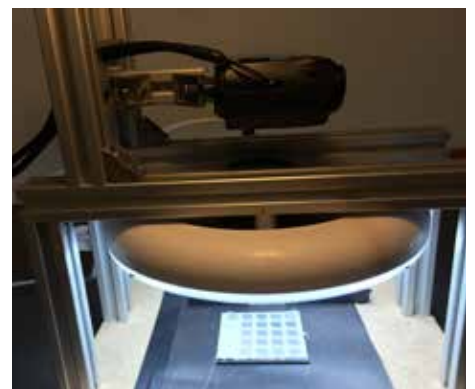
The items all contain features which highlight certain aspects of the laser mark (Figure 3). There is a large filled area to show the colour and texture of the final mark. The corner is cut off this shape which shows whether the fill method is able to adequately fill an uneven shape. The three lines at different angles show the line width and how the line will look against the texture of the part: fine lines running parallel to the grain of a brush surface can have a very low contrast. Finally the three letters highlight certain potential issues with laser marking such as double passes over the same point and distortion of the character shape if the mark is too fast.



*Figure 3: Details of the standard laser pattern designed to highlight potential issues*

### Collecting the information

Once the swatch samples have been created they are photographed under repeatable conditions. To do this a jig has been designed that can be used by any contributor to the database to ensure consistency (Figure 4).



*Figure 4: Sample illumination jig ensures consistent lighting*

The jig has a ring top light, side light, lens system, camera mount and target alignment feature. All contributors use the same jig but can fit their own (suitably specified) camera. The jig has been carefully arranged to provide uniform illumination over the whole swatch and to produce high resolution images.

Two photographs are taken of each swatch, one top-lit and one side-lit. The contributor's unique identifier code and swatch number are marked onto each sample when it is created and there is a feature on the jig which shows which light is being used, so each image is uniquely identified. Once the images are available, a software package identifies the individual swatch items, indexes them to the swatch identifier and stores the information on the database.

### Making the colours 'real'

A well-identified issue when viewing images on different screens is the colour variation that can occur. To counter this, every contributor to the database must colour-calibrate their jig with images of a set of standard RAL colours under the same conditions as the swatch photos. The end user can then obtain a widely-available pack of RAL colours and choose which colour they would like (Figure 5). The software allows the user to superimpose the chosen colour over the photograph of the marked sample.



**Figure 5: Set of RAL colour samples for comparison of marked colour**

### The PC database

DeBe Lasers has developed a PC-based database which can search information on every parameter associated with each swatch item. Figure 6 shows a typical screen shot. If, for example, a user had a particular material to mark and a particular type or colour of mark they wished to achieve, these two requirements can be used as search criteria in the data base to find the best set of parameters for the laser marker. Or, perhaps a user already has a specific laser marker and needs to find the best set of marking parameters; this information could be used as the basis for a database search.



**Figure 6: Screen shot of the PC based database developed by DeBe to facilitate retrieval of colours & parameters**

### Searching the database - an example

The example shown in Figure 7A-E is a search on marking of ABS plastic with a laser in the power range 10-19 W. The user is able to scroll through all the items marked on black ABS in the selected laser power range. Double-clicking on any of these items will bring up a detailed description on the laser marking parameters to achieve this mark.

Clicking on the Marking Steps will give all the parameters required to reproduce this laser mark, and clicking on the RAL sample icon produces the set of photos of RAL colour samples photographed under the same lighting conditions as the mark samples.

Double clicking on the desired mark colour will superimpose a patch of the photo of the RAL colour on top of the laser marked sample to allow the user to compare the colours. If the large image is displayed this will also have the RAL colour sample superimposed over it, and the RAL sample can be dragged over the mark sample to help comparison. Clicking the magnify icon will allow a magnifier patch to be dragged over the mark swatch to allow a detailed image of the marked part to be viewed.

### Next steps

DeBe Lasers is now exploring how to exploit and expand this ground-breaking database. The structure of the database allows global and private sub-sets of the database to be disseminated to users and contributors to add and use these global and sub-sets.

### Figure 7 (right): Screenshots of stored image retrieval:

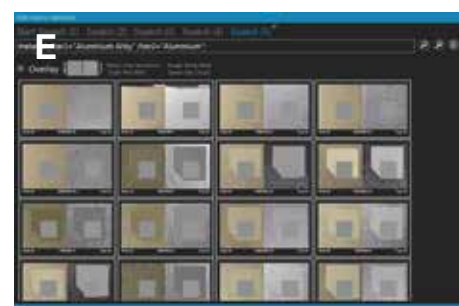
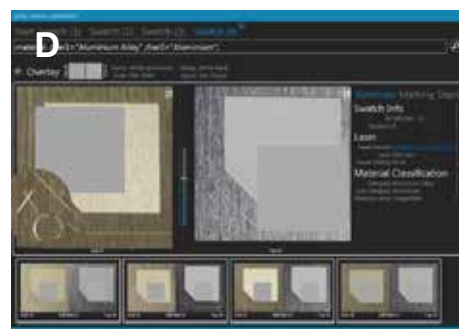
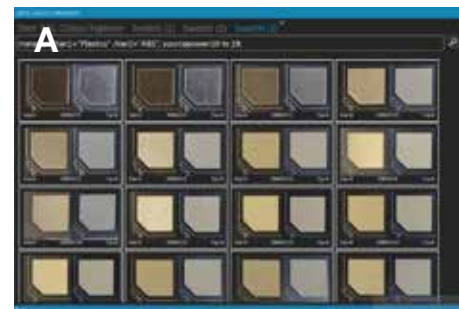
**A – ABS plastic marked with 10-19 W average power**

**B – Detail view of selected images with marking parameters**

**C – RAL colour samples stored in library**

**D – RAL colour superimposed on mark image**

**E – Detailed colour overlay view**



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**Neal Croxford** is a director of DeBe Lasers Ltd. who design and build standard and custom industrial laser systems and sub-assemblies, lasers and bespoke laser delivery solutions.

# PICOSECOND LASER GENERATION OF AG-TiO<sub>2</sub> NANOPARTICLES

ABUBAKER HAMAD ET AL.\*

In the last few decades, lasers have shown to be a unique and efficient technique to produce, manipulate and conjugate various types of nanoparticles. Laser-produced nanoparticles in liquids are pure and controllable and have found important and useful applications in physics, material science research, chemistry, healthcare and engineering. This wide application of nanoparticles is due to a large surface-to-volume ratio, quantum confinement effects and size dependant properties.

At the University of Manchester, picosecond laser ablation in deionised water was used to produce bimodal Ag-TiO<sub>2</sub> cluster nanoparticles with assisted ultrasonic vibration [1]. This method allowed the attachment of smaller Ag nanoparticles, in the range of 10-15 nm, onto the larger TiO<sub>2</sub> particles in the range 30-150 nm (see Figure 1). When ultrasonic waves are dispersed into the liquid solution, they rupture the water environment and generate micro-cavities. The large quantities of bubbles would collapse in the solution and generate very high temperature and pressure. The Brownian motion and the surface atom mobility would be increased due to these very high temperatures, followed by coalescence and adhesion between them. The Ag and TiO<sub>2</sub> nanoparticles did not combine while generation them with the ps laser without ultrasonic vibration.

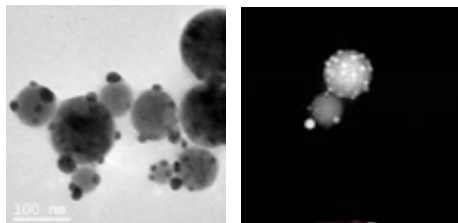


Figure 1: TEM images of bimodal Ag-TiO<sub>2</sub> cluster nanoparticles synthesised by picosecond laser ablation in deionised water supporting ultrasound vibration or waves in the bath of an ultrasonic cleaner [1]

Picosecond laser ablation in ice water was used to reduce the transition energy band gap ( $E_g$ ) of TiO<sub>2</sub> nanoparticles significantly, after the modification with Ag nanoparticles during co-ablation [2]. Indirect energy gap of the TiO<sub>2</sub> nanoparticles was reduced to 1.75 eV after doping with Ag nanoparticles in ice, while in

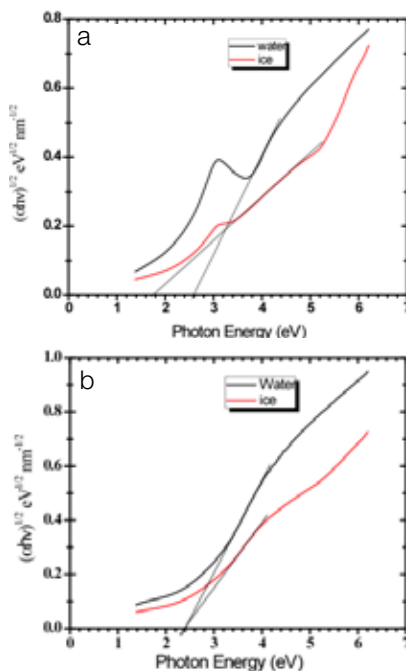


Figure 2: Indirect band gaps of the (a) Ag-TiO<sub>2</sub> nanoparticles and (b) TiO<sub>2</sub> nanoparticles produced in ice and deionised water [2]

room temperature deionised water this the indirect energy gap was 2.58 eV (see Figure 2a). However, indirect band gap energy of TiO<sub>2</sub> nanoparticles generated in both deionised and frozen deionised water (ice) using a picosecond laser were the same and about 2.4 eV (see Figure 2b). The ice water environment has two different advantages for the synthesis of the Ag-TiO<sub>2</sub> nanoparticles; one of them is ice water environment makes a role for cooling of the plasma plume during the laser ablation. The additional confinement and cooling process of the plasma plume from the liquid or ice leads to a shortening of the quenching time of the plasma plume. The second advantage is the restriction or confinement of the movement of the produced nanoparticles in ice water, which makes combination between the Ag and TiO<sub>2</sub> nanoparticles.

As shown in Figure 3, picosecond laser ablation was used to produce TiO<sub>2</sub>@Ag core-shell (TiO<sub>2</sub>-

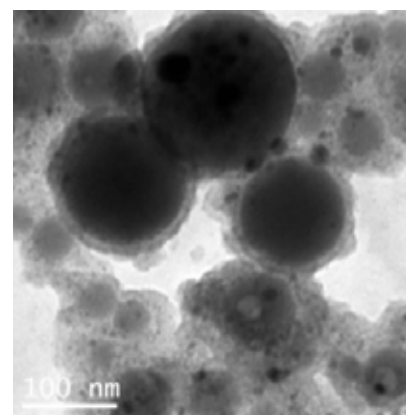


Figure 3: TEM images of the novel structured TiO<sub>2</sub>@Ag core-shell nanoparticles (TiO<sub>2</sub>-core and an Ag-shell) were produced using a novel generation procedure based on sonication of Ag-TiO<sub>2</sub> compound nanoparticles generated by a picosecond laser in deionised water [3]

core and Ag-shell) nanoparticles via ultrasonic vibration of Ag-TiO<sub>2</sub> compound nanoparticles [3]. Their antibacterial activity against *E. coli* bacteria (JM109 Promega UK) was found to be slightly higher than that of the Ag-TiO<sub>2</sub> compound nanoparticles.

[1] Hamad, A., L. Li, Z. Liu, X.L. Zhong, G. Burke and T. Wang, The characteristics of novel bimodal Ag-TiO<sub>2</sub> nanoparticles generated by hybrid laser-ultrasonic technique. *Applied Physics A*, 2016. 122(4): p. 1-12.

[2] Hamad, A., L. Li, Z. Liu, X.L. Zhong and T. Wang, Picosecond laser generation of Ag-TiO<sub>2</sub> nanoparticles with reduced energy gap by ablation in ice water and their antibacterial activities. *Applied Physics A*, 2015. 119(4): p. 1387-1396.

[3] Hamad, A.H., L. Li, Z. Liu, X.L. Zhong and T. Wang, Sequential laser and ultrasonic wave generation of TiO<sub>2</sub>@Ag core-shell nanoparticles and their antibacterial properties. *Lasers in Medical Science*, 2016. 31(2): p. 263-273.

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## HIGH POWER WELDING FOR THE MARITIME SECTOR

Nicholas Blundell (pages 22-23)

This article is mainly concerned with thick section welding and the differences between using fibre delivered solid state lasers with a wavelength of about 1 micron and CO<sub>2</sub> lasers with a wavelength of 10.6 microns. This comparison is very difficult to make as it is virtually impossible to set up identical conditions for both lasers so that the real effect of wavelength can be evaluated. The author appears to be concluding that for some applications CO<sub>2</sub> lasers would be better, and if this is the case it would be good to get to the underlying reasons (no physical explanation is offered by the author).

There are three main differences that can be expected due to the difference in wavelength. First is the inherent absorption of the material at different wavelengths. Given that most metals absorb the 1 micron wavelength better than 10 microns, it is difficult to see how there could be any benefit (e.g. steel is roughly 3 times higher at 1 micron). Second are the plasma interactions above the surface of the metal. It is well-known that these are much more significant at 10 micron wavelength due to energy absorption being dependent on the square of the wavelength (due to the inverse Bremsstrahlung effect).

Consequently much more needs to be done to manage the plasma with CO<sub>2</sub> laser welding than with solid state lasers which cannot be beneficial. The third difference is due to the inherent easier focus-ability of shorter wavelength lasers. Given that, for thick section welding especially, the beam diameter at the workpiece should be at least 0.5 mm and preferably larger, this should not really be a factor, unless it is the case that the beam delivery optics on the latest solid state lasers do not readily allow a spot size this large? In conclusion, I don't see how or why CO<sub>2</sub> should be better for thick section welding than fibre-delivered solid state lasers. My assumption is that the comparisons were not done under identical conditions so that this conclusion could not be readily made.

Just to clarify the point about Myer using both types of laser I think this is because they originally developed hybrid welding for panel lines before there were any reliable high power solid state lasers available and so had to use CO<sub>2</sub> lasers. They now use solid state lasers as well, pointing to the inevitable evolution of this process with time. I would agree with the author that for many applications laser hybrid welding is preferable to either autogenous laser welding or laser welding with a filler wire. Certainly for thick section welding I would say it is essential.

Stewart Williams, Cranfield University

## CAN HIGH SPEED CLADDING REPLACE HARD CHROME PLATING?

Markus Ruetering and Oleg Raykis (pages 24-25)

l625 will not resist wear compared to thermal spray coatings, this is not a fair comparison. Equally hard chrome plating is just that over 1100 Hv so

the laser clad Inconel 625 alloy will not compete in terms of wear. I would like to see information presented for a wear resistant laser clad coating deposited without cracks or pores. This would compete like for like with hard chrome.

It is not fair to suggest that thermal spray coatings don't last as long as hard chrome plating. In fact for valve applications HVOF thermal spray offers significant lifetime improvement over hard chrome plating as the tungsten carbide cobalt chrome coatings are far more abrasion resistant. Thermal spray has been successfully replacing hard chrome plating in the right applications for at least 20 years. "Ultra high speed laser cladding", as far as I can see, is using a finer diameter beam, which is not uncommon, and having a slightly higher standoff distance. Then you turn the speed up to ensure the coating is very thin.

I don't think it makes sense to suggest that the same effect can be produced with a 2-4 kW laser using this approach compared to a 20 kW laser. Perhaps the powder feed rates and deposition efficiency could be provided? It would probably be best to state that "ultra high speed laser cladding" is best suited to 2-4 kW lasers?

Sam Lester, LASE Ltd

An interesting article, introducing a potential solution to the major issue of replacing chrome plating, one that has been on the horizon for several years, now with more urgency. It would be good to see a laser solution to this, and this process seems like a viable contender. However, I find myself asking a few questions that could have been explored.

The process itself is reasonably obvious, the solution in terms of preheating the powder follows readily from a basic understanding of laser cladding. I can't help thinking that this process was explored over 30 years ago, in labs such as Bill Steen's at Imperial College where several important aspects of laser cladding were developed. At that time the need for thin coatings was probably not recognised and there was no immediate drive to replace chrome plating.

Laser process parameters were extensively studied in the generation of amorphous alloys – "glassy metals", the ability to produce glassy metal surfaces was considered a process which might revolutionise surface engineering, though I haven't seen much further development here. However it does indicate that high speed cladding could produce some interesting coating metallurgy. Also the article seemed to suggest that chromium had been replaced by Inconel 625, which still includes 20-23% chromium. This is described as a corrosion-resistant alloy, while chrome plating is often used as a hard, wear-resistant coating. It would seem reasonable to avoid deposition of 100% chromium, as this is likely to produce its own carcinogenic fumes, but what about alloys containing chromium which are regularly used for laser cladding? But is the final coating a replacement coating for chrome plating? The article implies that the coating is a replacement for chrome, but does not provide evidence. One of the reasons that chrome plating has taken so long to displace is the wear performance obtained, at a relatively low process cost.

But these chrome coatings have to go! And it

would certainly be good to see a viable laser solution on offer. I'd certainly appreciate the opportunity to discuss these material issues at ILAS 2017, I hope the authors will submit a paper and come to the UK to tell us more!

Martin Sharp, Liverpool John Moores University

## FIBRE LASERS MITIGATE CRACK FORMATION IN ALUMINIUM ALLOY

Sonia Meco et al. (pages 26-27)

Looking at the results reported, it seems that the cut speed is lower than might be expected. Our experience shows that a higher cutting speed and smaller spot size would also result in much better quality cutting performance. For the thickness range used, the spot size could be decreased further to 50 – 70 µm diameter which would reduce the heat input considerably, bearing in mind that when you reduce the spot diameter by half you increase the power density by a factor of 4. This would also enable much higher cutting speeds to be used, for the same laser output power. We have successfully cut aluminium using higher power with speeds an order of magnitude greater; for example with a lot more power (5-6 kW) we have been able to achieve a cut speed of 2000 mm/s for 1 mm thickness and 1000mm/s with 2 mm thickness. Although these speeds are perhaps higher than most standard cutting machines are capable of, an increase of cutting speed to 300-500 mm/s can be comfortably used at a moderate average power of 2 -3 kW, which is the typical power used in many current commercial cutting machines.

Michael Grupp, IPG Laser GmbH

## INDUSTRIAL FIBRE BEAM DELIVERY SYSTEM FOR ULTRAFASST LASERS

Björn Wedel and Max Funck (pages 28-29)

This article provides a useful summary of the hollow core fibre technology that has undergone rapid development in recent years and been exploited by ourselves at Heriot-Watt and others for delivery of high peak power ultrashort laser pulses. It provides a useful summary of pulse energy, peak and average power delivery results with these fibres, demonstrating their potential for many ultrafast laser industrial processes, where flexible fibres can greatly simplify manufacturing systems. The authors in particular highlight the work of their company, Photonic Tools GmbH to incorporate these fibres into an industrial fibre beam delivery system, thus taking these fibres out of the research lab into commercial reality. In the future I expect that all ultrashort pulsed lasers will be supplied with fibre optic delivery as standard, based on this or similar technology.

Duncan Hand, Heriot-Watt University

CONTINUED OVER

## MARKING RESULTS DATABASE IMPROVES CONSISTENCY

Neal Croxford (pages 30-31)

At Fimark we have been using flash lamp pumped Nd:YAG lasers for nearly 20 years and with the usual variables of speed, frequency and power thought we knew quite a lot about setting up the laser to get the best mark. When we bought our first fibre laser though, with variable pulse width, we realised we had to forget almost everything we had learnt. Whilst previously we wouldn't change the fill separation from a slight bit of overlap we realised we could get quite different effects by 'over' filling. For example with the fibre laser set with very short pulse width you can get black marks on clear anodised aluminium, but you fill at less than a micron. With a beam width of 40 times that this seems strange, but you have to use very low power and high speed so that you don't damage the anodic layer. We would never have discovered this on our own as the parameters were too far away from what we were used to. In this case we were told where to look to achieve this mark.

The work that Neal Croxford at DeBe Lasers is doing to create a database of marking parameters

for different materials therefore seems a very good idea. It will help the new user and the experienced one. At Fimark we are mostly working with metals and if we had to mark a plastic that we were unfamiliar with we could spend hours trying to achieve a good contrast with no expectation of success. Knowing that there is a high contrast mark for that material even if we don't have the exact parameters would be very helpful.

It is not clear from the article how the database will be made available, but perhaps it will be web based which means that it could be an easy starting point for anyone confronted by a new material. It is also not clear how people will be able to contribute to the database unless they have the correct lighting and camera. However I look forward to seeing how the work progresses as even getting close to the correct parameters could save a lot of time.

Charles Dean, Fimark

## PICOSECOND LASER GENERATION OF AG-TiO<sub>2</sub> NANOPARTICLES

Abubaker Hamad et al. (page 32)

This interesting article from the University of Manchester demonstrates the use of an ultrashort pulse laser for the generation of pure Ag-TiO<sub>2</sub> nanoparticles which have found very important applications in many areas of research, including healthcare for killing dangerous microorganisms such as *E.coli* bacteria. The authors briefly described an interesting approach to generate the Ag-TiO<sub>2</sub> nanoparticles by combining the picosecond laser ablation process with an ultrasound process, as well as explaining the advantages in carrying out the laser ablation process within ice instead of room temperature deionised water. However, it would have been very useful for the readers not being deeply involved in this subject to explain in more detail the significance of the changes to the indirect band gaps of the nanoparticles, i.e. why it is advantageous to control this parameter and how this influences the antibacterial properties of the nanoparticles.

Krystian Wlodarczyk, Heriot-Watt University

## A FUNNY THING: TEARS ON THE PLANE

The amazing landing of an A320 aircraft on the Hudson River in 2009 reminded me of a flight I took many years ago. Being naturally rather reserved, I am not the sort of person who normally strikes up conversation with my neighbour on a plane, but in this case since it was a long flight and he arrived somewhat after me I made an exception. "What brings you to Tel Aviv?" was something like my opening salvo, and I quickly regretted it when he retorted "I'm an Air Accident Investigator..." When I replied "Do you get a lot of accidents to investigate, then?" he replied "Mostly it's just bird strikes" Knowing that a bird strike is not that common and that most planes fly very nicely with one engine disabled, I didn't lose any sleep. However, some years later, to learn that an A320 was turned into a 70 tonne glider (with a rather severe glide angle) after flying through a flock of Canada geese made me re-assess my perceptions of risk. From that point on, I have considered whether to hire Captain Sullenberger as my personal pilot and also considered how many other regular pilots (EasyJet, Ryanair etc.) have his level of experience and skill. Having experienced flying a glider solo in my youth, I really admire the skill displayed by Sully in bringing the A320 down to land on water without loss of life, and perhaps with a smoother landing than some pilots have made on "terra firma".

Back to Tel Aviv 20 years ago, and business safely concluded, I found myself back at the airport and experienced the efficiency of EI Al security staff (this was long before 9/11 when flying was generally easier and security didn't normally occupy so much time). Questioned on my reasons for travel and the nature of my



business – I was put through the security routine twice by different staff-members. One of them quizzed me a little deeper (no doubt to prove that I was legit) and asked me how a laser worked. I had a wry smile as I put out my 2 hands and separated them, facing each other.... "This mirror is totally reflective", I said "and this one is semi-reflective and the laser beam that is used for welding or cutting passes through it". Apparently satisfied with my rudimentary knowledge of laser physics they left me alone to compare notes (presumably I passed!).

On boarding the plane and sitting alone, also perhaps a little less keen to strike up conversations with my neighbours, I settled back to watch the film I had chosen from the options available. I remember clearly it was "A Perfect World" with Kevin Costner and since I was missing my children, and had been away

from home for several days, I was perhaps a little more emotionally drained than usual. Finding the tale of good and bad parenting rather sad, I felt a tear or 2 running down my cheek – in these days the films all started simultaneously and as I looked around at my fellow travellers (90% male business flyers travelling alone) I could see at least 2 others dabbing at their cheeks with hankies. Since all was silence apart from the headphones it was only the presence of tears which indicated who was watching the same film.

The moral of the above? When you are long way from home it is good to remember family. Chatting to your neighbour doesn't hurt, and sometimes a few tears are good for the soul. Don't you think?

Dave MacLellan  
dave@ailu.org.uk

# AILU WORKSHOP

Presentations, Exhibition and Tour



## MICRO-NANO PROCESSING

14 September 2016

Botleigh Grange Hotel, Southampton, UK

### Programme

08:45 - 09:30 Registration, Refreshments & Exhibition

09:30 - 11:00 Session 1

Welcome Jack Gabzdyl (SPI Lasers)

#### High power microprocessing with ultra short pulsed lasers using innovative optical devices

Arnold Gillner *Fraunhofer ILT, Germany*

#### Spatiotemporal fibre lasers for advanced manufacturing applications

Dave Richardson *University of Southampton*

#### Laser-solid interactions

Guillaume Cadot *University of Nottingham*

11:00 - 11:30 Refreshments & Exhibition

11:30 - 13:00 Session 2

#### Pico- and femtosecond lasers for industrial material processing

Roland Mayerhofer *ROFIN Baasel Lasertechnik, Germany*

#### Micro-welding of dissimilar metals using ns-pulsed fibre lasers

Paul Harrison *SPI Lasers*

#### Recent advances in high precision laser micromachining

Alan Ferguson *Oxford Lasers*

#### Processing with ultra-short pulsed lasers

Florian Kanal *TRUMPF*

13:00 - 14:00 Lunch & Exhibition

14:00 - 15:00 Session 3

#### Laser micromachining and high power laser targets

Duncan Cooper *Scitech Precision*

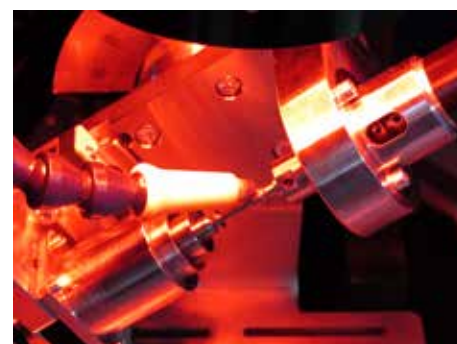
#### Future standard for welding applications: The graphical interface

Rafael Barcos *BS-Optics, Switzerland*

#### TBA

15:00 - 15:30 Refreshments & Exhibition

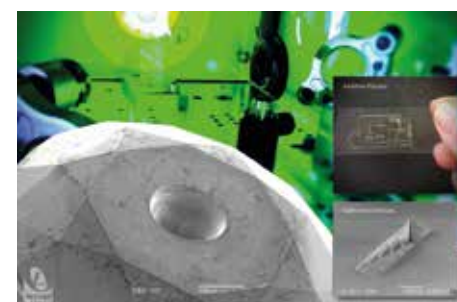
15:30 - 16:30 Tour Application Laboratories, SPI Lasers, Southampton



Courtesy: BS-Optics





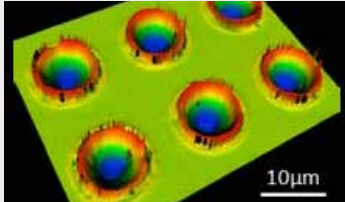









Courtesy: Scitech Precision



Courtesy: Oxford Lasers

# EVENTS: RECENT AND FUTURE

June 2016	July/August 2016	September 2016	October 2016
<p>16 <b>AILU PRESENTATION</b> Ric Allott (AILU Chair) <i>Lasers have the power to drive UK business</i> International Festival for Business, Liverpool</p> <p>22 <b>AILU BREAKFAST MEETING</b> LASER APPLICATIONS IN THE MARITIME INDUSTRY Birkenhead</p> <p>28-29 International Conference on Industrial Laser Processing (JNPLI) Liège, Belgium</p>  <p>Image courtesy Mersey Maritime Ltd</p>	<p>19 JULY LATEST DEVELOPMENTS IN LASER WELDING TWI, Cambridge</p>  <p>Image courtesy TWI</p>	<p>7-8 PRIMES WORKSHOP - LASER BEAM DYNAMICS Darmstadt, Germany</p> <p>13 FUTURE PHOTONICS HUB INDUSTRY DAY University of Southampton</p> <p>14 <b>AILU WORKSHOP</b> MICRO-NANO PROCESSING Botleigh Grange Hotel, Southampton</p> <p>21 LASER CUTTING AS A TOOL FOR DECOMMISSIONING TWI, Cambridge</p>  <p>Image courtesy Laser Micromachining</p>	<p>4 <b>AILU ANNUAL JOB SHOP BUSINESS MEETING</b> MTC, Coventry</p> <p>12-13 PHOTONEX 2016 Ricoh Arena, Coventry</p> <p>16-28 ICALEO 2016 San Diego, USA</p> 
November 2016	December 2016	January/February 2017	March 2017
<p>2-3 ADVANCED ENGINEERING 2016 NEC, Birmingham Visit AILU at stand L62</p> <p>29 <b>AILU WORKSHOP</b> HIGH POWER LASER SOURCES AND BEAM DELIVERY Heriot-Watt University</p>  <p>Image courtesy: Heriot-Watt University</p> 		<p>28 JANUARY - 2 FEBRUARY SPIE PHOTONICS WEST &amp; PHOTONICS WEST LASE</p>  	<p>22-23 <b>ILAS 2017</b> 5TH INDUSTRIAL LASER APPLICATIONS SYMPOSIUM Belton Woods Hotel, Grantham</p>    <p>Image courtesy: TWI</p>  <p>Image courtesy: TWI</p>