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WINTER 2019

AILU

# THE LASER USER

ILAS 2019
Full programme inside

IN THIS ISSUE:



## GAME-CHANGING BLUE LASER SOURCES: SHORTER WAVELENGTHS & IMPROVED APPLICATIONS

# THE LASER USER

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

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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 views and opinions expressed in this magazine belong to the authors and do not necessarily reflect those of AILU.

The Editor reserves the right to edit any submissions for space and other considerations.

Authors retain the right to extract, in part or in whole, their material for future use. The Laser User is published quarterly in February, May, August and November by AILU for its members and is available in print or online.

**Editorial Board for this issue:**



Cover image: A 500 W high power blue laser (AO-500) performing a lap weld of 2 x 300 microns pure copper sheets.

Courtesy of NUBURU

## ADVERTISING ENQUIRIES

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## WELCOME TO NEW AILU MEMBERS

**Aston University**
Janet Hull
j.hull@aston.ac.uk

**Blackman & White Cutting Solutions**
Susan Henderson
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**CROWN Packaging Manufacturing UK**
Peter Young
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**HV Wooding**
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**Laserax**
Charles McLaughlin
cmclaughlin@laserax.com

## AILU STEERING COMMITTEE 2018-19

| | |
|---|---|
| President: | Lin Li (University of Manchester) |
| Vice President: | Jon Blackburn (TWI) |
| Exec. Director: | Dave MacLellan (Anode Marketing) |

**Elected until 2021**

| | |
|---|---|
| Derrick Jepson | (Aerotech) |
| Arina Mohammed | (University of Hull) |
| Krste Pangovski | (University of Cambridge) |
| Mark Thompson | (IPG Photonics) |

**Elected until 2020**

| | |
|---|---|
| Shireen Khanum | (GF Machining) |
| Anke Lohmann | (Anchored In Ltd) |
| Vojtech Olle | (OSI Optoelectronics) |
| Mike Poulter | (SPI Lasers) |

**Elected until 2019**

| | |
|---|---|
| Duncan Hand | (Heriot-Watt University) |
| Louise Jones | (KTN) |
| Jonathan Lawrence | (Coventry University) |
| Ian White | (Yamazaki Mazak) |

**Co-opted**

| | |
|---|---|
| Adam Clare | (University of Nottingham) |
| Mark Millar | (Essex Laser) |
| Tony Jones | (Cyan Tec Systems) |

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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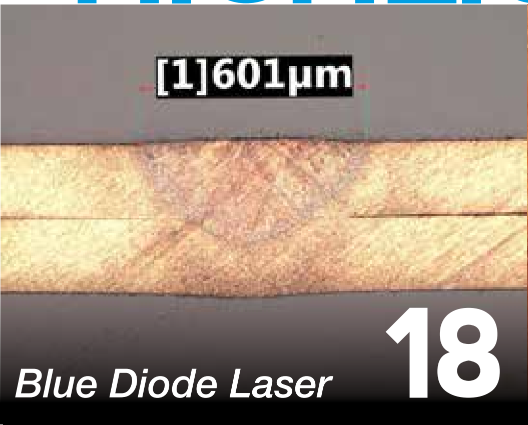
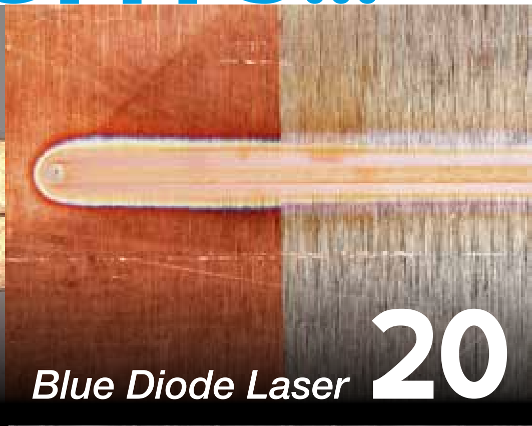
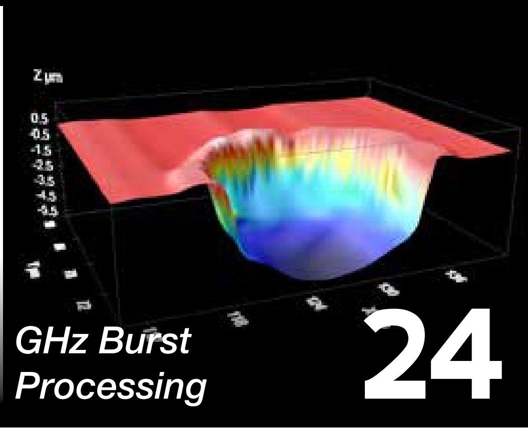
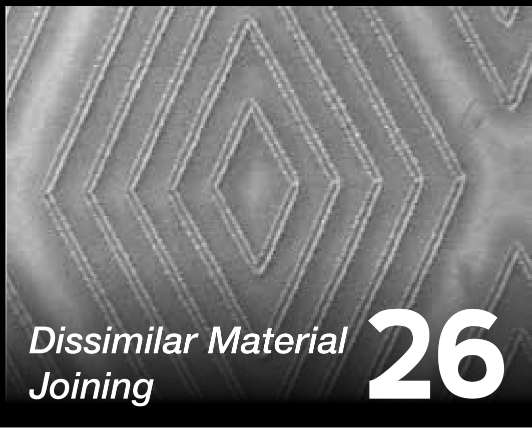
# HIGHLIGHTS...

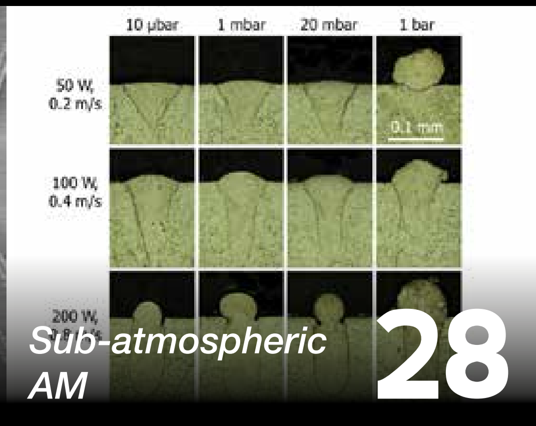









# ASSOCIATION NEWS

## FIRST WORD

This issue features two articles from manufacturers about lasers with wavelengths in the blue part of the spectrum. In recent years I have seen the increase in power of lasers in the green and blue wavelengths, where absorption in some reflective materials (like copper, silver and gold) is much higher.

Previously, the power available was limited as the wavelength was generated by doubling or tripling the frequency of IR lasers starting at around 1 micron wavelength – resulting in huge losses of output power and wall-plug efficiency. I am excited to see new options available for material processing enabled by diode lasers, which will no doubt be massively cheaper and more efficient than the blue and UV lasers used historically. Personally, I fully expect the "diode revolution" to be the next big thing in lasers, now that fibre lasers are becoming mainstream.

The Laser User is a great place to read about new technology and new applications, just as ILAS (March 20-21) is a great place to hear new applications and laser technology presentations. A few times I have been asked by people "do you know anything about application x?" only to recall that there was an article in a recent magazine issue or a presentation at a recent AILU workshop.

This issue of The Laser User is a bumper issue with 40 pages as it contains detailed information about ILAS and more content than usual. I know that people are often time-limited, but a quick flick through the magazine and the handy contents page should easily allow you to pick out the content that is most interesting and relevant to you.

I hope to see as many AILU members as possible at ILAS next month, just remember 3 things: Firstly, invite all your network to come. Secondly, register as many people as possible from your organisation. Finally, book a room today at Crewe Hall! See full details at ilas2019.co.uk.

**Dave MacLellan**
*dave@ailu.org.uk*

## PRESIDENT'S MESSAGE

**The 6th Industrial Laser Applications Symposium (ILAS 2019), organised by AILU, is just on the horizon (21-22 March 2019 in Crewe, UK). We will have 90 oral presentations and 10 poster presentations with over 200 delegates from at least 9 countries. I encourage our AILU members to attend this conference, it is a great opportunity to find out the latest developments in advanced laser processing research and innovations.**

**Two more workshops are planned before the middle of the year and these will both be aimed at end-users – though very different markets. The first one will be held in London on 22 May and will focus on "lasers for makers" – the creative use of laser cutting systems which are of the low cost "plotter" style. Although these lasers are surely the most widely used (by number of units) owing to their compact size and low cost, AILU recognised that this market is in need of support, training and networking to improve safety and know-how in this market which is traditionally unaware of AILU.**

**A second workshop is planned to take place with the National College for Nuclear in Cumbria, where we hope to attract the end-users in the nuclear industry who may not be aware of the impact that laser processing can have on nuclear manufacturing, maintenance and decommissioning. This will be held on 6 June and follows on from a talk I gave in December, at an event co-hosted by IMechE. A number of AILU members are active in the nuclear sector, and if you are interested in suggesting speaker recommendations or topic suggestions, please get in touch.**

**Finally, we will be holding the AILU AGM soon (date to be announced shortly) – if anyone is interested in joining the Steering Committee please put your name forward.**

**Lin Li**
*lin.li@manchester.ac.uk*

## RIC'S RAMBLINGS

Dear Readers, when I was pondering what to write and subject the loyal readers of "The Laser User" to this quarter, I had that terrible sense of time speeding by. Surely, I have only just submitted my last article the other day – but it was 3 months ago!

This sense of time flying by was enhanced greatly by the news that the EPSRC Laser Centre for Innovative Manufacturing (CIM-Laser) is coming to the end of its project lifetime this year. I have had the pleasure of being involved from the start of this excellent Centre as a member of the Industry Advisory Board. The concept is simple – but very powerful. Pull together and fund a collaboration of different university partners with key expertise and skills that complement each other across a whole range of laser processing and manufacturing – and match them together with industry and companies who have a real need and specific challenges to be solved. The result, if run correctly, is without doubt more than the sum of its parts, and the benefits to industry of connecting into this academic resource are substantial. I have always been a strong advocate of connecting academia to industry – it is a win for both sides and especially important in these days of Industrial Challenge funding. At STFC, we generate virtuous "triangles" of STFC – Academic – Industry and this really drives innovation and speeds up the translation of research into practical solutions providing economic and societal benefit.

Of course, AILU has been doing this too – right from the beginning and in particular, our flagship conference ILAS, which is coming up in March, is a great example of mixing academic and industrial research and allowing these interactions to take place in an informal but focused atmosphere. In fact, I would say that ILAS is one of the best conferences for this.

I note that this year at ILAS there is a whole session dedicated to CIM- Laser and you will be able to see its outputs and impact for yourself. I encourage you to attend. The future in my opinion is going to require even stronger links and interactions between Universities and Industry – AILU, and in particular ILAS, is where you can see this happening in real time with real people.

**Ric Allott**
*ric.allott@stfc.ac.uk*

## ACCESS TO MANUFACTURING GROWTH GRANTS FOR UK SMEs

Funding is avaiable to help with the cost of working with an external expert/coach to implement growth or business improvement action plans.

The Manufacturing Growth Programme (MGP) Grant scheme provides free advice and support to manufacturing SMEs including:

- An independent business review to identify opportunities for business improvement and growth.
- A detailed action plan guiding you through the process of improving your business.
- Access to matched industry experts to provide consultancy and/or coaching tailored to your needs.
- Access to grants to co-fund your growth/improvement project.

The grants are funded by the European Regional Development Fund (ERDF). An average project value of £4,000 of support would attract up to a 35% grant contribution.

The scope of the Growth/Improvement plan will be specific to each applicant's growth needs and will be agreed in advance with a Manufacturing Growth Manager. Grants can cover aspects of business strategy, finance, marketing, quality and environmental areas among others, and could be used towards implementation of new accreditations.

**The current round of grant applications ends on 31 March 2019.**

Contact Dave MacLellan for more information.

**Dave MacLellan**
*dave@ailu.org.uk*

## VERO SOFTWARE ADOPTS HEXAGON'S ID

As of January 2019, Vero Software became part of the Production Software business of Hexagon Manufacturing Intelligence, along with FASys and SPRING Technologies - adopting Hexagon's corporate identity. The formation of the Production Software business reflects Hexagon's broadening expertise in the production technology space.

"Over the last five years our available technology and solutions have evolved considerably from the CAD CAM heritage of Vero," explains Steve Sivitter, CEO of the Production Software business. "We're increasingly focused on developing product synergies that will help customers improve quality and productivity.

"Our technology experts from Vero, FASys and SPRING have been working very closely together for some time, so operating together as a single entity is a natural step for us. We're all excited at the prospect of what's possible now creating innovative manufacturing intelligence solutions in the production software space."

HEXAGON

**Contact: Marc Freebrey**
*marc.freebrey@verosoftware.com*
*www.verosoftware.com*

## RENISHAW SUPPLIES SANDVIK WITH AM LASERS

Renishaw has initiated a collaboration with Sandvik Additive Manufacturing to supply the company with high productivity multi-laser RenAM 500Q systems, which will substantially increase Sandvik's printing capacity.

The system features 500 W quad lasers in the most commonly used platform size, enabling a radical increase in productivity, without compromising quality.

The two companies also intend to collaborate in areas like materials development, AM process technologies and post-processing.


**Contact: Stuart Offer**
*stuart.offer@renishaw.com*
*www.renishaw.com*

## SPI LASERS OPENS NEW FACILITY IN SHENZHEN

SPI Lasers has increased its footprint in China with the opening of a new Sales/Service/Applications centre in Shenzhen in Southern China.

Staffed by fibre laser experts the new application, sales and service centre is fully focused on supporting SPI's Chinese customers and fits into their developing growth strategy of putting the customer at the heart of their business.

**Contact: Jack Gabzdyl**
*Jack.Gabzdyl@spilasers.com*
*www.spilasers.com*

## BOFA WINS SOUTH WEST EXPORT AWARD

Poole-based BOFA International has won the Export Award at the Made in the South West Awards ceremony in Bristol. The company was recognised for its impressive export performance, which sees 90% of its systems sold into 120 countries around the world.

BOFA's export strategy is supported by subsidiaries in the US and Germany, as well as its global distribution network.

Two recent appointments have boosted the International sales team and supported BOFA's international growth plans.

**Contact: John Horsey**
*john.horsey@bofa.co.uk*
*www.bofa.co.uk*

## TRUMPF TO ACQUIRE PHILIPS LASER DIODE DIVISION

TRUMPF is to acquire 100% of Photonics GmbH from Philips. This opens up a new market segment for TRUMPF in addition to its existing business with high-power diode lasers and expands its product portfolio.

Laser diodes from Philips Photonics are used, for example, in smartphones, in digital data transmission, and in sensors for autonomous driving. Photonics GmbH employs around 280 people. The transaction is expected to be completed in the second quarter of 2019.

**Contact: Gerry Jones**
*gerry.jones@trumpf.com*
*www.uk.trumpf.com*

CASE STUDIES

## BYSTRONIC BOOSTS COMPANY GROWTH

Sheet metal subcontractor Ackerman Engineering's factory was purpose-built in 2006 by the current managing director, Graham Ackerman, great-grandson of the company's founder.

$CO_2$ laser technology, which had been used by the company since 2001, was phased out in August 2018 and part-exchanged for a ByStar Fiber 8 kW fibre laser cutting centre, which joined a 3 kW BySprint Fiber installed four years earlier. A seventh press brake was added to the six Bystronic models already on-site.

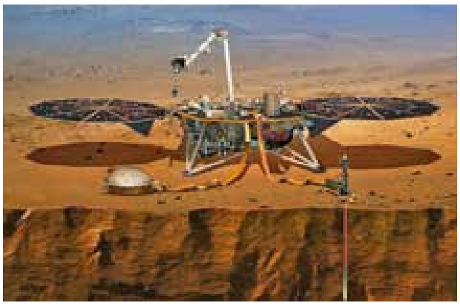

The advantage of profiling and bending components on the same make of equipment is that Bystronic's offline Bysoft 7 software modules, Laser and Bend, work together to produce very precise 3D sheet metal parts.

The Bridport factory mainly processes aluminium, stainless steel and mild steel sheet from 0.7 mm to 8 mm thick, with a lot of material in the 1.2 mm to 2 mm range for the manufacture of electrical cabinets destined for the electronics and telecommunications industries. When cutting these gauges, the 3 kW fibre machine is typically two to three times faster than $CO_2$. When the 8 kW fibre laser was installed, a further increase in throughput was seen, as processing times are less than half those using the 3 kW fibre source.

**Contact: Daniel Thombs**
*daniel.thombs@bystronic.com*
*www.bystronic.co.uk*

## SPECTRUM MAKES ITS MARK ON MARS

Spectrum Technologies' Nova laser wire marking equipment was used to process and identify all the wiring in the complex electrical wiring system for NASA Jet Propulsion Laboratory's Mars Insight lander.



Spectrum supplied Lockheed Martin Space in Denver, CO with a fully automated Nova 820 UV laser wire marking system in 2014. This is used in the initial stages of electrical harness production to laser mark, measure and cut wires to length. Apart from using the equipment for the InSight program, Lockheed utilise the equipment for many other different programs including the wiring produced for the Kennedy Space Center for the Orion program.

The Nova 800 product range was specifically designed for complex aerospace wire harness manufacturing applications.

Peter Dickinson, CEO at Spectrum, said: "We may only have played a small part in this interplanetary project but I and all the team at Spectrum are exceptionally proud and excited to be associated with the Mars Insight program. InSight is truly leading edge and we look forward with anticipation to seeing what new knowledge it turns up while it explores Mars and its deep interior."

**Contact: Sana Qazi**
*sqazi@spectrumtech.com*
*www.spectrumtech.com*

## NEW START-UP SELECTS TRUMPF FIBRE LASER


New start-up Staffs Laser Ltd has selected a TRUMPF TruLaser 2030 fibre to help propel the business into the Midlands subcontract sheet profiling market. Installed at the time of business launch in April 2018 as the company's sole laser cutter, the TruLaser 2030 fibre is on target to help Staffs Laser achieve a turnover of £800,000 in its first year of trading, way ahead of the £560,000 originally budgeted.

Staffs Laser is the brainchild of Eddie Hopkins, who has been working in the laser cutting arena for the past 15 years.

"At my previous employment we had $CO_2$ laser cutting machines, which are fine but cannot match the speed of fibre on thinner sheet," he explains. "My old bosses were reluctant to invest in the latest fibre technology, so I decided to leave and start my own business."

With limited budget, Mr Hopkins enquired about TRUMPF's entry-level machine, the TruLaser 2030 fibre, which is designed to provide an easy introduction to highly productive laser cutting.

"We cut mild steel up to 20 mm, stainless steel up to 16 mm and aluminium up to 12 mm," explains Mr Hopkins. "We also process copper, brass, galvanised steel and zintec."

**Contact: Gerry Jones**
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*www.trumpf.com*

# ILAS 2019 PROGRAMME OVERVIEW

**WEDNESDAY 20 MARCH**
**DAY 1**

| | Room 1 | Room 2 | Room 3 |
|---|---|---|---|
| 08:00 | Registration and refreshments | | |
| 09:00 | **OPENING of ILAS 2019** | | |
| | Plenary 1: Stefan Kaierle (Laser Zentrum Hannover) | | |
| | Plenary 2: Hideki Kyogoku (Kindai University) | | |
| 10:15 | Refreshments | | |
| 10:45 | **Welding** | **Additive Manufacturing** | **Surface Engineering** |
| 12:15 | Lunch | | |
| 13:45 | **Welding** | **Additive Manufacturing** | **Microfabrication** |
| 15:00 | Refreshments | | |
| 15:30 | **Cutting** | **Diagnostics & Measurement** | **Microfabrication** |
| 17:00 | **POSTER PRESENTATIONS WITH WINE RECEPTION** | | |

**THURSDAY 21 MARCH**
**DAY 2**

| | Room 1 | Room 2 | Room 3 |
|---|---|---|---|
| 08:00 | Registration and refreshments | | |
| 09:00 | Plenary 3: Stephan Barcikowski (University of Duisburg-Essen) | | |
| | Plenary 4: Duncan Hand (Heriot-Watt University) | | |
| 10:00 | Refreshments | | |
| 10:30 | **Cleaning** | **Sources & Beam Delivery** | **CIM-Laser Special Session** |
| 12:00 | Lunch | | |
| 13:30 | **Systems & Automation** | **Marking & Ablation** | **CIM-Laser Special Session** |
| 14:45 | Refreshments | | |
| 15:15 | **Drilling** | **Additive Manufacturing** | **Microfabrication** |
| 16:45 | **CLOSE of ILAS 2019** | | |

THE SYMPOSIUM DINNER: WEDNESDAY 20TH MARCH, 19:30 IN THE LONG ROOM

Detailed programme overleaf

# WEDNESDAY 20TH MARCH PROGRAMME

**Plenary 1 09:15 - 09:45 Joining of Dissimilar Materials for Lightweight Construction in Automotive, Aerospace and Shipbuilding — Stefan Kaierle, Laser Zentrum Hannover, Germany**

**Plenary 2 09:45 - 10.15 The Latest Actions of Technology Research Association for Future Additive Manufacturing (TRAFAM) — Hideki Kyogoku, Kindai University, Japan**

## WELDING 10:45 - 12:15

**RADICLE – Development of Adaptive Closed Loop Control of Laser Welding**
***Grafton-Reed, C. Rolls Royce***

High Power Fibre Laser Welding of Aerospace Alloys with and without the Filler Material
*Naeem, M. Prima Power Laserdyne*

In-bore robotic laser cutting and welding tools for nuclear fusion reactors
*Kirk, S. UKAEA*

Development of advanced seam tracking laser welding system
*Allen, C. TWI*

Variations of Remote laser welding of hang-on-parts
*Müller, A. II-VI Highyag*

## ADDITIVE MANUFACTURING 10:45 - 12:15

Problems with In-Space Additive Manufacturing
*Smith, P. University of Nottingham*

Innovation in wedge wire filter designs using Additive Manufacturing (AM)
*Geekie, L. Croft AM*

**Feature based Monitoring of Process Events in Laser-based Powder Bed Fusion**
***Thombansen, U. Fraunhofer ILT***

3D printing of metal-glass hybrid material objects using modified SLM with dual frequency ultrasonic selective powder delivery
*Zhang, X. University of Manchester*

The role of dendrite growth and cooling rates in the densification mechanism of L-PBF of AlSi10Mg alloy
*Zavala, M. TWI*

## SURFACE ENGINEERING 10:45 - 12:15

Laser Shock Peening evaluations of Ti-6Al-7Nb alloy: residual stress, microhardness, and microstructure
*Shen, X. Coventry University*

Impact of laser and external post procesing parameters in the anti-wetting transition of nanosecond laser generated textures
*Godoy-Vilar, J. MTC*

Effect of process and material disturbances on the response of biomaterial surfaces functionalized via laser surface texturing
*Batal, A. University of Birmingham*

Toughening advanced ceramics with Laser Shock Peening
*Shukla, P. Coventry University*

**Transition of Laser Patterned Ultrahydrophilic Surface to Ultrahydrophobic by Vacuum Process**
***Brajer, J. HiLase***

## WELDING 13:45 - 15:00

**Laser Welding: A Guiding Hand from Concept to Production**
***Silva, J. Carrs Welding***

High Brightness Fiber Lasers for E-Mobility Applications
*Reinermann, N. IPG Laser GmbH*

High power diode lasers from NIR to blue wavelength for advanced material processing
*Britten, S. Laserline GmbH*

BrightLine Weld – trend and improvements in laser welding applications
*Collmer, S. TRUMPF*

## ADDITIVE MANUFACTURING 13:45 - 15:00

Satalliting of WC-Co composite powder for Additive Manufacturing
*Al-Thamir, M. University of Nottingham*

The effects of laser beam characteristics in linear energy deposition mechanisms ... within SLM
*Rowbottom, M. TWI*

Anti-counterfeiting 3D printed parts via multiple material selective laser melting
*Wei, C. University of Manchester*

Laser polishing of additively manufactured Ti6Al4V parts and subsequent stress relieving
*McDonald, M. Heriot-Watt University*

Performance of additively manufactured Nickel Superalloys and Ti6Al4V on Renishaw's multi-laser AM systems
*Aswathanarayanaswamy, R. Renishaw*

## MICROFABRICATION 13:45 - 15:00

The use of sub-picosecond laser processing for producing surface structures/textures on diamond-like carbon coated replication masters
*Michalek, A. University of Birmingham*

Micro-machining with high-frequency bursts of ultra-short pulse lasers
*Barkauskas, M. Light Conversion*

**High throughput and high quality surface processing with ultrafast lasers**
***Neuenschwander, B Bern University of Applied Sciences***

A top-down strategy of synthesizing FePt, Fe3Pt alloy and Pt nanoparticles with controllable phase, structure and size...
*Peng, Y. University of Manchester*

## CUTTING 15:30 - 17:00

**Choosing the right resonator**
***Lo Guzzo, G. Mazak***

Highly flexible laser processing of single batch tubes for e-cars
*Draegar, A. Jenoptik*

Development of underwater laser cutting technology for offshore decommissioning applications
*Khan, A. TWI*

Optimisation of Sheet metal cutting with a high power, variable mode fibre laser
*Harrison, P. SPI Lasers*

Water-jet guided laser machining of metal matrix composites
*Marimuthu, S. MTC*

## DIAGNOSTICS & MEASUREMENT 15:30 - 17:00

Beam Analysis in the scan-field of powder bed laser additive manufacturing systems
*Maerten, O. PRIMES GmbH*

Analysing laser machined YBCO micro bridges using Raman spectroscopy and transport measurements
*Lange, K. University of Cambridge*

**Diagnostics and sensing for laser based additive manufacturing: Lessons learnt from laser micromachining and welding**
***Demir, AG. Polytechnic of Milan***

Measures and tools for quality assurance in metal AM throughout the entire manufacturing process
*Koegl, B. AMCM*

TBC

## MICROFABRICATION 15:30 - 17:00

Bandgap control of doped graphene by laser direct writing on PET polymer substrate from PBI ink
*Hunag, Y. University of Manchester*

Towards industrial implementation of laser surface texturing as a tool for enhancing wear resistance and friction reduction on sliding surfaces
*Arnaldo, D. Oxford Lasers*

Effect of laser micro texturing on the performance of a polycrystalline boron nitride cutting tool for hard-part turning
*Pacella, M. Loughborough University*

Laser Direct Grain Writing
*Gortat, D. University of Cambridge*

A study on laser generated periodic textures on tungsten carbide cutting tool surfaces for the reduction of frictional forces
*Butler-Smith, P. MTC*

TBC

Keynote speakers in bold

# THURSDAY 21ST MARCH PROGRAMME

**Plenary 1 09:00 - 09:30 Scalable Laser Synthesis of Colloidal Nanoparticles and their Application in Catalysis and Biomedicin Stephan Barcikowski, University of Duisburg-Essen, Germany**

**Plenary 2 09:30 - 10.00 5 years of CIM-Laser: industrial impact, UK strategy development and new research directions Duncan Hand, Heriot-Watt University, UK**

## CLEANING 10:30 - 12:00

Laser applications for efficient production in automotive Body in white and structure assemblies
*Gusenko, A. IPG Lasers*

Laser cleaning applications using the worlds smallest portable laser cleaning system
*Sexton, L. LaserAge*

**Fibre vs YAG laser cleaning, a comparison based on cost and quality**
***Metsios, I. Andritz Powerlase***

Corrosion studies of laser-cleaned and laser-marked metallic alloys
*Liu, Z. University of Manchester*

High power industrial laser cleaning studies and applications
*Jin, Y. ALT*

## SOURCES & BEAM DELIVERY 10:30 - 12:00

**The importance of laser beam intensity profile and shape in the optimisation of laser processing**
***Croxford, N Debe Lasers***

More power to the people' with a 60W Intracavity UV ns Laser
*Kilmer, J. Photonics Industries*

High-power femtosecond lasers for higher throughput and advanced processing
*Wolters, X. Amplitude*

Hollow-core anti-resonant fibres for transmission of high peak power laser light: impact of coupling misalignment
*Siwicki, B. Heriot-Watt University*

Modulase: A re-configurable laser processing system for welding, cutting and cladding
*Mortello, M. TWI*

## CIM LASER 10:30 - 12:00

Laser powder bed fusion in sub-atmospheric and high-pressure atmospheres
*Moore, A. Heriot-Watt University*

Ultrashort laser welding of optical-structural materials
*Carter, R. Heriot-Watt University*

Direct laser writing of anti-counterfeiting holographic structures on metal products
*Wlodarczyk, K. Heriot-Watt University*

Application of high-speed holographic imaging in laser-matter interactions
*Pangovski, K. University of Cambridge*

Next-generation Industrial Laser Technologies
*Esser, D. Heriot-Watt University*

Selection of welding parameters in pulsed wave micro seam welding
*Coroado, J. Cranfield University*

## SYSTEMS & AUTOMATION 13:30 - 14:45

**Modern Coordinated Control in Laser Systems, The Expanding Dominion of Motion Control Systems**
***Land, W. Aerotech***

Fully automated laser welding process in industrial seating component manufacturing by means of OCT...
*Demirbas, T. Precitec*

Laser Processing using Machine Learning for Real-Time Monitoring and Control
*Xie, Y University of Southampton*

Piezo based beam shaping for high dynamic laser material processing in 3D – PISTOL
*Nair, LD PI*

## MARKING & ABLATION 13:30 - 14:45

Galvanometer Scanning Technology and 9.3µm CO2 Lasers for On-The-Fly Converting Applications
*Hemmerich, M. Synrad*

High Average Power Pulsed Fibre Lasers for High-Quality Engraving
*Dondieu, S. Heriot-Watt University*

**Femtosecond laser applications and benefits for Surface texturing and micromachining applications**
***Wadkin, G. GF Machining***

Nanosecond laser ablation of woods: An insight to the ablation characteristics of woods
*Nath, S. Coventry University*

## CIM LASER 13:30 - 14:45

Multi-laser powder-bed fusion
*Wong, H. University of Liverpool*

Laser Powder Bed Fusion of Refractory Metals
*Sidambe, A. University of Liverpool*

Laser shock peening without absorbent coating and its impact on materials properties
*Rajamdili, K. Cranfield University*

Wire + laser additive manufacture
*Suder, W. Cranfield University*

Laser based polishing of cobalt chrome and titanium alloy additively manufacture parts
*Gora, W. Heriot-Watt University*

## DRILLING 15:15 - 16:45

Laser Drilling of Thermal Barrier Coated Nickel Alloy
*Marimuthu, S. MTC*

Influence of a Dielectric Surface on Laser Drilling Micro-holes in Single Crystal Germanium ...
*Maclean, J. University of Nottingham*

The morphological effect of top-hat beam shape on laser drilling of micron-scale high aspect ratio holes...
*Nasrollahi, V. University of Birmingham*

Tailored beam ultrafast laser drilling of crack-free blind holes in Al2O3 with vertical walls and flat bottom without recast..
*Li, Z. University of Manchester*

**High-Performance Cutting and Drilling with the 400W Laser MicroJet Technology**
***Richerzhagen, E. B. Synova SA***

## ADDITIVE MANUFACTURING 15:15 - 16:45

Large Scale Laser Additive Manufacture Processes, overview of the systems and future market impact.
Tosi, R. MTC

Porosity control of in-situ forming tungsten carbide in laser additive manufacturing
Sevcenko, P. University of Hertfordshire

**Open Architecture Additive Manufacturing - The OAAM Project**
***Hauser, C. TWI***

Desired Microstructures for Metallic AM Components
*Fearon, E. ALT*

Fire and Explosion Risks when Fibre laser processing Aluminium and Titanium BOFA
*Horsey, J. BOFA*

## MICROFABRICATION 15:15 - 16:45

**High-rate ultrashort pulse laser processing for advanced micro fabrication**
***Schille, J Laserinstitut Hochschule Mittweida***

Fibre Laser Processing for Fabrication of Perovskite and Dye-Sensitized Solar Cells
*Chen, Q. University of Manchester*

Scribing and cutting of silicon and alumina ceramics using fibre lasers
*Walsh, N. SPI Lasers*

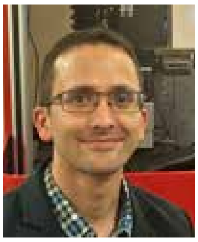
Application of laser surface texturing in enhancing the performance of additives in engine oils
*Khaemba, D. MTC*

Laser surface texturing with thermal post processing for the modification of wettability properties of titanium alloy
*Rico-Sierra, D. University of Liverpool*

Keynote speakers in bold

# EARLY CAREER RESEARCHERS

## SPOTLIGHT ON ECRs



*Name:* Jean-Michel Romano

*Nationality:* French-Italian

*Academic history:*

I completed my Masters study in Mechanical Engineering at Arts et Métiers ParisTech (ENSAM), France. I gained further experience in laser microprocessing at the Karlsruhe Institute of Technology (KIT), Germany and obtained a Dipl.-Ing. in Manufacturing Engineering at the Technical University of Dresden (TUD), Germany in 2013.

I launched my industrial career at Total S.A., working for 2 years on the corporate R&D strategy and its international development, especially in Germany. Since 2016, I have started working at the School of Engineering at the University of Birmingham as a research associate. I joined AILU's Early Career Researchers committee in October 2017.

I am currently involved as a Marie Curie Early Stage Researcher (ESR) in the H2020 European Innovative Training Network (ITN) LASER4FUN ("Short Pulsed LASER Micro/Nanostructuring of Surfaces FOR Improved FUNctional Applications", see www.laser4fun.eu). My research focuses on the mass-scale production of easy-to-clean and non-fouling surfaces. In my PhD study, I am developing a laser-based process chain that involves surface engineering, laser texturing and replication via plastic injection moulding. In particular, using femtosecond pulsed lasers, I fabricate novel bio-inspired submicron topographies and characterise their wetting properties on metals and polymer replicas.

*Hobbies:* I enjoy climbing, running and music. I also have interests in intercultural relations and French-German and European politics.

*Name:* David Rico-Sierra

*Nationality:* Mexican

*Academic History:*

I completed my Bachelor's degree in Mechatronics Engineering at the Monterrey Institute of Technology and Higher Education, Mexico. I received an academic scholarship from Mexico to study for a Masters degree in Product Design and Management at the University of Liverpool working in the design of a modular payload system for drones. During my PhD I was awarded a Certificate of Excellence from the University of Liverpool for academic performance and receipt of a merit scholarship.

During my PhD I've been working closely in collaboration with other PhD students in the departments of Materials and Additive Manufacturing observing the broad applications of laser processes for the improvement of materials.

I joined the ECR committee with the intention of sharing experiences and knowledge through the extensive network of contacts provided by AILU. Through these connections, we have been able to contribute to the content of the magazine and expand our horizons for the development of laser research through the universities in the UK. I look forward to contributing to the further development of the committee and the sharing of research knowledge for the industry.

*Hobbies*: I enjoy learning through history and science documentaries, reading and cycling. I love travelling and discovering regional culture.

## AILU PHOTO COMPETITION WINNER ROUND 4 (ISSUE 91)

**CONGRATULATIONS** to Dean Cameron, Marketing Executive at SPI Lasers, for winning Round 4 of the photo competition. Dean says:

"It's amazing what you can do with a fibre laser enhanced additive manufacturing machine! This is the top of our latest show piece; Queen Elizabeth Tower (Big Ben) – to be launched at the LWoP Shanghai show, showcasing the versatility of fibre lasers."

**THANK YOU** very much to everyone that submitted images to the competition. It has been a pleasure looking through them. The overall winner, and recipient of the £25 Amazon voucher, will be announced in the Spring issue of the magazine (May 2019).

## NEWCOMERS WELCOME!

If you would like to find out more about the ECR Committee, please contact the Chair, Prveen Bidare (Prveen.Bidare@the-mtc.org). Take a look at Prveen's research on pages 28 and 29. Below is a list of current members.

| Name | Affiliation |
|---|---|
| Xiaojun Shen | Coventry University |
| Subhasisa Nath | Coventry University |
| Armando Caballero | Cranfield University |
| Gonçalo Pardal | Cranfield University |
| Prveen Bidare | MTC (Chair) |
| Ioannis Bitharas | Heriot-Watt University |
| Michael Reilly | Heriot-Watt University |
| Nathaniel Marsh | Laser Trader |
| Saskia Childe | Thinklaser (Secretary) |
| Miguel Zavala | TWI |
| Jean-Michel Romano | University of Birmingham |
| Krste Pangovski | University of Cambridge |
| Yang Jiao | University of Cardiff |
| Arina Mohammed | University of Hull |
| Anton Serkov | University of Hull |
| David Rico Sierra | University of Liverpool |
| Chao Wei | University of Manchester |
| Nesma Aboulkhair | University of Nottingham |
| Marco Simonelli | University of Nottingham |

mtc
Manufacturing Technology Centre

With over 30 experienced engineers and technicians and state-of-the-art facilities, the Laser Material Processing group at the MTC aims at increasing the uptake of lasers within the high-value manufacturing sectors by addressing some of the key barriers to adoption. The group's research covers various laser technologies and applications from welding to cladding, polishing, cleaning, texturing, hardening, machining and micro-machining. This is supported by a wide range of laser sources (low to high (up to 20kW) power, fs to ms pulse duration and UV to IR wavelength).

The main focus of the group is resolving industrial challenges and delivering digitally enabled system solutions primarily at Technology Readiness Level (TRL) 4-7. The following sections provide a brief overview of some of the key project areas/research activities being undertaken within the business.

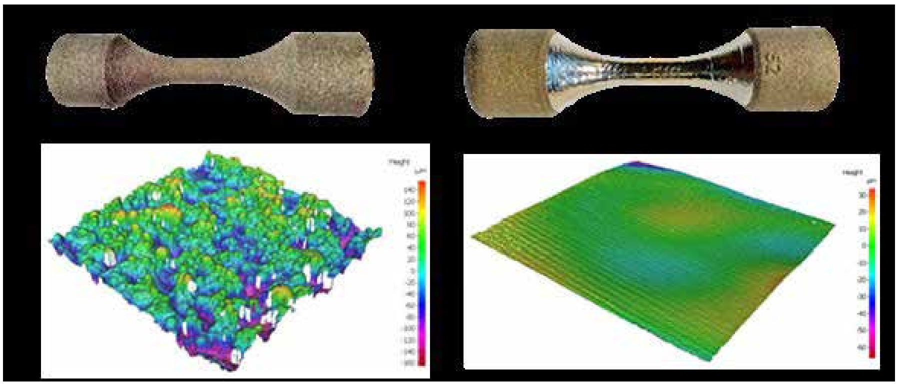
**Contact: Mohammad Antar**
*Mohammad.Antar@the-mtc.org*
*www.the-mtc.org*

## LASER WELDING

Using a range of cutting edge laser welding facilities, with laser sources up to 20 kW in average power, the MTC works with clients to develop laser welding processes, resulting in automated, consistent processes that eliminate reliance on tacit knowledge. The overall aim is to produce production-ready solutions for industrial-scale components whilst minimising or, where possible, eliminating the need for post weld processing and significantly reducing part distortion.

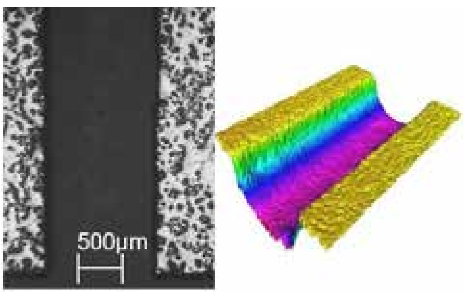
## LASER POLISHING

Despite the many advantages of Additive Manufacturing (AM), poor surface finish is still a major barrier to adoption, particularly in demanding applications. Laser polishing (re-melting) has been proven to significantly improve the surface finish of AM parts by up to 96%, often resulting in mirror-like surfaces. A key issue though is the scalability of the technology, a challenge which the MTC is addressing through the development of an advanced robotic cell supported by a 500 W CW N-IR fibre laser, in-process inspection, simulation tools and a digital infrastructure for right-first-time KPV identification (therefore, minimum or no rework). This project demonstrates the feasibility of automated surface finishing (laser polishing) of various components' sizes and geometries. In addition, a laser shock peening unit (N-IR Nd:YAG pulsed system, with a maximum pulse energy of 2J) has been integrated into the system with the aim of improving the mechanical properties/ fatigue performance of the treated components. Automated operation of ablative and tamping layer fluids is controlled by robot signals, and may significantly reduce overall process times by removing steps such as manual application of black tape to the component.



## LASER MACHINING

Advanced materials like ceramic matrix composites (CMC) and metal matrix composites (MMC) have a huge potential in the aerospace and automotive industries. However, conventional machining of these materials, including conventional laser processing, is challenging due to their highly abrasive and anisotropic nature. Recently, the MTC investigated various technologies for drilling and cutting of MMCs including water-jet guided nanosecond laser (WGL) processing. WGL drilling and cutting of MMCs is predominantly based on cold ablation, leaving no residual heat or melt layer with the cut surface. The cut surface seems to have a finish and metallurgy similar to electrical discharge machining, but at higher speed. These results should help to accelerate the exploitation of the advanced materials like MMCs and CMCs in high value manufacturing.




## LASER TEXTURING

Laser surface texturing is one of the most promising surface engineering techniques thanks to its excellent repeatability, and ability to achieve small feature size, and the possibility of achieving high quality finishing. Through a number of large-scale, multi-national development programmes, the MTC is pushing the boundaries of this area with the aim of advancing the technology from the current 'trial and error', lab-scale concept into a highly predictable, data driven industrial approach by developing a digitally enabled knowledge management platform with a comprehensive database of process parameters and functionalities. This will enable the end-users to successfully employ this process with semi-skilled operators without the need for surface engineering experts and will, therefore, maximise the industrial uptake for the technology.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## REAPING THE REWARDS OF TUBE LASER CUTTING

Mark Hutchinson of Hutchinson Engineering writes:

It is clear the current skills shortage isn't simply an issue in Northern Ireland. However, in the face of adversity there is always opportunity. We are finding more and more of our clients now ready to discuss automation as a solution to the skills shortage.

When we saw the business opportunity of the tube laser it wasn't solely the flexibility of this technology, but its potential to differentiate Hutchinson Engineering from our competitors. The new design possibilities that the tube laser can enable give us a clear competitive advantage.

Five reasons to reap the rewards of laser tube:

**1. Quality:** When cutting tube by hand it is often the case that there are differences from part to part as the operator may use slightly different methods each time. However, the laser will only use the settings that are programmed into the machine so there is less scope for deviation in dimensions from part to part. Repeatability is vitally important in today's manufacturing environment as the increase in lean manufacturing techniques mean that each component part has to be identical to the next. Laser cut components fit right first time and every time.

**2. Speed:** Lasers cut at multiple metres per second and can cut box section, pipe and channel faster than manual methods. This means that purchasers of parts processed on a tube laser can get their parts in a shorter time frame, reducing the amount of cash they have to keep tied up in stock.

**3. Versatility:** The flexibility of laser profiling parts on a tube laser gives far more options for designers, especially in the architectural and construction sectors. Complex designs can be cut into the materials which are not possible by traditional cutting methods. The tube laser can help products reach the market faster than before, because laser technology allows prototypes, product re-designs and specials to be completed with relative ease in a few weeks rather than months. In essence its rapid set-up and change-over capability is ideally suited to small batch work, while a large-capacity bundle loader and automated tube handling cater for long production runs.

**4. High Volume Manufacturing:** The standard supply of box section material is >6 m lengths, and managing these lengths in traditional factories was cumbersome. However, modern tube lasers allow for the loading of material in a single setup. This reduces the amount of time spent handling material thus aiding high volume manufacturing.

**5. Automation saves time and money:** The obvious advantage is reduced costs - operational costs can be driven down by using tube laser cutting technology, which reduces labour, simplifies processing and improves quality. One client managed cost reductions of

50%. Costs can be driven down as components can be completely processed on the same machine, with the same tool, in a single set-up and on a continuous automatic basis. There can also be a reduced stock and work in progress level due to the speed of the machine. Finally reductions in downstream assembly costs due to the ability to hold tighter fabrication tolerances resulting in better fit up, easier assembly, and simpler assembly fixturing.

Laser tube cutting technology, coupled with fabrication and flatbed laser cutting, will help us at Hutchinson Engineering remain globally competitive as it is a highly effective way allow UK and Irish manufacturing to remain competitive on a global stage.

**Contact: Mark Hutchinson**
*mark@hutchinson-engineering.co.uk*
*www.hutchinson-engineering.co.uk*

## DUMB PARTS IN A SMART FACTORY?

Florian Kanal, Product Manager Micro & Marking Lasers at TRUMPF GmbH writes:

The goal of a smart factory is to get machines acting and reacting in harmony with the wealth of information flowing through the manufacturing environment. To achieve this, the machines need to be equipped with hardware and software interfaces, automated workflows and sensor systems. This may be challenging, but it is perfectly feasible. Nevertheless, things get trickier when you bring workpieces into the equation, because how do they communicate with the machines? How do they provide information saying: "I'm Workpiece X. Please process me using Program Y!"

The first reflex is to say: "Let's give the workpiece a tiny brain in the form of an RFID chip that transmits and receives information." But that presents all kinds of problems. RFID chips are foreign objects that you somehow have to mount on the workpiece. They might fall off, and they're not robust enough to cope with all sorts of standard production processes such as annealing, hardening, burnishing and acid baths.

A better, more practical idea is to give the workpieces their very own laser-marked Data Matrix code right from the outset. That means the workpieces can leave all the thinking to the smart factory around them. By scanning the code, the machines get exactly the information they need to execute their part of the process.

Once a machine has finished with the workpiece, a marking laser applies a new code and the process continues. Any conceivable information can be accommodated in the space of just a few square millimetres - from the operations completed so far to traceability details, order numbers and quality control aspects. All the information is durably and permanently marked on the surface. Plus, if you are working in a laser machining environment, then 2D cutting machines can apply the marking themselves. In all other environments, you can simply use a marking laser.

**Contact: Gerry Jones**
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*www.trumpf.com*

# LASER RESEARCH ASSISTS IN MANAGING STRESSES

## AN INTERVIEW WITH PRATIK SHUKLA

SENIOR LECTURER, MANUFACTURING ENGINEERING, COVENTRY UNIVERSITY

### Q. Can you tell us about Coventry University?

I returned to Coventry University in 2017, having been an undergraduate and a postgraduate here over a decade ago. Coventry University has a long tradition of education (under different names) dating back to the Coventry College of Design which opened in 1843.

In the 1970s the institution became Lanchester Polytechnic, taking its name from Dr Frederick Lanchester, a famous automotive and aeronautical engineer who built cars in Coventry in the 1920s and 30s. In 1987, the name was changed to Coventry Polytechnic and then in 1992 it became Coventry University under UK Government legislation.

The logo of the university is the phoenix – a mythical bird with splendid plumage which is fabled to have lived in the Arabian Desert for five or six centuries and then burnt itself to death on a funeral pyre of aromatic twigs, ignited by the sun and fanned by its own wings. The phoenix rose from the ashes with renewed youth to live through another cycle.

This resonates with the city of Coventry, which rose from the ashes of heavy bombardment during the Second World War; the phoenix is a reminder of the city's resilience. Coventry University has adopted this symbol and takes pride in being associated with it.

## Q. How has Coventry University coped with the huge expansion over the past decade?

Overall, Coventry now has around 32,000 students and is the fastest growing university in the UK. As an undergraduate in 2001, I was one of just 25 students in Mechanical Engineering. Now we have 280 first years in the department. Since 2010, there has been a strategic increase in the student intake, particularly in engineering. In 2012, a new Engineering and Computing Building (ECB) was opened which was able to cope with the greater numbers and support the new investment in equipment and machinery. Now a second building (ECB-2) is under construction at a cost of £29 m, featuring a range of state-of-the-art facilities such as a gaming and virtual reality studio, rapid prototyping and 3-D printing, a laser facility and more.

> *We need more development in sources and beam delivery for LSP.*

## Q. How is the UK university sector, and Coventry in particular, coping with current uncertainty in the UK?

For a few decades the EU has provided a collaborative framework in which British universities have grown and thrived. With the onset of Brexit, both the funds coming in and the student intake from Europe could be reduced. This may put many universities in a state of financial melt-down, whilst the stronger institutions will be able to find a solution in due course. I believe all universities will suffer from this - for example, partnering with UK university will become less favourable in comparison with an EU university. Hopefully, we can limit the damage from Brexit – which is the way forward for everyone in my opinion.

## Q. What are the main areas of laser processing research at Coventry?

We have greatly benefitted from a £700 K investment in laser-based facilities and analytical equipment. We have a range of lasers from high and low power continuous wave $CO_2$s, through to low, high and ultra-high energy Nd:YAGs in multi-wavelength, ns pulse regime, all the way to a large disc laser system and a new picosecond laser. Our major focus is on surface engineering applications, to enhance the functional properties of materials, with the most significant areas being Laser Shock Peening (LSP) and wettability. We conduct LSP on metals and other difficult-to-peen materials such as ceramics and composites, and then undertake detailed analysis to understand the laser-material interaction. We also study surface treatment of a wide range of materials for biomedical applications and other areas. In addition, we have a range of metal 3-D printing technologies and we are interested combining these with surface engineering for cleaning and peening applications. This capability builds on our stress analysis expertise and we are working closely with aerospace partners. Other areas we are working on include: cutting of polymers for automotive recycling; laser joining of polymer-based materials for food processing and other sectors; and improving the efficiency of laser based processes in general as well as laser beam characterisation.

## Q. What are the future prospects for Laser Shock Peening?

The application of LSP is growing, but the total installed base of systems is quite small as there are only a few suppliers and the laser system price is very high. We need more development in the sources and beam delivery to reduce the overall cost – in the same way as has happened in laser marking for example. When the price comes down, the number of industries using LSP will increase. We are working on technology to make the process more efficient with lower power sources – this is one step which should help the economic case to improve significantly.

## Q. What are the biggest challenges you face?

With new facilities being built in ECB-2 and the Institution of Advanced Manufacturing Engineering (AME-2), the future plans for our equipment and infrastructure look very secure, since new buildings are under construction with both lasers and characterisation equipment already purchased. The task for us now is to manage this, in order to establish a world-class laser processing facility. It is also challenging to be able to successfully recruit staff of the right training, experience and mind-set to carry out the work we are planning to do.

> *The Laser User magazine enhances the impact of our research.*

## Q. What benefits has AILU membership given you?

As AILU members we have access to events which help us to keep up to-date with the latest in product and applications developments, as well as having access to the expertise of members. The Early Careers Researchers group is a useful recent networking initiative and Xioajun Shen, one of our PhD researchers is an active member of this group. We also find that The Laser User magazine enhances the impact of our research as it reaches the laser-based community more rapidly than journal papers. The format of the magazine articles is easy to read and directly becomes available to the right people in the laser community.

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*www.pratikshukla.com*

# ANNUAL MEETING: WORKING ON YOUR BUSINESS

Fifty-five delegates attended the annual Job Shop Business Meeting 2018 on 22 November which was generously hosted by Bystronic UK at their offices just outside Coventry. The theme of the day was "Work ON your business, not IN your business" and the main focus was on reducing business costs and increasing profits.

The day started with an introduction from Mark Millar (Chair of the Job Shop Group) and a welcome from Dan Thombs who recently took over from Dave Larcombe as MD at Bystronic. This was followed by three presenters who focused on saving energy, saving money on energy utilities and outsourcing HR.

After a coffee break, we had presentations from AILU Members telling us what's new. Bystronic, TRUMPF, Mazak and Amada gave details of new system solutions and then new members Steel Scout outlined their online steel sourcing service and TLM outlined their fixture-free marking solution using image recognition to improve productivity.

During the day, delegates were encouraged to fill in a "live" business confidence survey which asked questions about expectations for the next 12 months in terms of revenue growth, recruitment and the general environment of taxation and immigration policy. Many people mentioned Brexit as the largest single element of uncertainty, which is affecting decision making in the supply chain. Another issue raised by many was that of CE marking of structural steel or aluminium, this being a challenge to tackle in the near term.

During lunchtime and refreshment breaks, delegates were able to view the University of Wolverhampton Racing F3 car, which is sponsored by Laser Process. The car was present to view and some of the team including driver Shane Kelly were on hand to give some background to the University and the motor-racing experience available there.

After lunch, Dave MacLellan outlined the results of the AILU Breakdown Response Survey where TRUMPF and Bystronic customers gave feedback on the service received when systems break down. John Powell then encouraged people to take part in the gas survey, which analyses participants' processing gas costs to compare prices – in the past, this has led to substantial savings.

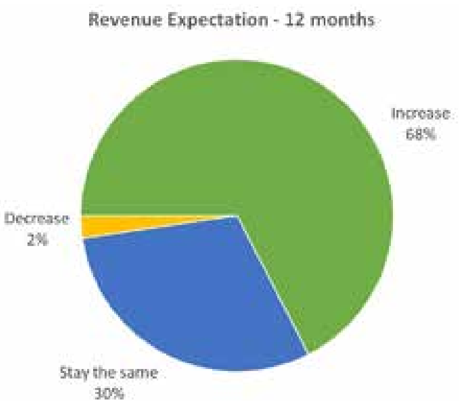
The open forum on the topic of "working ON your business, not IN your business" provided some lively discussion on a wide range of topics. After the discussion, Bystronic gave a tour of their showroom with a number of laser cutting systems and press brakes on show.

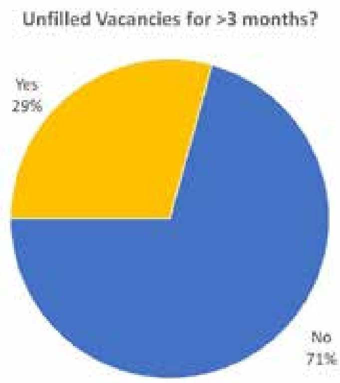
*Courtesy Laser Process*

## BUSINESS CONFIDENCE SURVEY 2019

With the prospect of Brexit looming large and the opportunity to get some live feedback and "take the pulse" of the UK subcontract marketplace, AILU used the Job Shop Annual Business Meeting to conduct a live business confidence survey.

Overall the survey, conducted in November, found people to be optimistic about the year ahead in terms of growth and increasing opportunities. One issue - staff recruitment - continues to be an issue for a significant number of companies. Here are two of the pie charts from the survey (number of participants =48), full details are available from the AILU Office.



CHAIR'S REPORT

# EMERGENCY BREX*T?

Welcome to the first issue of the AILU magazine of 2019! I was lucky enough to see some of you at the AILU meeting on 22nd November, it was a really great meeting - for those that didn't make it, do try to make the next one as information gleaned at this event really pays dividends.

So what's new this year? Well unless you've been living in a cave for the last few years, you'll know the Brexit deadline is rapidly approaching. Yes, I know it's practically a swear word these days and everyone is sick to death of hearing about it, but we are heading to crunch time at the moment. However, despite months of uncertainty, we still don't know for sure what the arrangement is going to be or how it will affect our daily lives.

I have no love for Theresa May but I do feel sorry for her, she is in an impossible situation. Her deal has been rejected by a landslide, but she still won the vote of confidence in her despite having no other ways forward. The problem with Brexit is twofold. Firstly there is no way to make everyone even vaguely happy, no matter what the deal is. Secondly, all of this uncertainly is also bad for the country and the economy. The only way forward at the moment is to try to extend the deadline for leaving, whilst we think of another plan, one that we couldn't come up with in the last 3 years, which just leads to more uncertainty. I feel like someone remade Groundhog Day!

Before the Referendum our economy was one of the strongest in the EU and showed decent growth, this has tailed off since the Referendum. We are currently sitting only just above Italy in the G7, and they have some serious economic issues of their own. No-one knows the true economic cost of leaving the EU but estimates range from £100 billion a year worse off with May's deal to £140bn per year with no deal. Joy! (take these numbers with a pinch of salt though as this estimate comes from a study commissioned by Vote Leave)

According to the Guardian November 2018, Philip Hammond has said that the UK will be worse off "in pure economic terms" under all possible Brexit outcomes – including the Prime Minister's own deal. He goes on to say that this is a prediction and not an analysis, however May's deal is the best way forward in his opinion to get most of the things we are negotiating for.

If we don't extend the leaving date everything is going to have to be rushed through parliament, which also sounds like a bad plan to me. Kind of makes you think, why are we bothering to give more power back to our politicians if they can't agree on anything? Either way it looks like any type of Brexit is going to take our economy a long time just to get back to where we were before the Referendum. The only good news is maybe by 29th March we might have an idea of what is going on? We can only live in hope.

**Mark Millar**

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*www.essexlaser.co.uk*

# HAPPY TO HAVE THE BLUES

## JEAN-MICHEL PELAPRAT ET AL.*

**In 2017, NUBURU® introduced the first industrial blue laser to the market which demonstrated the inherent physical advantages of blue wavelengths for materials processing applications. Copper, for example, absorbs more than ten times more energy from blue than from infrared wavelengths, which leads directly to qualitative and quantitative advantages for tasks such as copper welding. Extending the product line, a higher power blue laser at 450 nm opened up an entirely new range of applications for battery fabrication, e-mobility, electronics packaging, and automotive component manufacturing.**

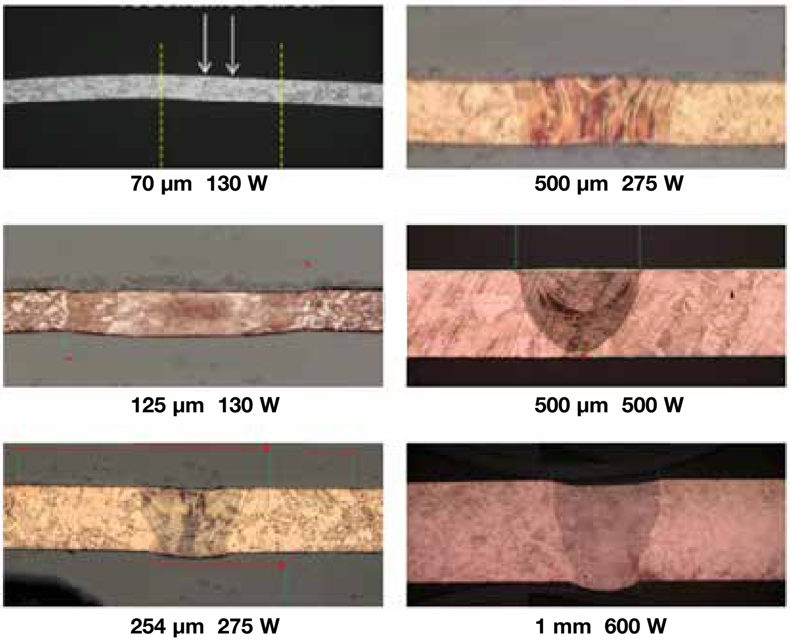


*Figure 1: Blue laser welding has a wide process window — laser parameters can be set and maintained to produce high-quality welding for a wide range of copper thicknesses.*

### Traditional industrial lasers

Traditional industrial lasers emit infrared wavelengths, at ~10.6 µm or ~1 µm. These lasers offer significant materials processing advantages over alternative fabrication tools. Lasers deliver their energy remotely, without the need for physical contact with a tool. This allows for flexible etching, cutting, and joining of many materials. A 12 mm-wide ultrasonic welding head, for example, cannot join two materials with a radius of curvature of 5 mm. Lasers do not have that limitation, nor are they subject to tool wear. Those advantages have led industry to adopt laser systems at a fast rate.

But “yellow metals” — prominently including copper and aluminium — absorb infrared wavelengths very poorly. Copper, for example, absorbs less than 5% at these wavelengths. This is, of course, very inefficient, but it also leads to other specific processing problems.

Consider welding, for example. The poor absorption means a lot of excess energy must be delivered to initiate welding — and it is also delivered to the melt pool. The melt pool, however, absorbs a much higher percentage of the incident radiation. The excess energy pushes the metal into the vaporisation state, with bubbles in the melt pool, leaving voids and “spattering” material from the joint. Various complex irradiation patterns (i.e. wobbling), can minimise — although not eliminate — spatter and voids, but they add to the process time and processing equipment cost. Infrared laser welding of copper, or other similar metals, is inherently limited to a very narrow process window, or in some cases not possible at all.

### The physics and engineering of Blue

Blue wavelengths are absorbed more then ten times more efficiently. In addition, the energy required to maintain a weld is essentially the same as the energy required to initiate a weld. This consistency allows for a high degree of process control, and it directly leads to rapid, high-quality copper welds — completely free of voids and spatter.

The physical advantages of blue wavelengths are no secret, but engineering a high-power blue laser has been a technical challenge. NUBURU’s AO-150 was the first commercially available high-power, direct-emission blue laser, and the AO-500 follows the same design path. The AO® series is built on a straightforward modular design, combining the output of dozens of individual gallium nitride (GaN) diode lasers into a single beam and into a 200 µm-core optical fibre. In the AO-500, micro- and macro-optics combine the individual diode beams into a 400 µm-core optical fibre. The output of the fibre is a highly symmetric 500 W beam of 450 nm light.

Because 500 W is transmitted through a 400 µm fibre, the brightness is high. This is particularly important for materials processing applications, where the effectiveness of a process is determined by the energy density delivered to a workpiece. Even in situations where the output beam is conditioned with relay optics, the optical efficiency is limited by the initial beam parameter product: higher brightness means more effective energy delivery.

The wide process window and laser stability combine to make blue laser welding a highly deterministic process. In practice, that means the blue laser can produce void-free and spatter-free welds in all three different welding modes: conduction, transition, and keyhole modes.

### Results

The theoretical advantages of higher absorption are clear, but how does that translate to real-world conditions?

Results from laboratory tests show spatter- and void-free welds for copper thicknesses from 70 µm to 1 mm. These results, shown in Figure 1, illustrate the process control possible with stable laser output powers from 130 to 600 W. As earlier mentioned, this performance is built on the foundation of fundamental physics: blue laser energy can produce a stable melt pool, well under the vaporisation threshold. High quality joining can be seen in the lap and butt welds shown in Figure 2. These images demonstrate the performance of a 500 W blue laser lap welding two 125 µm copper sheets at a rate of 3.3 m/min, lap welding two 200 µm sheets at 5.4 m/min, and butt welding two 200 µm sheets at 8.1 m/min. Again, there are no voids and no spatter.

# BLUE LASER WELDING

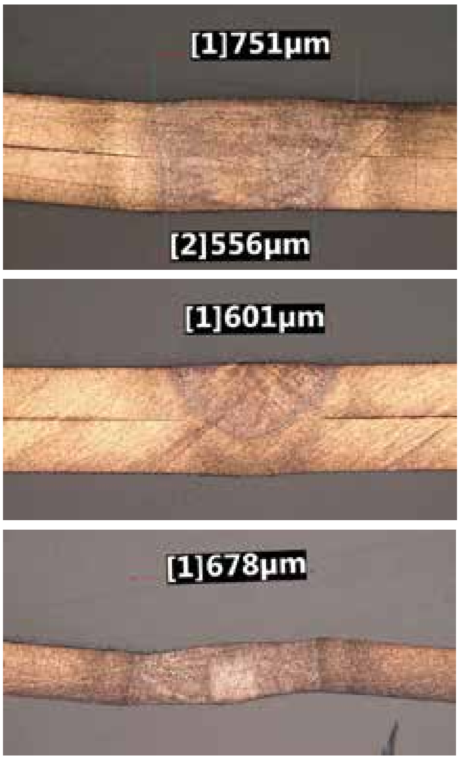


*Figure 2: Lap and butt welds illustrate the joint quality routinely achieved with a 500 W blue laser.*

The quantitative advantages of blue laser welding have also been demonstrated with traditional industry metrics. Even a pre-production version of the AO-500 achieved full penetration depth of 300 μm in copper bead-on-plate (BOP) tests at a speed of 4 meters per minute. That same laser system has demonstrated a penetration depth of greater than 150 μm at 12 m/min for both lap welding and butt welding. In BOP tests of 1 mm-thick copper the laser achieved full penetration at a speed of greater than 1 m/min. Again, these results are for welds that demonstrate no spatter and no voids — unprecedented performance for laser welding.

Although copper is a particularly challenging material for conventional industrial lasers, stainless steel and aluminum also present problems. Aluminum also does not absorb much energy at infrared wavelengths — absorbing more than 3 times more energy in the blue. Although the differences are not quite as dramatic as with copper, the fundamental physics leads to the same qualitative and quantitative advantages with blue laser welding. Laboratory tests with 500 W of blue light in a 400 μm spot, for example, have demonstrated lap welding of stainless steel to a penetration depth of 600 μm at a speed greater than 4 m/min. That same laser has demonstrated aluminum butt welding with a penetration depth of 200 μm at a speed of 10 m/min.

Welding of dissimilar metals is another recalcitrant problem that can be solved with blue laser welding. The different thermomechanical characteristics of aluminum and copper, for example, can lead to the formation of intermetallics — regions with inconsistent ratios of the two metals, leading to poor mechanical and electrical joint characteristics. Because these metals both absorb a high percentage of incident blue light, the welding process is deterministic. As shown in Figure 3, 300 W of blue laser light produces a lap weld of stainless steel on copper that minimises the formation of intermetallics and other defects common with dissimilar metal welds.

**Applications for today and tomorrow**

The AO® series of blue industrial lasers brings the flexibility of laser materials processing to an entirely new range of materials. Copper and aluminum are of growing importance in our increasingly electronic world. The ability to laser weld copper-copper and copper-aluminum joints offers the opportunity to significantly enhance the speed and quality of existing joining methods.

Consider the fabrication of lithium-ion batteries. Lithium-ion batteries consist of many separate foils. Chemistry at the surfaces creates the electrical potential, so the greater the surface area, the more battery capacity. But the individual foils must be joined together. Ultrasonic welding could be used, but physical contact of the ultrasonic welding tool generates unwelcome particles, limits the minimum thickness of the individual foils, and also requires frequent tuning. The blue laser can weld foils as thin as 6 μm, with no spatter. The AO-500 has also already demonstrated impressive reliability. All those advantages add up to a higher quality, more reliable process that produces batteries with higher energy density. That same kind of advantage extends to consumer electronics. The flexibility, speed, and quality of blue laser welding can, for example, bring new levels of automation to cell phone and computer assembly.

Laser processing has long been adopted in automotive manufacturing, where its versatile energy delivery options make it well-suited to automation. But autos themselves are becoming increasingly electronic, with extensive sensors and actuators, and electric or hybrid vehicles, of course, require batteries and motors. Reducing the size and weight of those components is critical for vehicle performance. As discussed above, no other joining method offers the combination of speed, quality, and form factor of blue laser welding. For example, Figure 4 shows the cross section of a hairpin assembly for an electrical motor. Replacing traditional coils with hairpin assemblies can reduce size and weight and improve performance in electric motors, but protruding ends of the copper wirdings need to be joined. The blue laser produces void-free, compact, thermally-focused and rapid joints — something not possible with other joining methods.

*Figure 3: Lap weld of 200 μm-thick copper and stainless steel. This dissimilar materials weld illustrates reduced formation of intermetallics and minimal to no spatter and defects.*

*Figure 4: This hairpin weld of two 1.5 mm x 2 mm copper wires demonstrates the quality and compact size possible with blue laser welding.*

Automotive vehicles are not the only application where the size, weight, and performance of electrical assemblies must be optimised. One can easily see how the advantages of blue laser materials processing could be useful in autonomous vehicle assemblies, renewable energy generators, factory automation machines, and other applications. The power of blue has already been demonstrated, and it is likely to be found in a growing number of applications.

*** Jean-Michel Pelaprat, Matthew Finuf, Robert Fritz, & Mark Zediker, NUBURU**

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SEE OBSERVATIONS P32

# BLUE KILOWATT LASER FOR ADVANCED COPPER PROCESSING

SIMON BRITTEN

**Over the last few decades, Continuous Wave (CW) laser applications have become established as a versatile tool in modern manufacturing, covering a range of processes including welding, cladding, surface treatment, hardening, brazing, cutting and many more. These applications are nowadays dominated by near-infrared (NIR) industrial lasers, predominantly working around the 1 µm wavelength. These lasers are suitable for the processing of steel alloys with over 50 % absorption. With an absorption of < 5 % at 1 µm wavelength, the processing of materials such as copper and gold, is however very difficult. In order to process these highly reflective materials, high laser intensity is used for the creation of a vapour channel in the material, which increases the absorption. However, this approach limits copper processing capabilities to a deep penetration process regime, with the inherent risk of sputter occurrence and the challenging control of energy deposition.**

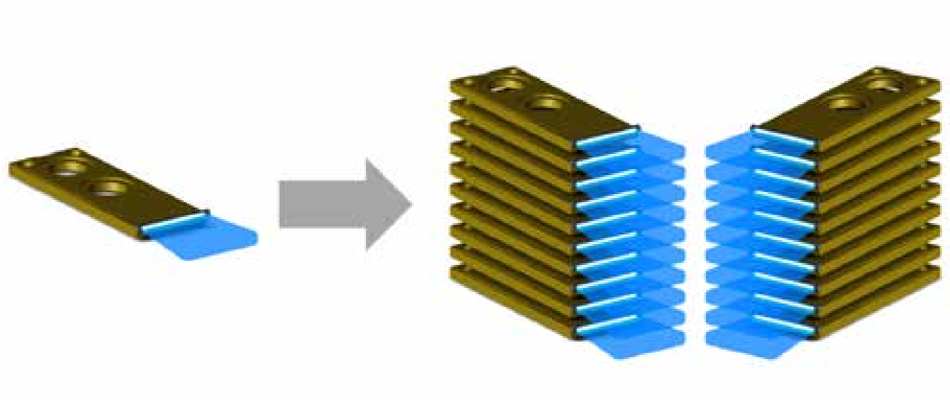

*Figure 1: Concept of power scaling with diode bars for the high power blue diode laser.*

A wavelength below 500 nm is much more suitable for the processing of copper, since the absorption increases strongly to 50%. Some laser sources are already available on the market in this wavelength range, which are based on frequency doubling, resulting in wavelengths of 515 nm and 532 nm of the green spectrum. However, these laser sources rely on a conversion process, in which a crystal is converting only a fraction of the pumped laser wavelength into the target wavelength. The conversion process leads to high power losses, complex cooling requirements and a sophisticated optical set-up.

Today, the solution to the technical challenge of copper processing is addressed with additional urgency, due to the close connection to the social challenge for the reduction of greenhouse gases. The replacement of combustion engines with electric engines creates a vast demand for reliable processing solutions for copper, which is used in emobility, as well as in other renewable energy systems such as wind turbines.

**Blue Laser Diode Technology**

In order to address this challenge, the company Laserline developed a high power diode laser with a blue wavelength of 450 nm in CW mode. In contrast to other laser source concepts, the diode laser based on GaN-material enables the direct emission of 450 nm, without further frequency doubling and therefore with higher energy efficiency. With a wavelength of 450 nm, an increase in the processing efficiency of up to 20x is expected for copper materials, compared to a wavelength around 1 µm.

Based on long-term proven scaling techniques, Laserline uses laser bars to mount, electrically connect and cool the blue laser bars on heat sinks (Figure 1). This is in contrast to the conventional use of single emitters, which are limited to a power of 3-5 W. Each laser bar on its own is actually creating a power level of over 50 Watts. Using special optics it is possible to combine several mounted diode bars in a stack and even combine two stacks in one laser source. By this approach, an unpreceded level of power scaling is possible.

The success of this approach is demonstrated with the presentation of a continuous wave 1000 W high power diode laser with a wavelength of 450 nm and a beam quality of approx. 100 mm*mrad. The laser beam delivery to the work piece is achieved with a 1000 µm fibre and a conventional focusing optic, which is equipped with an adjusted anti reflection coating to the blue wavelength. The new process capabilities

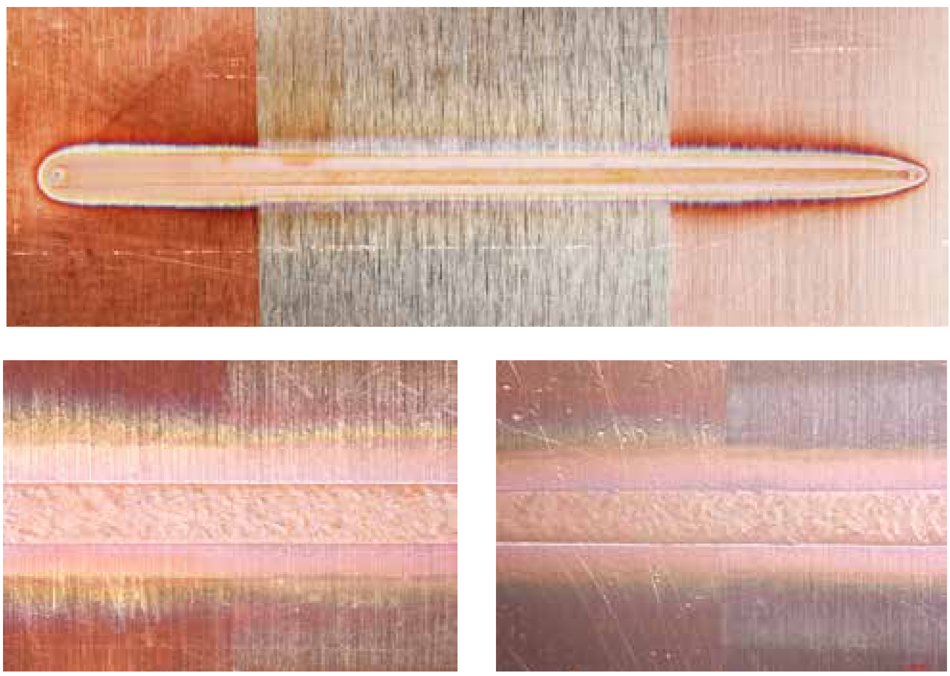

*Figure 2: Welding of a 0.5 mm thick copper sheet prepared with three different surface conditions (etched (top), oxidised (left) and polished (right).*

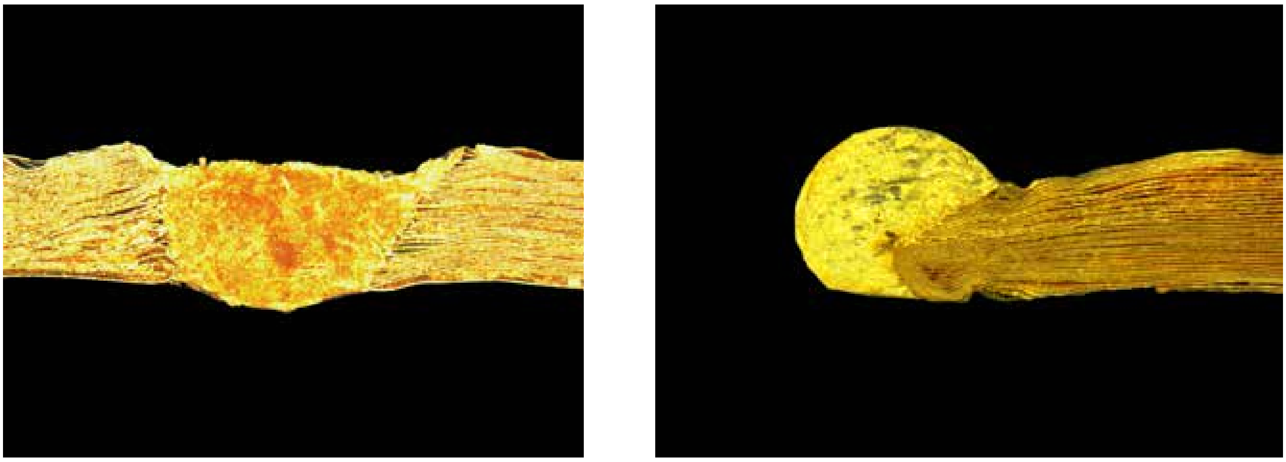

*Figure 3: Welding of 34 stacked copper foils (each 11 µm) in butt welding (left) and edge welding configuration (right).*

with this unprecedented laser power in the blue wavelength range, opens up new applications for metals, especially in copper processing.

The absorption level of nearly 50 % on copper material leads to a reproducible energy deposition, which is in contrast to the 1 µm wavelength, independent of the surface condition of the copper material. A weld over a copper sheet with an etched, oxidised and a polished surface zones generates a highly homogeneous weld bead surface (see Figure 2).

In addition to the welding results on varying surfaces, the high absorption level allows for the first time the capability to weld copper materials in the heat conduction mode. In contrast to the deep penetration welding mode of NIR lasers, the heat conduction mode does not create a vapor capillary and allows the precise adjustment of the melt pool geometry for thin copper materials also. The stable energy deposition of the heat conduction process mode is especially important for applications, where the high pressure of a deep penetration welding mode would lead to the cutting of the material or an undesirable splatter occurrence. This can occur while welding stacked thin copper foils, which may be subject to an uncontrolled gap due to warping of the stacked foils (Figure 3).

While applying a butt welding approach with 580 W laser power and 2 m/min feeding speed on stacked copper foils, a weld bead width of more than 0.8 mm can be created with minimal porosity and low undercut. For a fillet weld approach with an irradiation on the edge of the foil stack, the foil endings are molten over a large cross–sectional area with a complete attachment to the solid foils. In both butt and edge welding the process results in a perfect mechanical joint, as well as creating a very good electrical conductivity.

Furthermore, the availability of 1000 W laser power at 450 nm allows new engineering design approaches, which are based on the high gap bridgeability of the liquid copper melt. In contrast to NIR-laser processes, the liquid copper in the heat conduction mode exhibits a very stable melt pool. The stable melt pool in combination with the surface tension of the liquid copper, closes gaps, which would otherwise be challenging in the processing of corner welds or butt welds. This characteristic opens up new perspectives regarding improved material efficiency, compared to conventional overlap joints.

The LDMblue will be available in different product configurations, ranging in laser power from 300 W up to to 1000 W. Like all modules of the Laserline LDM series, it contains the laser head, cooling, power supply and system electronics, all in a 19” rack mounting enclosure. Based on the development experience of diode lasers in the near infrared wavelength, an outlook to a further increase in power and an improvement of the beam quality is expected. Laserline GmbH is convinced that diode lasers are going to be the leading photonic tool in medium to high power material processing in the near future.

Laserline systems are available in the UK through Laser Lines Ltd, Banbury.

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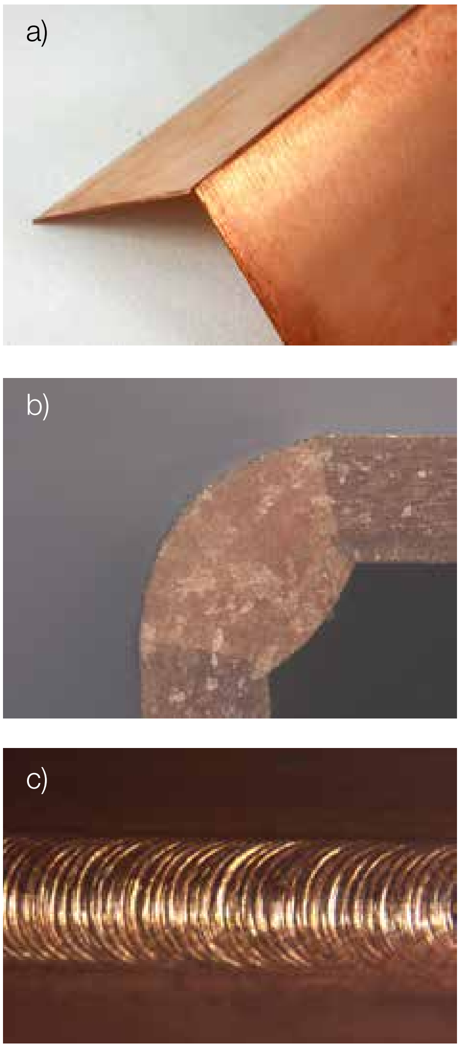


*Figure 4: a) Corner weld of 0.5 mm copper sheets, feeding speed 3m/min, b) cross-section view and (c) close up weld bead.*

**Simon Britten** is Innovation Manager/New Business Development at Laserline GmbH.

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# A MARKET GROWING AT THE SPEED OF LIGHT

## OLIVIA GILLEN

**Ultrafast lasers are emerging from research and development laboratories into the mainstream of manufacturing. They have the potential to transform the processing of a wide range of materials, for industries as varied as medical devices, semiconductors, automotive and consumer electronics. Why are ultrafast lasers so attractive compared with traditional lasers or other techniques, and what are the range of applications that might benefit from this technology?**

**In this article we explore the market potential and explain how we at Blueacre Technology are harnessing the power of the latest generation of ultrafast lasers.**

### What are ultrafast lasers?

Ultrafast lasers emit short pulses of light with durations of picoseconds or femtoseconds. When used in materials processing they provide high levels of precision and repeatability. They can mark or cut the very finest of features, down to the micron level. They perform effectively across a range of materials - plastics, ceramics, glass, silicon, metals and even diamonds.

Crucially, ultrashort pulses of laser energy limit the amount of heat input to the surrounding material ensuring ablation only happens in the area where the laser is focused. To benefit from this, it is ideal to have pulses as short as possible, with data showing that 7 picoseconds is a reasonable upper limit.

Being classed as a “cold” process, you could potentially drill a hole through an icecube with a short pulse laser without the ice melting at all!

The flexibility offered by ultrafast lasers, combined with high performance and high precision, signal a bright future for this emerging technology and significant commercial opportunities.

### What are the possible applications?

A recent market research report [1], predicts strong growth for this technology across a range of industries and applications.

Leaving aside for the moment applications such as biomedical, surgical, spectroscopy and imaging, the global market for ultrafast lasers in materials processing alone is predicted by BCC Research to grow by an CAGR (compound annual growth rate) of almost 25% between 2017-2022, to reach nearly $2billion by 2024. This is the projected market for the lasers alone, it does not account for the many upstream and value-added processes carried out using these lasers. This means that the actual market size for materials processing using ultrafast lasers is likely to be many multiples of the projected market size for the lasers alone.

While North America is currently the largest market for ultrafast lasers for materials processing, the other key global markets (Europe and Asia-Pacific) are expected to come close by 2022, with growth in the Asia-Pacific region predicted to achieve a particularly impressive CAGR of 26.5% from 2017-2022.

Ultrafast lasers are expected to perform well across a range of industry sectors as the technology offers a unique combination of flexibility, precision, efficiency and high-performance, all useful for a range of advanced manufacturing processes.

For the medical device industry, ultrafast lasers have the potential to be a truly disruptive technology. They offer the ability to machine and engineer features in materials that could not previously be machined to the same degree of accuracy. This opens up a host of possibilities, not least the opportunity to design and manufacture totally new medical devices in materials that offer significant clinical and commercial benefits.

For example, a new generation of biodegradable stents and implants are coming to the market, made out of bio absorbable polymer tube materials. These bio absorbable polymers are sensitive to heat and melt at temperatures around 200°C. Traditional lasers, or other machining technologies, could damage the device functionality, through the unwanted transferal of residual heat from the machining process to the bulk material. Due to the low heat affected zone, ultrafast lasers enable complex features to be machined precisely with no damage or limitations to device functionality.

In addition, the reliability and robustness of ultrafast laser machining processes offers reassurance in this sector where quality and traceability are key.

In consumer electronics, the new generation of ultrafast lasers offer high precision manufacturing processes that can help address some of the challenges presented by the maturity of some current technologies. The latest display technologies, such as OLED (organic LEDs) and AMOLED (active-matrix OLEDs) make use of heat sensitive polymer and organic materials. This makes them ideal candidates for micromachining which does not involve heat generation.

*Figure 1: Complex shape machined in 3 materials: nylon, polymide, nitinol.*

*Figure 2: A line of 20um holes in Nylon*

Similar market drivers – miniaturisation, high precision, quality, cost-effectiveness and flexibility – are also at play in the automotive industry. Ultrafast lasers offer automotive manufacturers precision and flexibility across a range of applications such as microstructuring of moving parts and machining that enables highly precise control of the pattern and size of nozzles in gas direct injectors.

**How are we using ultrafast lasers?**

At Blueacre Technology we closely follow trends and developments in laser technology. As far back as 2009, in a previous article for the AILU magazine, we predicted that cost would represent the only barrier to a more widespread adoption of ultrafast lasers in medical device micromachining.

As ultrafast laser technology has matured and ultrafast laser costs have come down, we have made a considerable capital and R&D investment in ultrafast laser technology.

As a simple example, moving from a UV-nano second process to a femtosecond process allows us to machine highly repeatable and accurate holes in common materials such as nylon and PEBAX.

Although a UV-nano second laser can drill a hole in nylon, the heat affected zone around the hole imposes a limit to the minimum hole diameter. Tests with UV picosecond lasers at 7ps, give an improved hole, but again there is a residual heat zone and splatter material deposited around the hole entrance. We have found that femtosecond pulses, in the range of 500 fs, are ideal for polymer materials and sub-10 µm holes can be drilled in nylon with a high degree of process repeatability.

As the minimum hole size determines the limits on larger features, we can now machine features in polymers +/-6 µm at high throughput. Achieving tighter tolerances on parts being machined results in higher yield and greater confidence in the laser process from customers. At the end of the day it is confidence that drives growth.

However, in the same way that being a great butcher is not just about having the sharpest knife, so the laser technology on its own does not guarantee superior results. All the other elements of laser processes, such as how parts are presented and handled, inline inspection, machine vision and traceability, need to combine with the technology to meet medical device customers' stringent requirements.

We will carry on exploring the potential of this technology and see some exciting opportunities ahead.

**New opportunities**

The first of these opportunities is using ultra short lasers to transform micromoulding. The demand for micromoulding is growing, driven by trends for ever smaller and more complex parts and components for medical devices and other advanced manufacturing industries. Typical challenges for micromoulding processes are not just the tiny dimensions of the moulded parts, but also tight tolerances, complex geometries and materials that can be difficult to cut.

One application of micromoulding that we are focusing on is the production of microneedle moulds for the emerging trans-dermal drug delivery market. Initially microneedle producers were limited in the materials with which they could produce moulds – typically PDMS/silicone based. R&D labs working on microneedles are currently eager to explore the potential of alternative materials as these may have clinical or other benefits. These include both metals and polyurethane blends.

The key to making any moulds is the ability to create sharp features, and this is particularly critical in microneedle moulds. This is relatively straightforward in polymers where the laser ablation is a physical-chemical process of bond breaking. However, working with metals involves melt-based material removal. Using ultrashort laser pulses to reduce melt has enabled us to create sharp features in metals, and we are producing some encouraging results in this area.

Another new opportunity that ultrashort lasers present is the capability to work with transparent materials. Historically most of our micromachining has been divided between metals, alloys and polymers with linear absorption being the key driver. Ultrashort pulses enable the machining of materials that would normally be transparent to the incident laser wavelength. Therefore, we usually worked with UV lasers ignoring fundamental and green light sources.

Ultrashort pulses enable the use of higher wavelength light in transparent materials. One of the applications we are currently working on is the use of Bessel lenses which rely on constructive/destructive interference to create high aspect ratio beams. These high aspect ratio beams can have sub-micron diameters allowing to produce ever smaller holes. Although this at early stages we believe that this process has industrial scale potential for applications across a range of industries.

The future is bright … the future is femto …

**Reference**

[1] BCC Research LLC (2018) "Ultrafast Lasers: Technologies and Global Markets"

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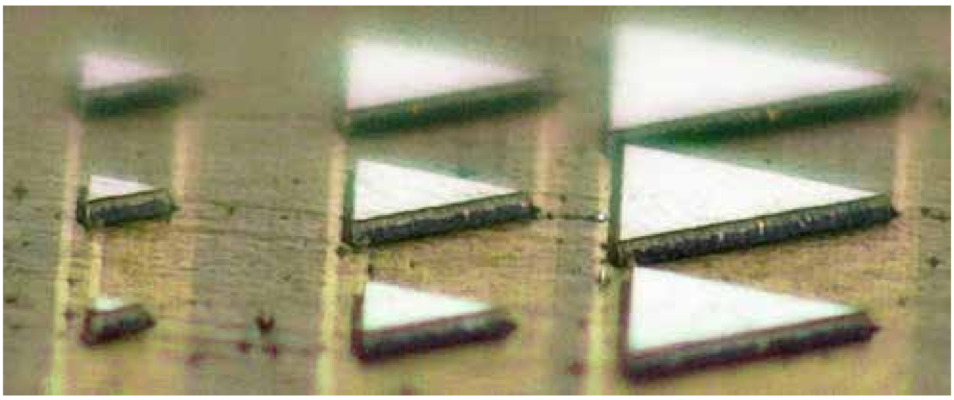

*Figure 3: 2.5D laser milled stainless steel micromoulds*

**Olivia Gillen** is Commercial Director of Blueacre Technology, Ireland, which provides specialist laser micromachining contract manufacturing services.

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# A NEW FRONTIER IN ULTRAFAST LASER PROCESSING

## ERIC MOTTAY

**During the last decade, femtosecond laser technology has gained considerably in maturity and reliability. The short duration of laser pulses enables materials to be machined with minimal thermal collateral effects. It also allows outstanding precision, especially on hard materials but also on brittle ones sensitive to temperature. The machining quality promotes a better reproducibility of the process and reduces the number of pre- or post-processing steps.**

With a continuous drive in all industries towards smaller feature sizes, complex materials and technologies, ultrafast lasers are today experiencing rapid market penetration. Although usually located deep in the value chain and far from the end customer, ultrafast lasers are a key enabler in many industrial and mass markets: cutting of display screens, advanced manufacturing of AMOLED displays, manufacturing of medical devices (stents, intraocular implants, surgical tools). Other applications are rapidly growing, in semiconductor or neurosciences, and large potential markets are emerging, such as battery processing or surface texturing.

The European Union has labeled photonics as one of the 6 key enabling technologies essential for the future of Europe's industries. Ultrafast lasers embody such a definition. They provide the basis for innovation in a range of products across all industrial sectors. They underpin the shift to a greener economy, are instrumental in modernising Europe's industrial base, and drive the development of entirely new industries. Their importance makes them a key element of European industrial policy [1].

Over the past decade, ultrafast lasers have evolved from sophisticated technology products to reliable, industrial light sources for demanding applications, from an eye doctor clinic in the Andes to 24/7 manufacturing operation in Asian factories.

A second step of this ultrafast technology revolution is now underway and will further increase penetration of ultrafast lasers in new domains. While ultrafast lasers excel in processing with an exquisite precision, each laser pulse only removes a very small amount of material. Most future industrial applications of ultrafast lasers require high processing quality, but also high throughput and productivity. The laser ablation rate, i.e. the amount of matter removed per minute, becomes a good proxy for industrial throughput.

Multiple approaches are currently being developed to increase the ablation rate/ throughput of ultrafast laser processing. A first step, led by the laser manufacturers, is the development of high average power lasers. While current commercial lasers are in the range of 100 W of average power, new sources in the 500 W range are making their way to commercial maturity, and several research projects within the H2020 programme of the European Union are demonstrating kW average power.

Yet, laser processing at high average power raises specific new challenges that need to be addressed for high productivity applications. For instance, even if ultrafast laser processing is said to be athermal, residual heat effects become non negligible and can degrade the processing quality. At high laser repetition rates, the material does not have time to cool down before the next laser pulse occurs, leading to a gradual temperature increase that can reach the melting point. Similarly, the plasma generated during the laser ablation may not have time to dissipate before the next pulse and shield the material from the laser light, decreasing the process efficiency.

New processing strategies are being investigated such as high-speed scanners for fast beam steering or diffractive optics for parallel processing. In both cases, the challenge is to maintain the quality and precision of femtosecond processing obtained at lower power or lower repetition rate, either by its synchronisation with the scanner for beam steering or by its spatial phase management for diffractive deflection.

While these developments gather considerable attention in the laser processing community, a new breakthrough strategy promises to increase the ablation efficiency by a factor of up to 10 times thanks to a significant redesign of the laser source.

A research group led by Professor Ömer Ilday from Bilkent University in Ankara, Turkey, has recently proposed ablation cooling as a novel interaction mechanism leading to higher heat extraction efficiency [2].


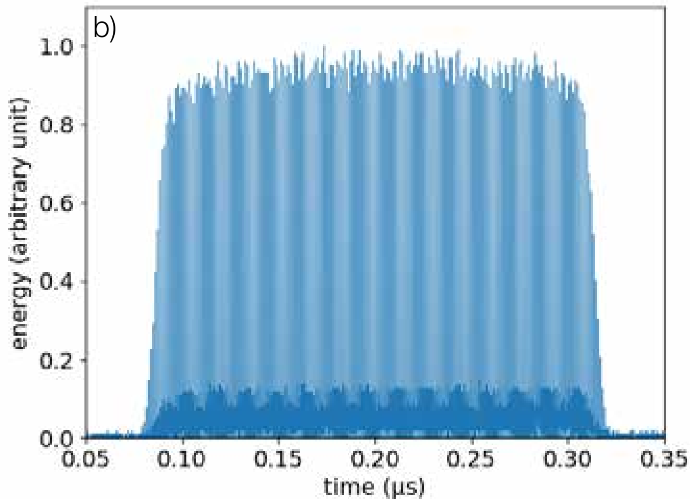


*Figure 1: (a) Silicon processing based on Amplitude's Satsuma platform, and incorporating a specific GHz burst source. (b) Typical burst train, with 200 sub pulses at 0.9 GHz repetition rate. Burst total energy 2 mJ. Average power 100 W.*

| Material | Max. specific ablation rate, $mm^3/min/W$ | | | | |
|---|---|---|---|---|---|
| | GHz bursts This work | GHz bursts [1] | Single fs pulse [2] | Single ns pulse This work | Single ns pulse [3] |
| Copper | 0.7 | 0.4 | 0.2 | 0.6 | 0.4 |
| Aluminium | 2.3 | | 0.4 | 2.4 | |
| Stainless steel | 1.4 | | 0.3 | 1.8 | |
| Silicon | 2.5 | 1.8 | | | |

*Table 1: Ablation rate in $mm^3/min/W$ for different materials.*
*[1] Optics Letters, Vol. 43, No. 3, 535-538 (2018); [2] Journal of Laser Applications, 27, S28008 (2015); [3] Appl. Surf. Sc., 217, 170-189 (2003)*

The ablation cooling process is inspired by the ablative layer used in the cooling of Apollo's command module during re-entry. It relies on the heat carried away by particles ejected during the laser ablation interaction process to lower the material temperature. At low average power, and moderate repetition rates, the amount of heat that can be removed is negligible. However, simulations show that at very high repetition rates, in the order of a GHz, significant heat removal can be achieved.

Unfortunately, such a repetition rate is unaccessible to current lasers. The Bilkent University group has proposed the use of bursts of GHz pulses as a practical means to reach the ablation cooling process. In such a laser, several hundreds of individual pulses, each separated by a period of a nanosecond (corresponding to a GHz repetition rate), are emitted at a standard repetition rate (kHz to MHz).

Figure 1a presents an industrial version of the initial concept, based on Amplitude Satsuma's platform, and incorporating a specific GHz burst source. Figure 1b shows a typical GHz burst emitted by the laser. The repetition rate of the bursts can in this case be tuned from the kHz range up to several MHz. The laser generates bursts with an average output power up to 100 W and a pulse duration below 550 fs. The number of pulses per burst and the inter-burst period are freely adjustable and three intra-burst repetition rates are available: 0.88 GHz, 1.76 GHz and 3.5 GHz.

Although the initial concept of ablation cooling is very elegant, it is somewhat controversial in the laser processing community. Even if part of the heat is indeed removed by the ejected particle, thermal accumulation plays a significant role in the ablation scheme. To further investigate this question, and in collaboration with researchers at the University of Bordeaux, Rochester Institute of Technology and Alphanov Technology Centre, we have studied the ablation efficiency and processing quality on several materials, from metal to semi-conductors, using the Amplitude Satsuma industrial laser source in the GHz regime.

Table 1 presents the main results of these experiments and demonstrate an increase by a factor of 4 to 10 of the ablation efficiency, while maintaining a good processing quality. Figure 2 shows a typical ablation crater on silicon, where we can still see a small recast around the edge, typical of a residual heat accumulation.

We demonstrate a new ablation-rate record (42.3 µm3/µJ or 2.5 mm3/min/W) for silicon. We conceptually show that efficient GHz ablation can be achieved through balancing pulse energies used for heat accumulation-based incubation and for effective ablation. We experimentally demonstrate that silicon ablation with high efficiency and better quality is obtained using a burst with 200 pulses at 0.88 GHz intra-pulse repetition rate.

The novel GHz laser and the demonstrated processing methodology open a path for achieving high-throughput, high quality processing of silicon and other materials. GHz laser processing shows that ultrafast lasers can reach ablation efficiencies equivalent to those achieved with nanosecond lasers, with limited heat-related side effects. Combined with other technology developments in the field of high speed scanning or spatial beam shaping, as well as a new generation of kW level lasers, the future looks bright for high throughput precision micro-processing.

**References**

[1] http://ec.europa.eu/growth/industry/policy/key-enabling-technologies_en

[2] Kerse, C et al. (2016) Ablation-cooled material removal with ultrafast bursts of pulses. Nature 537, 84-88

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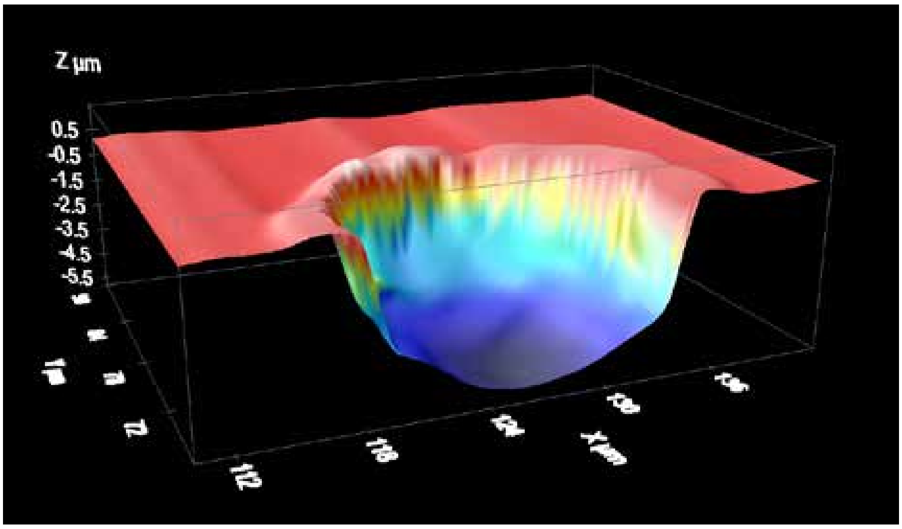


*Figure 2: Ablation crater on silicon.*

**Eric Mottay** is the founder and President of Amplitude Laser Group, a manufacturer of ultrafast lasers for industry and science.

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# HYBRID JOINING OF DISSIMILAR MATERIALS

## ANNE HENROTTIN ET AL.*

**The development of new technologies for joining dissimilar materials continues to advance and grow. Laser welding can join different materials whilst avoiding the addition of chemical adhesives, assembly elements or additional parts. This technology makes it possible to join assemblies with complex geometries whilst maintaining their integrity. Various industries, such as automotive and aerospace, are seeking these new capabilities in order to manufacture lighter structures and to reduce energy consumption.**

LASEA has developed a new approach for performing high strength hybrid joining between a metal and polymer. This complete non-contact laser process allows strong joining of the substrates up to the breaking point of the polymer part without affecting the joining area. Hybrid joining between complex substrates has been performed, and research has been focused on substrates with high reflectivity, high thermal conductivity, thin metallic plates and transparent polymers.

Many methods can be used to weld metal with polymers. High power lasers, typically in the kW range, CW or long pulsed, are commonly used for the overall process, structuration and joining. A method based on a two-step process has been used in this study: the first step uses a short or ultra-short pulsed laser for creating the micro-structuration, playing the role of a clamping tool. The second step, joining, uses a continuous wave (CW) laser for progressively heating the polymer in order to melt it.

The laser machine used for performing the hybrid joining has been developed and manufactured by LASEA. The machine can have a short or ultra-short pulsed laser for the micro-structuring process and CW lasers for the joining. Composed of linear and rotational axes, the machine can process complex geometries. Moreover, the machine also integrates an accurate vision system for ensuring exact positioning of the sample and quality control.

The joining strategy has to be adapted depending on the polymer opacity to the joining laser wavelength. Two strategies are possible, conductive and transmission joining.

- **Conductive joining**

Conductive joining is used when the polymer is opaque to the joining laser wavelength. In this case, the laser beam interacts directly with the metal surface and the heat is transferred to the polymer, inducing melting.

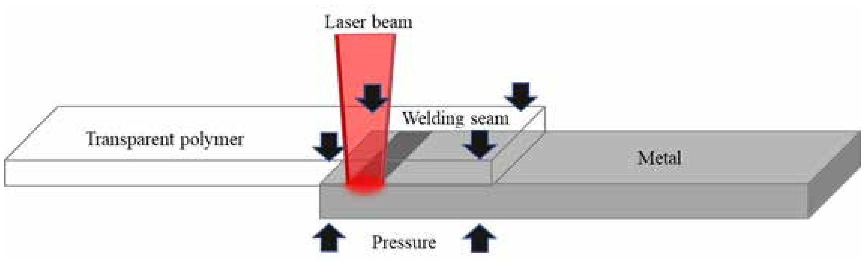


*Figure 1: Schematic picture of transmission joining.*

- **Transmission joining**

In transmission joining (Figure 1), the laser beam passes through the polymer, transparent to the laser wavelength. The beam interacts at the interface between the polymer and the metal. The laser energy is transformed into heat which melts the polymer. The polymer fills the micro-structures formed previously in the metal plate. A natural clamping system is created, blocking the polymer inside the metal when it cools.

Transmission joining is the more complex of the two methods to implement. The process is more sensitive given that the beam passes through the polymer, and consequently the process is dependent on the quality of the polymer and micro-structures. Development has been focused on this particular case and the process for reaching high joining resistance has been improved.

One critical factor in the hybrid joining process is micro-structuration. LASEA has developed a new geometrical design created by observing the natural characteristics of different living organisms, for example the gecko finger. Micro-structure geometry has been developed by taking such natural characteristics into consideration and adapting them to the laser process. The design is based on grooves having various orientations forming a specific geometrical pattern which improves the clamping efficiency. With this design it is possible to reach the rupture of the polymer keeping the joining area intact. Laser hybrid joining is consequently more resistant than the intrinsic resistance of the polymer, at least under tensile stresses.

After a detailed study of the influence of the distance between grooves, and the depth and width of the grooves, an optimal design has been selected consisting of concentric lozenges (Figure 2). The study has also focused on the influence of the ratio between the micro-structured surface and the global joining area (also named the density of structuration). The study shows an optimum, above which the efficiency of the joining would decrease. Indeed, the purpose of the non-structured area is to

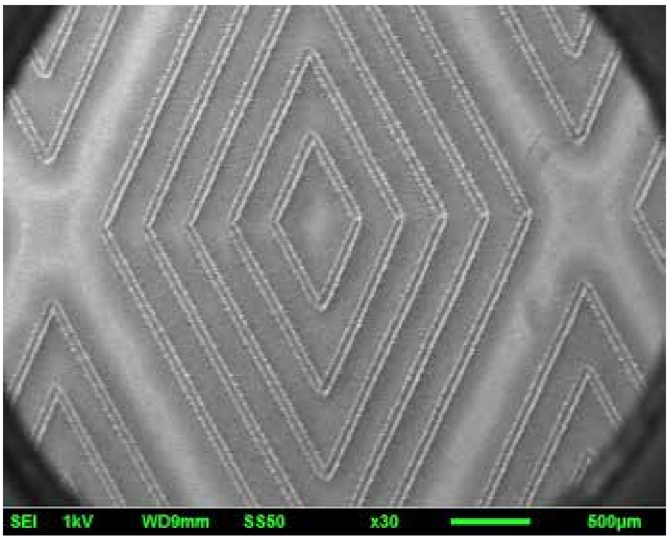


*Figure 2: SEM images of lozenge design.*

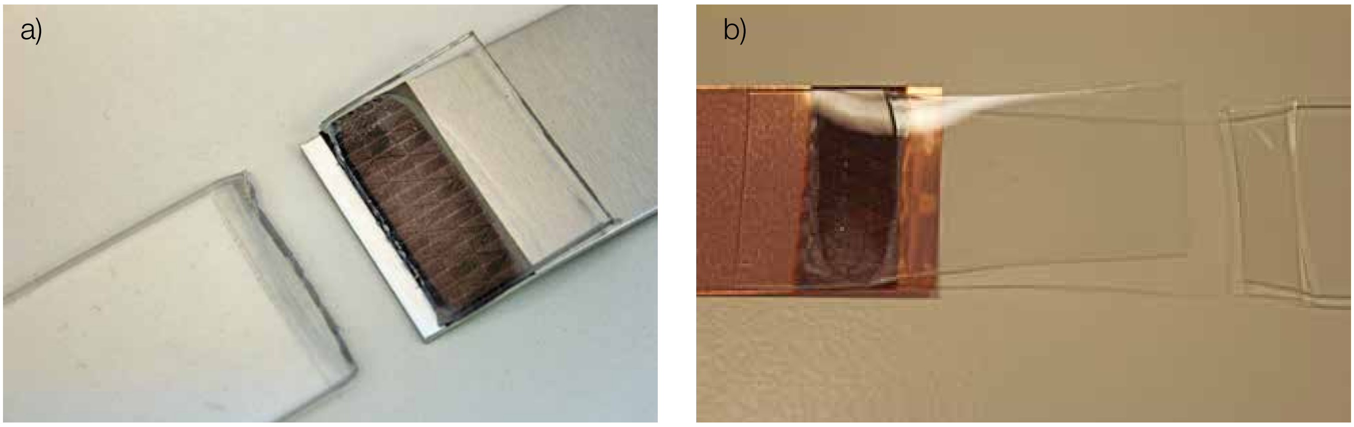


*Figure 3: Result of tensile test: Rupture of polymer keeping intact the joining area (a) Al/PC and (b) Cu/PC.*

transfer the heat between the metal and the polymer. If the density of structuration is too high on a defined surface, the transfer of heat is impacted leading to a decrease in the joining resistance.

Consequently, the combination of this complex design and an (ultra)-short pulsed laser gives a new solution for joining of very thin or high reflective metal plates.

Four different pairings of substrates have been studied. For metal plates, titanium alloy (Ti90Al6V4, thickness t = 100 µm) commonly used in implants, copper-O.F.H.C (thickness t = 200 µm), stainless steel (15-7PH, thickness t = 250 µm and t=800 µm) and aluminium (EN AW-1200A, thickness t = 1 mm, EN AW-6063 and EN AW-5182, thickness t = 2 mm) were selected. The polymer was fixed depending on the targeted application. For medical use, the titanium alloy has been joined with Poly-L-lactic acid (PLLA, biopolymer, thickness t = 50 µm). The other metal sheets were joined with polycarbonate (PC).

In the study, the influences of different parameters were also explored and are described below.

- **Influence of laser sources**

Three different laser sources, with different pulse durations, have been compared. From nanosecond to femtosecond passing through the picosecond range, the study covers short and ultrashort pulsed laser systems. The pulse duration of the laser source influences the quality of the grooves. Due to its longer pulse duration, the nanosecond laser induces greater heat affected zones. The heat created during the laser structuration process with the nanosecond laser produces indirect effects, such as bending of the thin metal TiAl6V4 alloy sheet or oxidation on the surface of copper. Depending on the application, these effects must be avoided to maintain the integrity of the surface. Whereas, using a femtosecond laser allows clean surfaces to be achieved without distortion.

With femtosecond lasers, the density of structuration can be reduced in comparison with the nanosecond and picosecond laser sources. In fact, for a density of structuration of 0.4, it is only with the femtosecond laser that we can induce rupture of the polymer without affecting the hybrid joining area. For nanosecond and picosecond lasers, a higher structure density is needed to ensure the quality of the hybrid joining. These results are for hybrid joining aluminium/PC and copper/PC (Figure 3). For the combination of TiAl6V4 and PLLA, only the femtosecond laser could enable the joining. With this laser source, the TiAl6V4 metal is less thermally affected, and no bending of the sheet is apparent which allows successful joining.

- **Influence of polymer thickness**

An important aspect of the study has been to determine how the thickness of the polymer influences the quality of the hybrid joining process, all other parameters remaining constant. The study has been focused on polycarbonate, and three different thicknesses have been compared - 0.5 mm, 1 mm and 2 mm.

For a structuration density of 0.6 and a nanosecond laser, the rupture of the polymer can be achieved without affecting the joining area. However, if the polymer is 2 mm thick, the nanosecond structurations cannot allow the joint failure point to reach the rupture of the polymer, the welding is only cohesive. Consequently, the nanosecond structuration induces a limitation in terms of polymer thickness. The femtosecond laser structurations allow good joining quality to be obtained up to the rupture point with a density of structuration of 0.6 for all thicknesses tested. Due to this analysis, the thickness of the polymer could be increased in this case, allowing more flexibility in the material combination. These results confirm the importance of the selected laser source for the hybrid joining process depending of the quality of the joining expected. Moreover, it seems that the groove shape and the quality of the structuration process (no bending, less thermal affecting zones) help in the joining process of dissimilar materials.

- **Influence of aspect ratio**

We have defined the aspect ratio as the ratio between the groove depth and the groove width. The analysis of this parameter gives us an indication of the influence of the laser parameters in relation to the geometry generated. For example, for ultra-short pulsed lasers, the joining has shown to be most resistant when the depth of the groove is higher than 0.6 times the groove width.

**Summary**

The methodology has been developed and adapted for applications where there are some technical limitations in terms of temperature reached during the joining phase or chemical modification (for example oxidation) of the metallic foil. Depending of the application, the laser source should also be adapted to achieve high quality joining. In this work, a laser solution is proposed for joining metals with complex properties (high reflectivity and thin thickness) and polymers while obtaining high joint quality and strength, i.e. up to the rupture of the polymer part without affecting the joining area. Based on laser micro-engraved structures on the metallic part, this methodology is relevant for various metal/polymer pairs and laser sources but could also be applied in other combinations of dissimilar materials. LASEA is ready to offer technical solutions to hybrid joining applications thanks to a wide range of laser systems for the different operations necessary for structuring or joining.

*Anne Henrottin, Jérôme Patars & Jose A. Ramos-de-Campos

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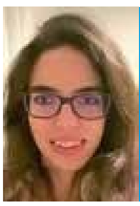

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SEE OBSERVATIONS P33

# LASER POWDER BED FUSION AT SUB-ATMOSPHERIC PRESSURES

## PRVEEN BIDARE ET AL.*

**In this study, high-speed imaging was used to investigate the interaction of the laser beam with the powder bed at sub-atmospheric pressures. At atmospheric pressure, the laser plume produces a flow in the ambient atmosphere that entrains particles toward the melt pool. As the pressure decreases, this hydrodynamic entrainment increases but eventually the expansion of the laser plume prevents the particles reaching the melt pool. Further decrease in pressure results in the particles only being repelled away from the melt pool. In order to enable processing at most lower pressures, pre-sintering is a must.**

The perceived advantages of laser powder bed fusion (PBF) at reduced pressure include a more stable melt pool and reduced porosity. In laser welding, the penetration of a keyhole weld is typically twice that achieved at atmospheric pressure, with an associated reduction in voids in the weld seam and an increase in weld pool stability. The deep, narrow weld is similar to that achieved with electron beam welding but without the production of harmful x-rays associated with that technique. The improved penetration at reduced pressure is attributed to two principal effects: the reduction in the metal vaporisation temperature, so that less energy is required to create and maintain the keyhole; and the increase in laser energy reaching the workpiece due to reduced absorption and scattering of the beam by the atmosphere.

In this work, we investigate single powder layers in order to resolve the inconsistences in the PBF literature regarding suitable process settings for sub-atmospheric pressures. We report the penetration depth obtained in PBF at these sub-atmospheric pressures in order to gain further insight into the process.

### Experimental system

The design and characterisation of an open-architecture PBF system for in-situ measurements have been presented in Issue 80 of The Laser User and in [1]. For this work, the system was encased in a custom-made vacuum chamber (Figure 1). A key feature of the PBF system is computer control for the automated build of fully dense components, enabling in-process measurements under realistic build conditions. However, for this study, the laser interaction with a single powder layer was investigated in order to understand the process conditions that might enable multiple layers to be built in the future.

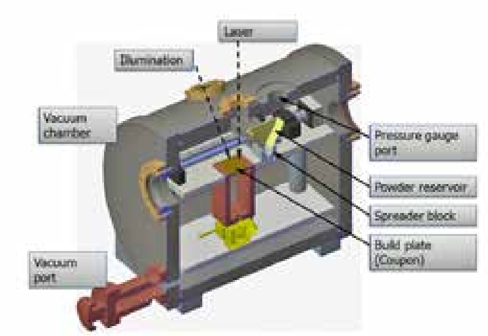


*Figure. 1: Schematic cross-section of the open-architecture PBF system with vacuum chamber*

Experiments were performed on layers of gas-atomised stainless steel 316L powder (Renishaw PLC) with particle diameters in the range 15 to 45 µm and a mean diameter of 30 µm. The powder layer thickness for all experiments was 50 µm. Individual tracks were melted with a single mode fibre laser (SPI 400 W continuous wave, 1070 nm).

Initially the chamber was purged with Ar shield gas to reduce $O_2$ concentration to <0.1%. The chamber was then pumped down to just below the pressure required, using an oil-free, scroll vacuum pump (Edwards XDS35i), and slowly back-filled with Ar until the required test pressure was reached. The lowest pressure tested was 10 µbar, limited by the pump performance. The pressure increase due to leakage was negligible during the time required to scan the laser tracks at a given pressure.

The powder bed was illuminated with a white light (Lumencor SOLA SM light engine) source, through the illumination port shown in Figure 1, to produce a circle of ~10 mm diameter on the powder bed. Image sequences were recorded with a Phantom V2512 monochrome high-speed camera through a symmetrical observation port (not shown in the Figure). The full resolution for this camera is 1,280 × 800 pixels up to 25,700 fps. The results reported here were recorded at 40,000 fps and 768 x 368 pixels. The camera was fitted with a C-mount adaptor and a QiOptiq Optem Fusion lens, configured to provide a zoom of 7:1 and a working distance of 155 mm. At this working distance, the region of interest could be varied between approximately 6 × 8 mm$^2$ (depth of field 2.6 mm) and 0.9 × 1.2 mm$^2$ (0.2 mm). The camera was fitted with a band-stop filter to block light from the PBF laser. All pressures reported are absolute, i.e. 1 bar corresponds to atmospheric pressure.

### Results

- **1 bar** (Figure 2): The results are consistent with our previous observations at atmospheric pressure: both the direction of spatter ejection and the denudation mechanism change with different process parameters [2].
- **20 mbar** (Figure 2): A far larger number of powder particles are entrained in the flow induced by the laser plume, and they are drawn in from considerably further away on the bed. It is inferred that the vertical speed of the laser plume is larger than at 1 bar. At the

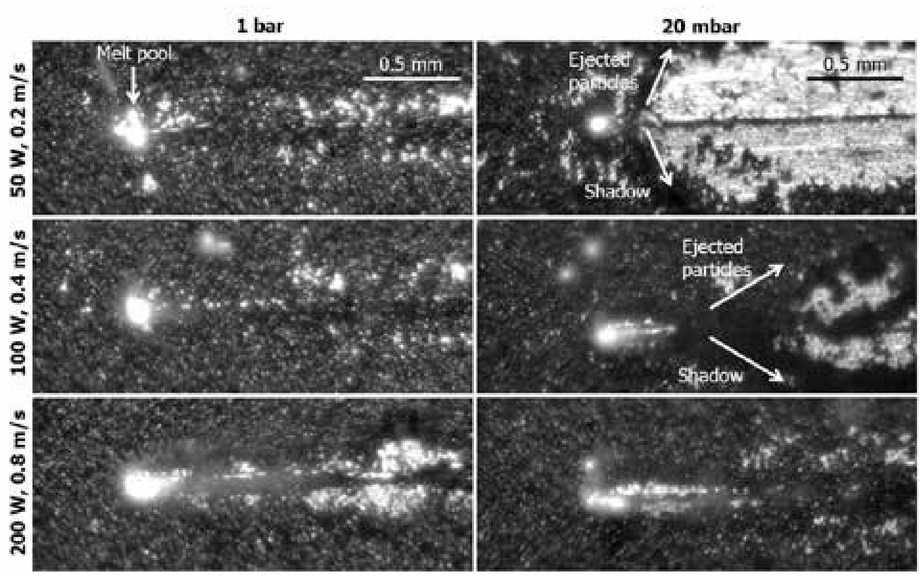


*Figure 2: High-speed images when scanning single tracks (right to left scan direction) at 1 bar (Kn≈0.018) and 20 mbar (Kn≈0.9). Videos are available online in [3].*

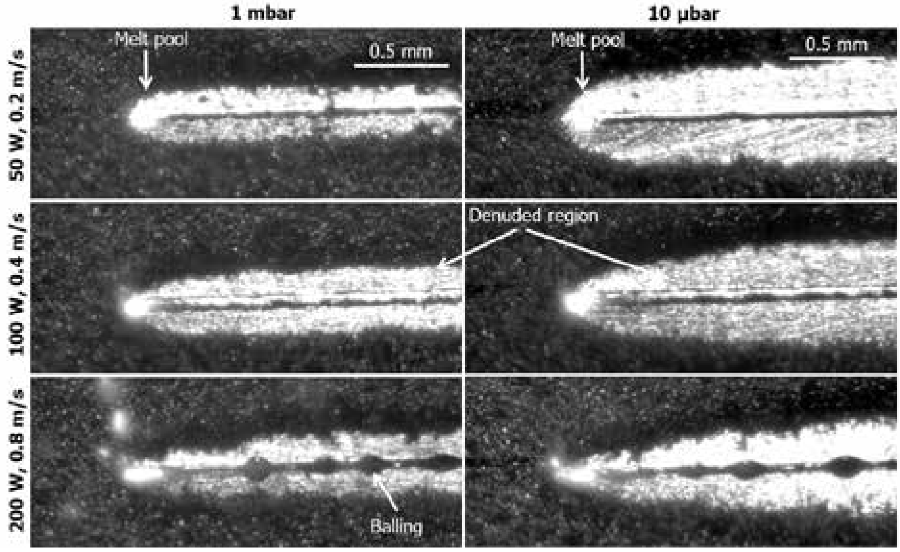


*Figure 3: High-speed images when scanning single tracks (right to left scan direction) at 1 mbar (Kn≈18) and 10 µbar (Kn≈1,800). Videos are available online in [3].*

same time, the inward flow begins to be offset by the lateral expansion of the laser plume that is associated with the transition to molecular flow. The flow transition with reduced pressure can be characterised by a Knudsen number Kn ≈ 1, from the hydrodynamic flow at 1 bar where Kn<<1 to a molecular flow where Kn>>1 at even lower pressure.

- **1 mbar** (Figure 3): Powder particles are still drawn in from a considerable distance away on the powder bed. At the lowest scan speed, the bare metal surface of the coupon is just visible in a distinct gap between the front of the melt pool and the powder in front of the track: the outward flow of the laser plume carries sufficient momentum to overcome the inward flow of entrained particles and to clear the laser track. At 0.4 m/s, the scan speed of the laser matches more closely the speed at which particles are repelled by the vapour, whilst at 0.8 m/s the particles do not have sufficient speed to escape and are still incorporated into the melt pool. The laser scan speed is acting cumulatively with the inwards drag forces exerted on particles by the induced ambient flow, whilst competing with the vapour expansion velocity which repels particles from the melt pool.

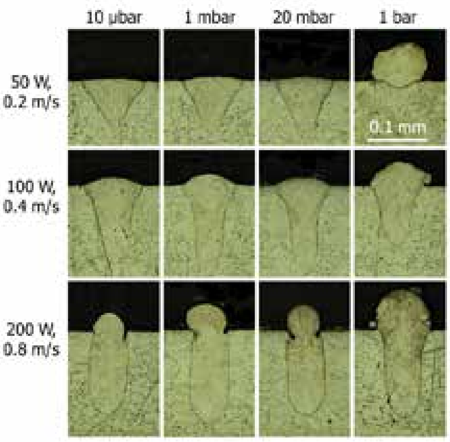


*Figure 4: Micrographs of single tracks*

- **10 µbar** (Figure 3): No inward flow of entrained particles from the powder bed is observed and the flow has become fully molecular (Kn≈1,800). The outward flow of particles directly affected by the laser plume at 0.2 and 0.4 m/s is slightly increased with respect to 1 mbar, indicating that the velocity of the plume in the plane of the powder bed has increased between the two pressures. However, the 0.8 m/s scan speed is still sufficiently fast to prevent particles escaping the melt pool.

### Micrographs

Typical track cross-sections are shown in Figure 4. In general the penetration increased with a decrease in ambient pressure but became independent of pressure at some threshold pressure above 20 mbar. This increase is attributed to the reduction in vaporisation temperature at low pressure, similar to that observed in laser keyhole welding. For laser welding at low speeds, the threshold pressure below which there is no noticeable effect on the penetration depth has been approximated at ~Pc/10, where  is the pressure in the keyhole due to surface tension,  , and r is the radius of the keyhole. This threshold pressure is ~50 mbar [3] for the conditions reported here, although in practice it is likely to be somewhat higher for PBF because the higher laser scan speed will make a small pressure contribution in addition to the surface tension pressure. This estimate of the threshold pressure requires further experiments to be validated, but it is consistent with Fig. 4 where the deepest penetration has already been reached by 20 mbar.

These results and observations lead to some guidance for exploring potential PBF at sub-atmospheric pressures. Operating in a soft vacuum in the hydrodynamic regime would provide the simplest implementation. In that case, there is no benefit in reducing the pressure below the threshold at which the penetration depth no longer increases (~50 mbar): the disruption to the powder bed increases with no gain in penetration. If the disruption to the powder bed remains too great in this hydrodynamic regime above 50 mbar, even with the potential reduction in laser power, a pre-sinter analogous to e-beam PBF might be required. However, the hard vacuum (nbar) and x-ray production associated with the e-beam technique would be avoided. Clearly a reduction in porosity in the built part should be critical for its intended use if the additional processing time and increase in process complexity associated with a pre-sinter are to be tolerated.

### Conclusions

Considerable disruption to the powder bed has been observed at sub-atmospheric pressures. In the hydrodynamic flow regime, powder particles are drawn in towards the melt pool. In the molecular flow regime, the expansion of the laser plume repels particles away from the melt pool. The resulting disruption to the powder bed means that most pressures would require a pre-sinter for the process to be viable, with a corresponding increase in processing time and complexity.

### References

[1] P. Bidare, R.R.J. Maier, R.J. Beck, J.D. Shephard, A.J. Moore, Addit. Manuf. 16 (2017) 177–185. https://doi.org/10.1016/j.addma.2017.06.007

[2] P. Bidare, I. Bitharas, R.M. Ward, M.M. Attallah, A.J. Moore, Acta Mater. 142 (2018) 107–120. https://doi:10.1016/j.actamat.2017.09.051

[3] P. Bidare, I. Bitharas, R.M. Ward, M.M. Attallah, A.J. Moore, Int. J Mach. Tools and Manuf. 130-131 (2018) 65–72. https://doi.org/10.1016/j.ijmachtools.2018.03.007

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SEE OBSERVATIONS P33

# INTEGRATED PIERCE DETECTION ENHANCES CUTTING PRODUCTIVITY

MARK RICHMOND

**Piercing is a necessary but time consuming step in sheet metal cutting, particularly in thicker materials. Knowing exactly when pierce though is achieved is key to cutting efficiency, by eliminating wasted dwell time. Pierce detection has been a high priced optional extra on top-end cutting process heads, but its uptake has to date been limited. SPI Lasers has developed a novel sensor within the laser that looks at back reflected light from the work piece. This provides a signal that accurately indicates when pierce through is achieved which can be used to eliminate fixed pierce times and yields significant time savings that can be 10% or more. This article explains the technical approach and the advantages that machine builders can benefit from by integrating this feature.**

Fibre lasers have a number of advantages for materials processing that have made them the first choice for many industrial laser applications all over the world. In particular, fibre lasers have been steadily replacing $CO_2$ lasers in the metal cutting market sector, due to advantages such as higher efficiency, high beam quality and the ability to process highly reflective material such as copper and copper-alloys, such that Fibre laser sales in this sector now exceed $CO_2$ sales. Total laser sales for metal cutting are over $1.5 billion annually, and growing at 3-4% per year, despite the recent slow down in some key markets such as China. Performance improvements for this application will have significant impact on global economies, with so much dependence on fabricated metal goods. Newer generations of fibre lasers are now beginning to incorporate additional sensors and diagnostics which allow more advanced functions to be performed.

Industrial laser cutting systems pierce and cut using separate operations, especially on thick section metal sheets, typically with fixed parameter sets for each given material and thickness. The actual piercing time will depend on the particular conditions on the sheet at that point, including the temperature due to previous nearby cutting operations. This variability leads to the piercing procedure being programmed for a maximum fixed dwell time to cover the worst case conditions. This results in a loss of machine efficiency and pierce quality, particularly for thick samples with many holes. However, it is possible to improve these processes by sensing the light returning from the work-piece to the laser in real time. This back reflected (BR) light is usually considered a nuisance, but it contains information about the cutting process and can be used to detect the end of the pierce phase.


*Figure 1: A 3kW redPOWER fibre laser is able to cut a variety of metals, including highly reflective ones, utilising the integrated back reflection protection.*

Pierce detection systems based within the cutting workstation already exist. However next-generation fibre lasers, such as the redPOWER QUBE laser, have an integrated pierce-detection system, which removes the need for any costly additional sensors that are usually incorporated within the cutting head (Figure 1).

### Pierce Detection

Many types of pierce detection systems now exist which provide feedback to the cutting machine controller as soon as a pierce breakthrough is achieved. This allows the controller to move on to the cutting phase with the minimum necessary dwell time. Usually the pierce detection systems are based within the cutting workstation around the focusing head, but this results in a more complex and costly cutting head and an optical system with additional optical surfaces that can degrade the laser beam. They are susceptible to damage due to the dusty environment often experienced when working in close proximity to the cutting process.

For a skeleton cutting job on a 3 m x 2 m sheet, up to 2,500 pierces may be needed. A time saving of 100 milliseconds per pierce reduces the process time for this sheet by over 4 minutes! Modelling across a range of materials and thicknesses has shown typically a 10-15% time saving using a pierce detection system. Thus the economics of investing in automated pierce detection are clear, and indeed the investment is considered necessary for all high performance cutting systems today.

A typical laser cutting process is structured in several different phases. Piercing is the first phase of the laser cutting process which produces a near-vertical cut front through the sheet metal, forming the start point of every cut. Depending on material and sheet thickness, a complex pulse shape and power ramp may be necessary to achieve short pierce times and reduce spatter and bulging on the work piece surface. Depending on temperature, surface roughness and material quality of the work piece, pierce times can vary widely for the same pierce program. For industrial processes, a certain safety factor (typically up to 3 times) is added to the average dwell time which is obviously not necessary for most pierces, but vital to ensure a stable process for every pierce.

A sheet metal pierce with a fibre laser and gas assisted cutting head is very similar to a laser hole drilling process. Initially the focused beam will be absorbed by the top surface of the sheet, causing a localised temperature rise leading to melting and potentially vaporisation, depending on the beam intensity. The coaxial gas jet pressure and the vapour pressure of the evaporating metal will create a blind hole with molten metal droplets sprayed upwards and outwards. The drilling process continues as the laser beam continues through the full sheet thickness. Whilst the pierce-hole is blind (i.e. not yet fully drilled through the sheet thickness) there will be an increased level of laser light reflected upwards since all of the beam will impinge on the metal sheet. This is in contrast to the steady-state cutting process where the angled cut front will enable most of the unused portion of the beam to emerge from the backside of the sheet.

During the pierce process a time-variant BR signal will occur. If this can be suitably detected, the information can be used by the laser control system to determine the end of the pierce. This status is presented as a clear digital flag to the cutting workstation to stop the piercing cycle. Figure 2 shows typical results obtained for a sheet metal pierce using a perpendicular, focused beam. The process can be divided into several distinct stages:

- From the beginning of the pierce to t1 there is a large BR signal. This is consistent with the laser hitting the blank surface and breaking down the initial reflectivity.
- From t1 to t2 the pierce is a blind hole as the laser drills through the sheet thickness. The BR is unstable as the shape and position of the melt-pool changes, but at higher levels compared to steady-state cutting.
- From t2 to t3 there is a transition as the pierce breaks through the back-side of the sheet.
- After t3 there are relatively low (but non-zero) levels of BR, until the laser is switched off at t4.

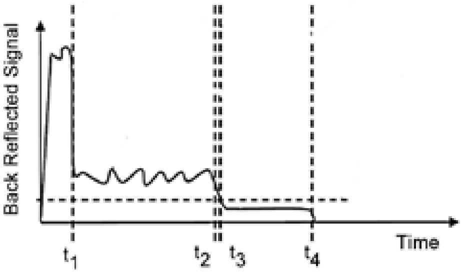


*Figure 2: Typical back-reflections observed during the piercing process.*

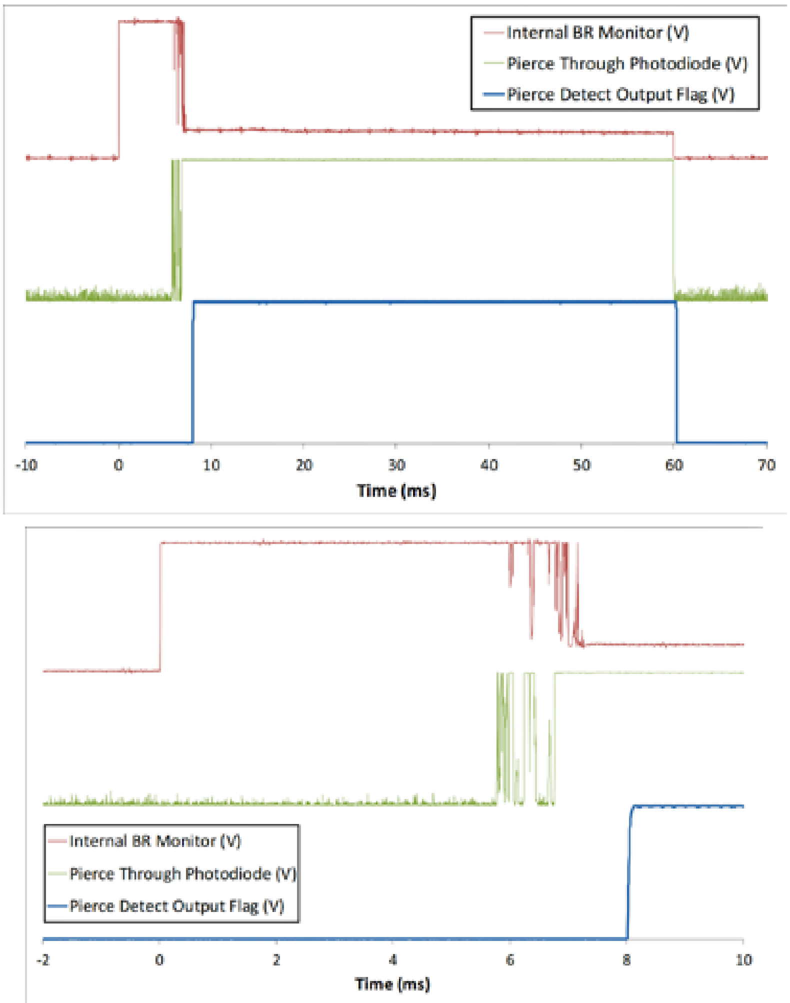


*Figure 3: Example of BR during piercing (Red – internal BR monitor, Green – pierce through photodiode, Blue – pierce detect flag). Top image – complete laser pulse. Bottom image – piercing period only.*

Figure 3 shows an actual back reflection signal trace from a piercing cycle (with the detector initially in saturation). This was obtained using a 1.5 kW laser delivered through a 50 µm fibre (BPP = 2.0 mm.mrad) processing a 6 mm stainless steel plate with a Ø100 µm focal spot, with the beam waist positioned below the workpiece surface. For the purposes of this experiment a supplementary detector was placed underneath the workpiece to confirm pierce through. The digital Pierce Flag can be clearly seen to go HIGH as the supplementary detector goes into saturation, indicating full pierce through. Importantly, there is an automatic reset of the Pierce Flag at the end of the laser ON period.

The pierce detection system operates by identifying the point where t3 (see Figure 2) has been reached. This activates a programmable delay time, which is important to ensure that the pierce process has completely finished. Once the BR signal is below the threshold for the duration of the delay time the pierce is considered finished, and the laser provides a digital Pierce Flag signal which can be integrated into the production machine. The thresholds and dwell times are programmable, so the User can adjust the settings to ensure that the Pierce Flag behaviour is optimised for their process, with the Pierce Flag going High just as the pierce through is completed. In many operations the pierce is achieved using a pulsing mode of operation for the laser to give a cleaner and more controlled pierce hole. By choosing suitable parameters for the detection algorithm, the Pierce detection flag will still trigger at the appropriate point.

### Conclusion

Pierce detection systems are becoming a required component of modern flatbed cutting workstations in order to ensure high performance and efficiency. With the pierce detection sensors integrated in the redPOWER laser itself, the customer can decide to use a more cost efficient cutting head rather than a high end expensive product.

Being able to monitor the amount of back reflection from the cutting process is a huge advantage, for both setting up the correct process parameters and for in-process quality monitoring. Both piercing and cutting operations can be examined and optimised, and high levels of back-reflection from highly reflective sheet materials can be avoided.

Ultimately the productivity of a Laser Cutting System can be increased by using a Pierce Detection system to ensure high machine efficiency and reduced time loss during piercing. Simulations have shown that process time can be shortened by up to 15% on a typical 3 m by 1.5 m sheet with realistic part layout. Depending on the part complexity and size, actual time savings could be even higher; not to mention the possible cost savings!

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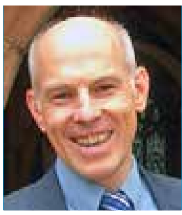


**Mark Richmond** is Product Manager for CW Fiber Lasers at SPI Lasers, UK, promoting fibre laser technology into a broad range of manufacturing processes.

SEE OBSERVATIONS P33

## HAPPY TO HAVE THE BLUES

JEAN-MICHEL PELAPRAT ET AL.

This article discusses important issues occurring when laser processing copper, and generally 'yellow metals'. Both the low optical absorption of copper at 1µm wavelength and the low power conversion efficiency in green wavelengths have been a prevailing barrier in implementing laser welding of copper for industrial applications. This study shows very promising results in terms of weld quality. Typical weld imperfections, such as material vaporisation, blow-holes and melt ejection, seem to have been well controlled.

I am aware of copper welding conducted at 1µm wavelength (using fibre laser sources) which has led to successful results, in terms of controlling the weld imperfections mentioned above. However, I agree that the blue 450nm wavelength technology enables the opportunity of achieving a much wider process window, strongly linked to the greater stable coupling on copper substrates which adds significant value.

In future publications, further details explaining mechanisms of the blue laser technology for minimising intermetallic phase formation in challenging dissimilar joints would be welcome. This is a very interesting topic and I will certainly watch this space!

**Paola De Bono, TWI**

## BLUE KILOWATT LASER FOR ADVANCED COPPER PROCESSING

SIMON BRITTEN

I enjoyed reading this article from Laserline, which describes well challenges the research community and industry are facing when laser processing copper. The direct emission at 450nm wavelength and the novel power scale-up technologies of the Laserline high power diode laser certainly constitute an important advancement in laser processing copper material, maximising the output power (eg compared to 532nm wavelength laser sources) while maintaining stable coupling.

The Beam Parameter Product of the 1000W Laserline high power diode laser source is significantly higher than commercially available 1µm wavelength fibre laser sources, resulting in a lower beam quality and less effective energy delivery. However, the promising weld quality results of this work indicate that the greater stable coupling of the 450nm wavelength laser beam on copper material might compensate for the lower beam quality of this diode laser, compared to fibre laser sources.

Presented results on thin copper foils welding are significant. When processing thin foils I am aware well-controlled intimate contact between the foils is a critical factor to achieve a sound joint (avoiding material vaporisation). I would welcome the opportunity to see further publications comparing effects of fixturing (enabling intimate contact among the foils) versus a stable coupling at 450nm wavelength.

**Paola De Bono, TWI**

## A MARKET GROWING AT THE SPEED OF LIGHT

OLIVIA GILLEN

It is certainly true that the adoption of ultrafast lasers is growing in many industries and it could be said that this is the long-promised arrival of short pulse lasers as an industrial tool rather than just an interesting scientific option. This article highlights this with some impressive pictures of micro results in different materials. Many readers will be familiar with the wide-ranging benefits of short pulse machining and this article nicely presents some of the ideas about the femto vs. pico vs. nano debate. It is often cited - as this article concludes - that femto is best but there is a lot of evidence that this is not always the case. Some jobs (e.g. cutting of ultra-thin glasses and some types of polymers) are often better in terms of quality and speed when processed with ps rather than fs pulses so this should be kept in mind. Its a truism that no single laser will do everything so its good to know the capabilities of different options. This article certainly helps place some of the given examples in this regard.

**Nadeem Rizvi, Laser Micromachining Ltd**

Picosecond and femtosecond lasers (USP lasers) provide unique micromachining capability on almost any material. As the article highlights these lasers have been implemented across a wide range of industries and applications with great success, with continued growth. When these lasers entered the market much data was presented on processing metals with near zero heat affected zone. However looking forward it is non-metals where the USP lasers really shine; polymers, coated materials, mixed layer materials, glasses, ceramics, sapphire. UV and green USP wavelengths have further enhanced results, especially for polymers. Initial adoption of the technology was limited to highly value add applications, now with lower laser prices, robust sources, higher energy and average powers and special USP optics, these systems are more easily justified. These lasers are real game changers and offer the design and manufacturing engineer a tool that can support product innovation through unique application capability. If you haven't done so, go check them out!

**Geoff Shannon, Coherent Inc**

## A NEW FRONTIER IN ULTRAFAST LASER PROCESSING

ERIC MOTTAY

This article discusses a hot topic in USP laser processing, which is how to retain efficiency while increasing average power. The solution highlighted is the tuning of GHz rate pulse bursts. This capability already existed in research-grade USP laser systems, but with limited tuning flexibility, in contrast with the system used in the research described. The higher removal rates especially on a silicon semiconductor are promising. However, the burst ablation cooling is still a controversial area of laser processing and further experiments are needed to fundamentally understand the phenomenon. We may thus be seeing some early stage positive results of this capability of GHz rate pulse bursts. The large space for parametric improvement in burst processing still leaves a lot of unexplored space for process tuning, whether this is based on cooling or just matching a material's opto-thermal characteristics and process plume dynamics.

**Ioannis Metsios, ANDRITZ Powerlase Ltd**

As an academic working in laser material processing, it is very encouraging to see that femtosecond laser technology is maturing and gaining a significant foothold in industrial and commercial applications. What is more, the development of capability-enhancing femtosecond laser processes for material processing, will only make this technique more attractive.The introduction of an ablation cooling process shows how such a development can give rise to an advancement of ultrafast laser system technologies for material processing. The demonstration of a new ablation-rate record for silicon, indicating the major opportunities for further developing such laser technology are promising. Given these developments, it is a very exciting time to be working in the field of laser materials processing and shows how these developments can be exploited by industry. This is especially heartening considering how the EU has confirmed that it has identified photonics as one of the key enabling technologies for the future development of industry.

**David Waugh, Coventry University**

## HYBRID JOINING OF DISSIMILAR MATERIALS

ANNE HENROTTIN ET AL.

Industrial sectors in precision machinery, electrical and healthcare require the development of improved micro-joining and welding techniques. Traditionally, joining techniques such as adhesive bonding, arc bonding, anodic bonding and soldering have been employed for the manufacture of micro-optical, mechanical, electronic, and fluidic devices. Laser micro-joining is relatively new and it is a superior method due to its advantages of high speed, high precision, consistent weld intensity, and low heat distortion. Here, LASEA is offers a new capability to perform high strength hybrid joining between dissimilar materials such as metal-polymer. This non-contact laser process presumably allows for strong joining of the substrates up to the breaking point of the polymer part without affecting the joining area. A critical factor in the proposed hybrid joining process is laser micro-structuring, and here LASEA used a bio-inspired geometry design for the structures, similar to the gecko finger.

**Amin Abdolvand, University of Dundee**

LASEA's work on joining dissimilar materials without the need of adhesive is highly applicable. Laser patterning to realise a lozenge type geometry at an interface is interesting, and on a microscopic scale complex. Tensile stress tests have been carried out and results indicate strong adhesion between the dissimilar materials. If not carried out already, it would be interesting to investigate alternative laser patterning geometries for interfaces experiencing forces applied in other directions. In addition, a two-stage spot weld approach for components that critically rely on alignment may be interesting. Anne briefly discusses an interesting area of bio-inspired design from gecko feet. Conformal contact plays a role in the attractive force at the interface and is realised by thousands of microscopic hairs called satae that are in contact with the surface. Hence, microscopic studies of the surface roughness on geometrical features may provide further insights. The work reported is very encouraging.

**Chris Walton, University of Hull**

## LASER POWDER BED FUSION AT SUB-ATMOSPHERIC PRESSURES

PRVEEN BIDARE ET AL.

Around 20 years ago I recall being impressed with the appearance of microstructures achieved following investigations in to new uses of Powder Metallurgy Materials. So the good results that can be achieved in Additive Manufacture, and the similarities that can be drawn, don't surprise me. However, the open atmosphere conditions and the combined aggression, power and intensity of the laser, offer challenges that Bidare has investigated well here. I concur that we can learn a lot from the similarities between different processes - such as AM and laser welding, as outlined in the article. Identifying and assessing all the surrounding variables in a processing environment is important in improving a process, to make it acceptable and suitable for the required application of the final part produced.

Longer term I think the challenges facing AM are to enable researched knowledge to be integrated into simple processes through recommendations and process controls that will further encourage the integration of AM into modern manufacturing. I think we all watch this with great interest.

**Christopher Ogden, Laser Lines Ltd**

## INTEGRATED PIERCE DETECTION ENHANCES CUTTING PRODUCTIVITY

MARK RICHMOND

The issue of piercing is one that was relevant to my recent experience with helping a client to get up and running on cutting with a lower power (sub kW) laser. I am familiar with using a dwell to ensure that the pierce is complete, but to be able to close the loop and get feedback using back-reflection seems like a good thing. My concern is that a high level of integration is needed to get the most of these new functions, and the machine builder will need to be made aware of the new feature and integrate it into the machine code (or CNC) to ensure the process is utilised.

**Dave MacLellan, AILU**

FEATURE

# E-MOBILITY OFFERS MULTIPLE OPPORTUNITIES FOR FIBRE LASERS

E-mobility is continually in the headlines and represents one of the great predicted mega trends for the next decade. The rationale is clear – the world needs to break its dependency on fossil fuels, and electric vehicles offer the obvious solution. Predictions suggest that by the mid-2030s electric vehicles will be outselling petrol/diesel models. From a manufacturing perspective this is a paradigm shift from combustion engines to electric motors. Passenger vehicles can be either plug-in hybrid vehicles (PHEV) or battery electric vehicles (BEV) both of which need batteries and electric motors. The manufacturing of batteries and electric motors must undergo a transformation to match the forecasted growth in volume, accompanied by dramatic improvements in cost, yield and throughput. Fortunately, today's industrial lasers are the ideal tools for the manufacture of key components within both batteries and motors; this has stimulated a significant rise in demand particularly for fibre lasers.

**Cutting of lithium-ion coated foil electrodes**

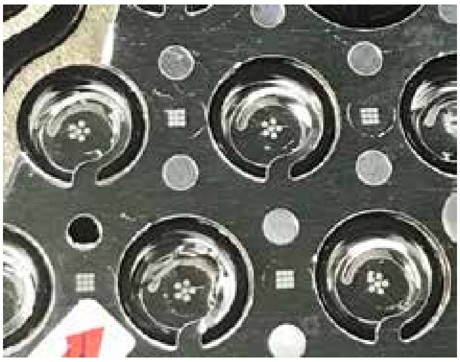
Breaking down the key requirements in terms of opportunities for lasers we can start with the individual lithium-ion battery cells. These are made up layers of coated anodes/cathodes made from thin aluminium/copper foils used in both cylindrical and prismatic cell designs.

Quality is key and there are stringent requirements on aspects such as burr formation, delamination, particle debris formation and heat affected zone. Single mode CW fibre lasers can be used very effectively for the cutting of bare foils but may not be the best choice for the cutting of coated electrodes. Here the ns pulsed fibre lasers excel as the short, high peak power pulses can cut at high speeds with today's 200W sources. SPI's EP-Z model can reach cutting speeds greater than 1m/s with appropriate cut edge quality. There are parallel developments looking at alternative sources such as green and even ultrafast ps with the promise of higher quality, but the reality is that this comes at a cost, which is in direct conflict with the prime driver for manufacturers looking to increase speed and reduce total cost.

*Copper anode and aluminum cathode foils, coated with lithium ion compound.*

**Tab welding and Bus Bar welding of battery packs**

Within the cell manufacturing process there are numerous opportunities where lasers are being considered including welding, cleaning and drilling. Whether they are cylindrical or prismatic cells these self-contained modules need to be assembled into battery packs where copper or aluminium bus bars are welded to the cells.



*Battery tab welding using a nanosecond laser*

The thickness and types of materials vary quite considerably but these welds are in general quite challenging. They rely on welding highly reflective and conductive materials such as copper or aluminium either to similar or dissimilar material combinations; the latter being a process that is becoming increasingly common. Given that there are hundreds if not thousands of individual cells that need to be joined in a battery pack for an electric vehicle (EV) these joints need to be of high quality, reliability and repeatability. Requiring good static and fatigue strength, these joints must provide excellent electrical contact resistance as the power loss at each joint affects the overall efficiency of the pack. Traditional mechanical fastenings with nuts and bolts add weight and cost – laser welding provides the answer going forwards.

Initial installations focused on high energy multi kW multimoded laser sources with limited success. Improved solutions have been developed based on the specific challenges of individual manufacturer's designs. In instances where material thicknesses are low and the need for control of heat input is high, then the unique proposition of SPI's ns welding process offers an ideal solution.

Using lasers with only a 100 W excellent welds can be made in 300 micron Cu tabs. This technique enables multiple spots to be made to give appropriate bonding to the focus area using a spiralled spot. Control of heat input and penetration is extremely high, but welding time can be quite slow given the low average power when compared to multi kW CW.

For applications that require high productivity and the ability to weld through thick metal, the recent introduction of high power single mode CW fibre lasers has enabled these welds to be carried out using an oscillation or wobble welding technique. This uses a very small focused spot that is rapidly oscillated to enlarge the weld area. This enables the width of the weld to be controlled independently of the spot size enabling the weld to be tailored to the application. The rapidly oscillating spot also has the effect of controlling the heat input and the stability of the key hole/melt pool. The resulting weld tends to have greater consistency in weld profile, top bead appearance and lower spatter. A 2kW single mode fibre laser can now create welds that are up to 2mm in penetration with exceptional quality both in copper or aluminium.

**Hairpin ablation and welding for electric motors**

Another significant opportunity for lasers is in the manufacture of electric motors, particularly in the welding of the copper hairpins on the stator. These pins are typically coated with an insulating material that needs to be removed prior to welding. Conventionally this has been done using mechanical means such as through wire brushes, but this is difficult to control and prone to maintenance. These coatings can be effectively ablated by ns pulsed fibre lasers leaving no residual material whilst simultaneously getting the parts selectively down to bare metal ready for the subsequent welding step.

*Hairpin ablation of dielectric coating prior to welding.*

These pins come in various shapes and sizes but are often in a rectangular form with the long sides up to 6 mm in length. Welding with high power CW multimoded laser sources in the 4-6 kW range are currently being adopted, but this proves to be a challenging application for several reasons including fit up, need for minimal spatter and the lowest heat input so as not to burn the insulating material only a few mm from the welding zone. Again, the use of a 2 kW single mode fibre laser using the beam oscillation technique offers an alternative that provides good control of heat input and limits spatter.

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## SYSTEMS & SOURCES

### COHERENT SIMPLIFIES PROCESS MONITORING

The new HighLight SQD option for Coherent HighLight fibre lasers provides cutting and welding systems integrators with a turnkey, simple to use and cost effective means to implement process monitoring. The HighLight SQD comprises process sensors integrated directly into Coherent's special fibre laser connectors, which detect back reflected laser power and visible spectrum process emissions.

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### HIGH REP RATE GREEN LASER FROM UNILASE

Unilase Ltd has developed a high rep rate green (532 nm) laser with an average output power of 25 W and a pulse repetition rate of 500k Hz.

The Unilase DPSS green laser supports a number of applications, including the processing of battery terminals, PCB cutting and glass processing, by delivering high quality, high throughput laser materials processing from a robust laser source.

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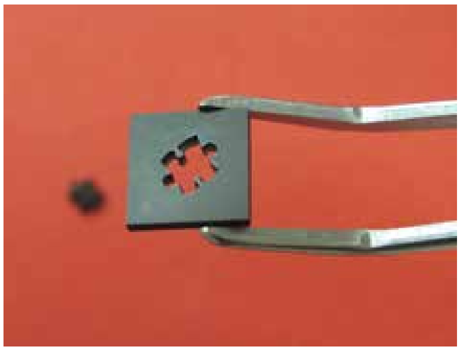
### NEW FEMTOSECOND LASERS FROM INNOLAS

The new FEMTO 1030-25-Yb-2500 is a fibre based ultra-short pulse (USP) laser with output powers of up to 25 W, engineered for demanding 24/7 industrial applications that require a high level of stability and reliability. Applications range from micromachining, engraving, glass processing, SEMI/electronics/display/PV/OLED manufacturing, pump-probe experiments and thin film structuring to microscopy and security markets.



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### LASER 2000 INTRODUCES NUBURU BLUE LASER

Laser 2000, UK distributor of NUBURU lasers, welcomes the company's second high powered blue laser, the AO-500, the 500-Watt 450-nm industrial laser. "The AO-500's higher power opens up new applications with thicker copper and other yellow metals," according to NUBURU's Co-Founder Jean-Michel Pelaprat. "It can even solve the notoriously difficult challenge of welding dissimilar materials."

See J-M Pelaprat's article on page 18 of this issue.


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### NEW 1 KW BLUE LASER FOR COPPER PROCESSING

Laserline have launched the world's first 1 kW blue diode laser for copper and non-ferrous metal welding. In contrast to other laser source concepts, the diode laser enables the direct emission of 450 nm, without the need for further wavelength conversion. This allows for highly efficient processing and the heat conduction welding of copper. The LDMblue 1000-100 is available as a 19" rack module.

See S. Britten's article on page 20 of this issue.

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### LASEA LAUNCHES NEW 7-AXIS LASER MACHINE

LASEA has developed a way of micro-machining based on a femtosecond laser combined with a 5-axis accurate CNC system; these 5 axes being synchronised together, and combined with 2 additional optical axes controlled by a scanner. This full assembly allows the combination of the possibilities of a standard 5-axis system with the possibilities of fast scanning strategies. The full 7-axis laser system enables the processing of complex geometries in 3D.


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## PRODUCT NEWS

### LVD OFFERS LARGE-FORMAT FIBRE LASERS

LVD Company nv introduces new automation offerings for its Phoenix FL 4020 and Phoenix FL 6020 large-format fibre laser cutting machines, including options for an automated load/unload system and a range of Compact Tower (CT-L) solutions for the Phoenix FL 4020.

The flexible automation systems keep pace with the high-speed cutting of the Phoenix laser and reduce material handling and preparation time to maximise machine productivity. They also facilitate fully automated, lights-out processing.

The load/unload automation system available handles maximum sheet sizes of 4 m x 2 m (Phoenix FL 4020) and 6 m x 2m (Phoenix FL 6020) and material thicknesses from 0.8 mm to 25 mm.

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### AMADA'S NEW LASER/PUNCH COMBINATION

AMADA has developed a new fibre laser/punch combination machine that is capable of delivering the ultimate in production flexibility to any subcontractor or OEM faced with manufacturing a high mix of sheet metal components. Among the new features of the EML-AJ are a number of innovations that help to minimise operator input. For instance, as standard the machine comes with an automatic nozzle changer, an automated scrap conveyor that prevents any possibility of overfilling, and an automatic laser cutting plate cleaner to remove any spatter created by the laser profiling process.

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### LIGHT LASER CLEANING BY ANDRITZ POWERLASE

The new Vulcan handheld tool from ANDRITZ Powerlase is compact and lightweight, weighing just under 2kg. This makes it easy to reach through openings and confined spaces, and allows users to clean for longer periods. This ultra-light handheld packs the worlds highest pulse energy and average power delivered by a commercial laser cleaning machine on a handheld device. It can be readily deployed for working on cranes, lifts, conveyor belts, mining, power plant equipment, and oil and gas installations.


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## LASERAX'S NEW PATENT-PENDING PROCESS

For the past three years, laser experts at Laserax have been working to provide die casters with foolproof traceability systems that are able to mark permanent identifiers directly on the castings. Now, with Laserax's patent-pending laser marking process, it is possible to identify parts right out of the die and feature tracking codes that will resist any post-process treatments, including shot blasting.


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## ANCILLARIES

## NEW GALVO SCANNER FROM AEROTECH

Aerotech introduces the AGV-SPO, a new high-performance galvo scanner. It offers a larger field of view than conventional 2D scanners, reduces laser spot distortion, and is flexible enough to accommodate a wide range of laser wavelengths thanks to a large variety of mirror surfaces. As a result, the laser scanner is suitable for a wide range of applications, from Additive Manufacturing to medical devices.


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## EDGECAM INTRODUCES NEW AM MODULE

Responding to the increase in hybrid manufacturing, the latest release of Edgecam introduced a new Additive Machining module. Supporting the Direct Energy Deposition method, Edgecam now offers a dedicated manufacturing cycle which accurately guides a laser as it deposits material to form a shape.

**Marc Freebrey**
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## SCANLAB ADDS NEW POWER CONTROL

SCANLAB GmbH adds more materials-processing power control capabilities to XL SCAN, the combined solution for simultaneously controlling scan heads and XY stages. New features offer control capabilities such as constant pulse intervals and deflection-angle-dependent energy densities.

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## NEW FROM SIMPSON TECH - RADIUS 2 IN ONE PASS

Q-Fin Quality Finishing Machines from The Netherlands introduces the new SER600 Super Edge Rounder. This machine is specially designed to apply a 2 mm radius on steel in one pass, with a speed of 1 m/min. The SER600 with magnetic conveyor belt is suitable for working steel sheet metal parts up to 600 mm wide, with a material thickness of 4 to 150 mm.


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# FRIENDS YOU CAN RELY ON


There are a few things that seem like indispensable tools in the 21st century. You might have seen the flow diagram which is often posted on social media with a title like “Engineer’s Flowchart” which leads to two ubiquitous tools (that I also swear by): WD40 to make things move and Duct (or Duck) Tape to stop them moving. I have personally used WD40 to free seized-up locks, polish a slate fireplace, remove sticky tape residue from plastic and many other things.

The best thing about Duct Tape is I can rip pieces off without needing to find scissors or a knife. A third tool that also stops things moving – and would be on my desert island wish-list is the humble set of Mole Grips or vice pliers. These can substitute for adjustable spanners, hold things together while they are glued, open jam jars and squeeze things much tighter than fingers. The last time they saved my skin was when I had to stop a radiator dripping and nothing else did the trick like a tightening tweak from the Mole Grips on the offending nut.

I discovered a new favourite thing a couple of years ago, which goes by the typically American name of “Bar Keepers Friend” (yes it’s a scandal there is no possessive apostrophe!). This magic white powder in a can, which looks a little 1950s, is actually safe to use as long as you don’t put it into your eyes or eat it.

Oddly, I don’t remember how or where I first learned about it – or even where or why I originally bought it. Probably I was looking to clean stainless steel in the kitchen or something – I soon discovered it could be used on metal, glass, china and enamelled cookware. Once used, never forgotten, and when I was looking to take some close-up photos of laser cutting samples (in brass, steel, copper etc.) I found that a quick wipe with this on a damp cloth could remove rust, oxide or tarnish and make them look as shiny as new! If your sample case needs a spring clean, why not give it a go? I guess every laser based “Apps Lab” should have some…

The moral of the tale is perhaps that finding friends (be they useful objects or people) and keeping them handy, can make life easier and solve many problems you can’t work out on your own.

Dave MacLellan
*dave@ailu.org.uk*

# DIAMONDS ARE FOREVER… LASER MARKED

Luxury jeweller Tiffany & Co is adopting a new approach to the sale of its diamonds by marking sure their source can be traced. In a first for the industry, the American jeweller has begun a scheme adding a serial number to every diamond it sells.

The company is using laser technology to mark each precious stone with a T&C serial number, which will be invisible to the naked eye. Each gem will be individually registered and customers will be able to find out the specific region or country from which the stone was mined.

From February, every diamond certificate will include its provenance. By 2020, they will also be able to learn where it was cut, polished and set. And eventually, the company hopes to share the name of the mine where it was found, who shaped its contours and the jeweller who secured it in its setting.

Alessandro Bogliolo, CEO of Tiffany, told The New York Times the decision had been made to offer more information as consumers became more concerned about provenance of goods.

Many customers are concerned about the use of child labour to mine the diamonds or the profits financing wars or terrorism. “It’s relevant nowadays for customers”, Alessandro Bogliolo, CEO of Tiffany, told The New York Times. This scheme aims to ensure they can trace the stone and know it was ethically sourced and “conflict free”.

*Credit: Tiffany & Co*

Source: https://inews.co.uk/news/consumer/tiffany-co-diamond-marking/

# AILU WORKSHOPS

**Presentations, Exhibition, Networking**

## Lasers for Makers

22 May 2019

Venue

Plexal,
Here East
14 East Bay Lane
Queen Elizabeth Olympic Park
Stratford
London E15 2GW

Preliminary Programme

| | |
|---|---|
| 9.00 | Registration |
| 10.00 | Welcome and introduction to Plexal & Eagle Labs |
| 10.20 | Introduction to lasers – what can they do? Overview of laser processing applications |
| 10.40 | Let's talk about laser cutting: how lasers cut, wavelength of light vs. materials |
| 11.00 | Keeping lasers safe: eye & skin safety, cutting fumes, fire hazards |
| 11.20 | Case studies of successful businesses |
| 11.40 | Getting the most out of your laser cutter: software, tips and techniques |
| 12.00 | Lunch & Networking with suppliers/exhibitors – demonstrations of systems |
| 13.30 | Q & A Forum: ask the experts |
| 14.30 | Tour of Plexal (optional) |
| 15.00 | Close |

Save the Date - 06 June 2019

## Laser Applications in the Nuclear Industry

Venue

National College for Nuclear (Northern Hub)
Lakes College
Hallwood Road
Lillyhall Business Park
Workington
Cumbria
CA14 4JN

www.ailu.org.uk/events

| DATE | EVENT | LOCATION |
| --- | --- | --- |
| 05 March 2019 | Manufacturing in Aerospace Open Day | Renishaw Innovation Centre Gloucestershire |
| **20-21 March 2019** | ILAS 2019<br>6th UK Industrial Laser Symposium<br>AILU | **Crewe Hall, Crewe** |
| **22 May 2019** | **Lasers for Makers Workshop**<br>AILU | **Here East, London** |
| 21-24 May 2019 | 8th international congress on Laser Advanced Material Processing (LAMP)<br>LAMP2019 | Hiroshima, Japan |
| **06 June 2019** | **Laser Applications in the Nuclear Industry Workshop**<br>AILU | **National College for Nuclear Cumbria** |
| 23-27 June 2019 | LiM 2019 – Lasers In Manufacturing<br>WLT LiM 2019 | Munich, Germany |
| 24-27 June 2019 | Laser World of Photonics<br>LASER World of PHOTONICS | Munich, Germany |