ISSUE 106
AUTUMN 2022

AILU

THE LASER USER

IN THIS ISSUE:

Basics of Laser Safety

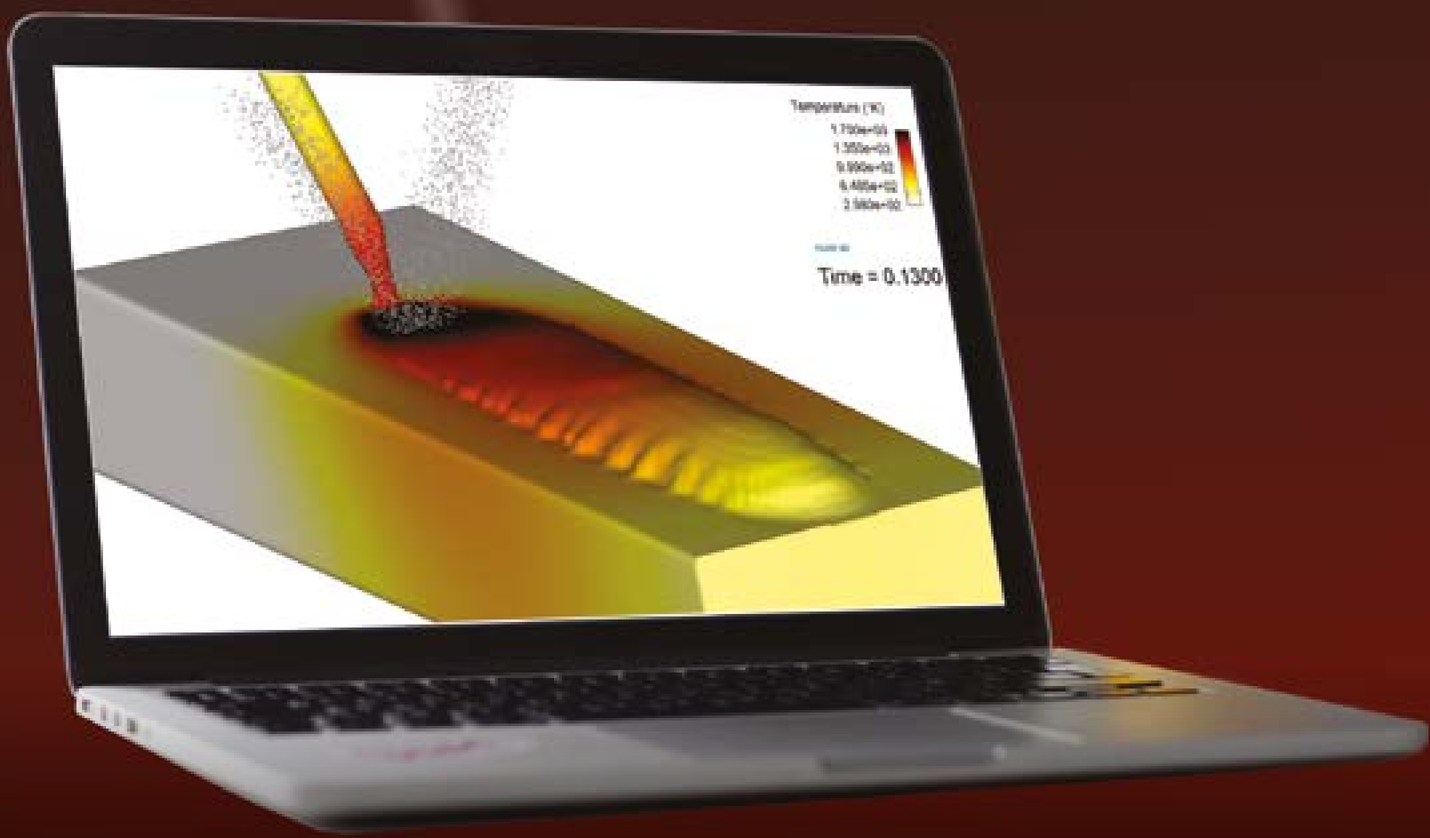
Surgical Additive Manufacturing

Blue Laser Welding of Copper

Ultrasonic Aluminium Welding

Mould Tool USP Micro Engraving

USP X-Ray Photon Emission



HIGH POWER LASER WELDING:

BEAM SHAPING, ULTRASONICS & AUTOMOTIVE 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.

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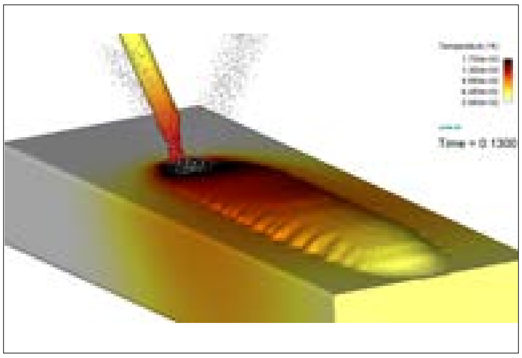

Cover image: Melt pool simulation of wire/powder deposition additive manufacturing in FLOW-3D AM

Courtesy Flow Science UK Ltd

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WELCOME TO NEW AILU MEMBERS

EKSPLA
Lukas Rimgaila

Flow Science UK Ltd
Mark Keating

Lasertec BV
Marco Bak

Optoman
Lukas Ceizaris

Trident Power Cleaning Ltd
Mike Allpress

UKAEA
Chris Peters

Woodrow Scientific
John Clowes

ASSOCIATION OF INDUSTRIAL LASER USERS

AILU STEERING COMMITTEE 2022-23

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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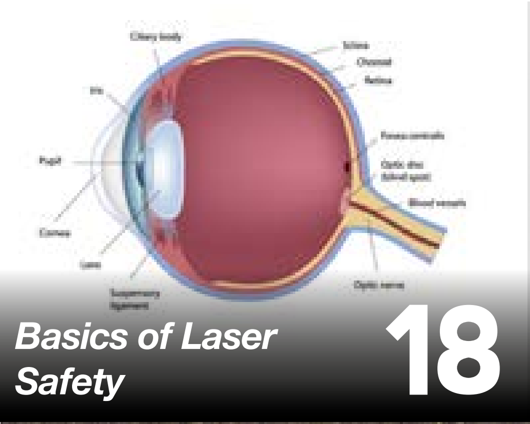

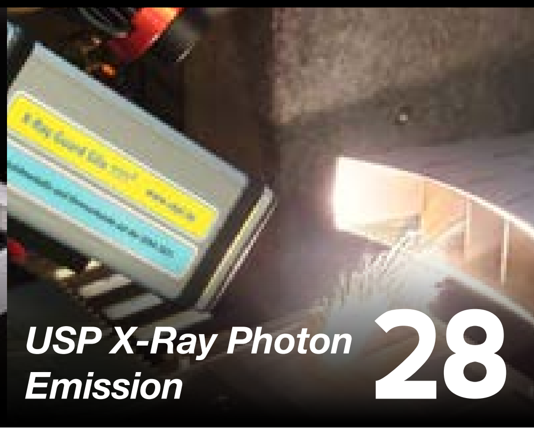

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ASSOCIATION NEWS

FIRST WORD

Between our last issue and ILAS 2023, we have a very busy period of events and look forward to seeing more members as presenters, delegates and exhibitors. Particularly exciting is the development of our Early Careers Researchers Group which sees them presenting to each other (and other delegates) on the topics of their research. As they return to meeting in-person, it is great that they get to know each other and form working relationships and friendships that I expect in many cases will last for the rest of their careers.

Diversity and inclusion are enhanced by our younger members, and I am particularly excited that we have an equal number of female authors as male authors for the 6 articles in this issue. It would be great to see the number of female members increase to redress the typical balance of our industry and events (we normally have 80-90% male audiences and presenters). Please help me to encourage new and notable speakers for ILAS and our other workshops. I am always disappointed to attend events with an all-male platform – it is never by design! I look forward to seeing you at ILAS or before.

Finally, as we prepare for our Job Shop Annual Business Meeting, I would like to take this opportunity to thank Mark Millar who has been the Chair of this group since 2015 and is now standing down. Mark has also served on the Steering Committee and been a strong supporter of AILU through the years and I personally really appreciate all that he has given to AILU. If you run a laser job shop, make sure you come along to the meeting this year –to learn about improvements to your business as well as network with peers and suppliers.

Dave MacLellan
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PRESIDENT'S MESSAGE

Greetings and welcome to another issue of The Laser User magazine. I am writing this month's welcome from British Columbia where I have recently started an academic position after 13 years at the University of Nottingham. Most of this time was spent as an AILU member during which I have seen several changes in the commercial and research landscapes associated with laser technology. In some ways the laser has become "de rigueur" in the high value (and not so high value) manufacturing sector and this can be attributed to three principle factors in my mind; i) increased competition and new technology reducing prices for laser sources, ii) significant advances in the ancillary technologies (controls, safety, optics) which facilitate uptake, and iii) the incorporation of lasers into automated production solutions. Now that 'we' and 'the laser' are no longer 'outsiders' where can AILU go from here?

As I make a new start professionally, I am reminded that my time as President of the Association will come to an end in 2023. This provides an opportunity to strategically consider how we serve our members and the laser industry better. Since summer 2021 Mike Poulter, Dave MacLellan and I have been giving this careful consideration and have been in discussion with stakeholders across AILU. Working with these members we are forming proposals as a board, to consider opportunities to work with peer group trade organisations to elevate our position in the broader landscape of manufacturing technology. This is very much a work in progress and we hope to report more news early in the New Year, but we are optimistic this will allow our membership new opportunities in laser business and innovation.

Adam Clare
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RIC'S RAMBLINGS

Now that the nights are fully drawing in and the house lights and heating are reluctantly switched on, I would like to talk about energy. Not just any old energy, but Fusion Energy. Yes, this is the thing that as the joke goes is always 30-50 years away. I recently attended Fusion 22 - a one-day event organised by the Fusion Cluster. The first thing that struck me was the large number of attendees - some 200 or so in person at the Science Museum in London and a further 800 people online - gathered together to talk about something that not that long ago attracted the attention of a very few select plasma physicists. Clearly something big has happened between now and 20 odd years ago when I was dabbling with high power lasers to try to work out the physics of Fast Igniter Fusion. That big thing, I am now convinced, is need! Goodness me we are in need of a serious energy revolution - 2050 when we are supposed to be net zero is less than 10,000 days away.

For the uninitiated, fusion is the process whereby you get a shed load of energy (hopefully more out than you put in) by fusing deuterium with tritium (other fusion reactions are available). This process essentially generates heat that in turn boils water to generate steam that drives a turbine and produces electricity. Hey presto and away you go… Problem is it turns out that you need the product of temperature x density x time to exceed a certain value and typically that means temperatures of around 100 million degrees! It is after all the process by which stars, including our very own sun, shine. Here on earth making that happen is not easy. Containing the plasma has been likened to trying to squeeze jelly together with your hands - we all know how that ends up. There are lots of different schemes, the main 2 being magnetic confinement (tokamaks) and inertial fusion (lasers).

The good news is that recently there have been big scientific and technological breakthroughs in both fusion schemes that indicate that we really might have a working fusion based power station in the not too distant future. Encouragingly there are also quite a number of fusion start-up companies that are attracting significant investment so the momentum is really building now.

So why am I banging on about Fusion? Well there are massive opportunities for lasers, optics, photonic based systems, not just the high power lasers required for inertial confinement but also lasers for use in new materials development and characterisation, surface modification, welding, micro-machining, diagnostics… the list goes on. I would encourage you to take a look at the fusion landscape and see if there is anything in it for you and your organisation. Fusion is coming and we in the laser industry should be ready to take opportunities and be part of this incredibly exciting and game changing energy revolution.

Ric Allott
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WHAT'S NEW AT AILU!

THE STEERING COMMITTEE'S INTERNAL ENGAGEMENT WORKING GROUP

Paola De Bono, TWI

Danijela Rostohar, Coventry University

Tian Long See, MTC

Members of the AILU Steering Committee have been actively working together to set a clear direction for AILU's future growth and development, defining its Purpose, Vision, Mission and Objectives. The Summer 2022 edition of the AILU Magazine (Issue 105) shared initiatives promoted within the External Engagement Group, led by Matthew Wasley (Innovate UK), focusing on external opportunities with Institutions, Photonics Associations and events. I am coordinating another flourishing initiative - the Internal Engagement Group - with the support from Tian Long See (MTC) and Danijela Rostohar (Coventry University). Dave MacLellan and Simon Hutchinson of AILU are also closely involved with the Group.

The Internal Engagement Group is focusing on the following objectives:

- To run best-in-class events such as workshops, business meetings and ILAS, to enhance awareness.
- To facilitate the sharing of best business and operations practice for laser users.

We have been working together to define a framework for action, with the intention of providing first class services for existing and potential new AILU members. These include:

- The establishment of an effective engagement platform, offering themed/targeted workshops (industry sector needs-related or technology/process/innovation-related). More details on events can be found on the AILU website.
- The establishment of an AILU Photonics knowledge database, available to its members. This has the goal to provide access to interesting articles/reports/events. The AILU website already offers the opportunity to access a series of past workshops and webinars across a range of photonics based topics. And of course, there is The Laser User offering members an excellent window to novel research and technology articles, on which the laser community is focusing.
- The opportunity to expose students/early career members to the laser community, within the UK and beyond. The AILU Early Career Researchers Committee has been setup to increase the visibility and engagement of younger members within AILU.
- Access to a dissemination platform, enabling promotion of Member's new offerings through AILU's social media pages, the monthly newsletter and the AILU magazine.

The Internal Engagement Group has been active in achieving its objectives through collaboration with other Photonics-based European Organisations. These include collaboration between AILU and the Bavarian Laser Centre (BLZ, Germany), and the European Federation for Welding, Joining and Cutting (EWF, Portugal).

AILU's mission is to support the progression and acceptance of laser technology through raising awareness of laser technologies and applications. As well as fostering research and development of new/existing laser technology and applications.

Both the Internal and External Groups are working hard to achieve the above, through multiple interactions with our Members and the wider Global network. Support from Members to capture areas of interest is also very important for us. We are keen on hearing from our Members on any ideas/initiatives you feel should be included.

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Internal Engagement in action at recent AILU events: L-R Laser Surface Texturing (Cranfield University), High Power Laser Welding (MTC), Sources & Beam Delivery (TRUMPF Lasers)

BUSINESS NEWS

II-VI REBRANDS AS COHERENT

COHERENT

II-VI Incorporated has announced a corporate name change to Coherent Corp. At the same time, the company launched a new brand identity, following the successful completion of II-VI's acquisition of Coherent Inc. on 1 July 2022.

LASEA ACQUIRES LASER CHEVAL

The LASEA Group announces the acquisition of LASER CHEVAL, located in Marnay, France. Continuing on its growth trajectory, LASEA consolidates its strong position in Switzerland and France and extends its offer in welding and marking applications.

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BOFA LAUNCHES NEW FILTRATION PODCAST

BOFA International has launched a new podcast series highlighting innovation in portable industrial fume and dust filtration.

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SSLS BECOMES UK REP FOR CORACTIVE

SS Laser Solutions (SSLS) has joined forces with OriginTec to supply Coractive fibre laser sources in the UK. The SSLS/OriginTec agreement will allow UK fibre laser users to upgrade exisiting sources with Coractive products.

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NUBURU WINS US AIR FORCE CONTRACT

NUBURU has been awarded an Innovation Research contract to develop a blue laser-based 3D printing solution with area printing technology. The new class of 3D printers will aim to offer micron level resolution, increased part size and metal density, up to 100X build speed.

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GROWTH AT SCANLAB

SCANLAB GmbH is extending its company building in Puchheim. By doing so, the company is paving the way for continuous growth while also increasing its production capacity.

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CAILABS MOVES TO NEW PREMISES

To support growth of more than 60% per year in recent years, Cailabs is moving into new premises in Rennes. This move doubles the surface area of the SME.

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CUT-TEC INSTALLS 3 NEW BYSTRONIC FIBRE LASERS

It has been a year of big investment for Cutting Technologies, who recently installed 3 new Bystronic 6 kW fibre lasers. As part of its £2 m investment plan, Cut-Tec will soon be installing a Trotec laser, suitable for high volume cutting of woods and plastics.

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OXFORD LASERS CELEBRATES 45 YEARS & RETIREMENT OF ANDREW KEARSLEY

On 5 October, Oxford Lasers celebrated 45 years in business with a party at their Didcot, UK headquarters. Around 70 past and present employees of the company met to share memories of the growth of the company, enjoy afternoon tea together, and wish Andrew Kearsley well on his retirement.

Alan Ferguson hosted the event (Martyn Knowles the CEO, still testing positive for COVID, watched on over Teams from home) and welcomed the visitors. Alan introduced Colin Webb, who led a laser research team at Oxford University in the 1970s and founded the company with a small team including Andrew Kearsley who was a PhD student under him. Andrew invented the “automatic pre-ionisation” technique used in rare gas halide lasers, while still at Oxford University. This invention enabled the early laser technology to be exploited, initially in research labs. Colin shared anecdotes on the first decade of the company and Andrew described the period of re-focus in the company in the 1990s when they introduced micromachining as a new pillar of the business.

One of the key insights was the history of the development of the trepanning head which was able to drill perfectly circular holes (a huge improvement on the XY motion system in use at the time) by the novel method of rotating a wedge optic. Andrew worked on this innovative concept and the first prototype was assembled using cardboard tube, the bearing from a trolley and his fingers to rotate the wedge slowly and verify the results.

After the speeches, Andrew cut the celebration cake (design inspired by a 1970s excimer laser) and was presented with a plaque to commemorate the occasion which included a piece of copper from the last ever Copper Vapour laser built by Oxford Lasers.

The event ended with a gift for attendees and the option to tour the factory, where a visit to the latest inspection and micromachining labs gave an insight into some of the applications in micromachining and laser imaging of droplets.

Oxford Lasers were one of the founding members of AILU. Colin Webb received the prestigious AILU Award in 2003 and Andrew Kearsley received it in 2017.

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MAZAK CELEBRATES 35 YEARS IN UK

Yamazaki Mazak celebrated 35 years of UK manufacturing. The manufacturer first opened the doors of its European Manufacturing Plant in Worcester, in 1987. During that time, the site has produced over 30,000 machine tools.

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20TH ANNIVERSARY FOR PRO-LITE

Pro-Lite Technology Ltd celebrated its 20th anniversary in September. From humble beginnings, Pro-Lite has grown substantially and today employs over 30 staff based in four countries.

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BYSTRONIC'S SUCCESSFUL INNOVATION WEEK

Bystronic UK welcomed over 100 people to their Innovation Week at the beginning of October, held at the Coventry facility, and were pleased to receive customer orders as a result.

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ALE LASER ENGRAVER DOUBLES PRODUCTION

India-based Acme Rolltech has added a second ALE engraving machine to double its production capacity for anilox rolls and sleeves.

Started in 2019 by three childhood friends, Acme Rolltech claims to be the first Indian company to manufacture ceramic anilox rolls and sleeves in India. The company provides its products to narrow web flexo, offset, corrugated, stack flexo, CI flexo and film coating line segments.

Sandeep Sharma, director of Acme Rolltech, says: 'Our USP is quality and service lead time. Previously, anilox rolls in India were imported from Europe, the US and China, so the lead time was 45-60 days or more. We provide our products within 15-20 days.'

The new engraving machine was supplied by UK-based Applied Laser Engineering. The order was placed in 2021 and the machine is now at the company's plant in Ahmedabad. Acme will also add new equipment for pre- and post-processing. The new investment will allow Acme Rolltech to double production from 200 to 400 anilox rolls a month. Half of that total goes to narrow web labels and the rest is split between the other segments.

Acme has introduced two new products – anilox rolls for high opacity white ink to replace screen printing with a raised embossing effect. Additionally, Acme plans for the new machine are to introduce next generation heavy deposition coating rolls for films and paper flexo and offset coating applications.

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ADDITIVE COMPANY INVESTS IN SECOND TRUMPF TRUDISK LASER

Laser Additive Solutions Ltd (LAS), a rapidly expanding provider of laser processing services, has invested in its second TRUMPF TruDisk high-power solid-state laser. Featuring two fibre heads, the new laser will allow LAS to add 3D laser cutting to its ever-expanding portfolio of processes.

LAS typically handles high-integrity, high-value parts, including many for the aero-engine sector. Power generation turbine repairs are another key revenue stream, along with the repair and welding of nuclear industry parts made from exotic metals. The oil and gas market is also strong. LAS recently had a large industrial pump component on one of its machines that measured 6.5 m long and weighed around 1 tonne. The machine rotates the part at a speed suitable for the laser cladding application.

"In addition, we undertake collaborative research projects within the UK and Europe," says Mr Brown. "That's the reason for our acquisition of a new TRUMPF TruDisk laser: we won a project from BEIS [Department for Business, Energy and Industrial Strategy], the part-funding from which allowed us to invest."

The TruDisk 3 kW laser is at the heart of a new system that can perform a variety of different tasks: laser additive manufacturing/cladding to build/repair parts using powder or wire; laser welding; and laser hardening.

LAS has integrated its 3 kW TRUMPF TruDisk with a high-specification KUKA robot to provide a fully automated, multi-purpose laser processing system and has retained its original 2 kW TruDisk, which still runs continuously, day-in, day-out. "We had it serviced just the other week and got really encouraging feedback – the laser is still in very good condition, despite working really hard for the past seven years," says Mr Brown.

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www.trumpf.com

ILAS 2023

8th Industrial Laser Applications Symposium

22-23 MARCH 2023

www.ilas2023.co.uk

Mercure Daventry Court Hotel, Daventry, NN11 0SG, UK

PLENARY SPEAKERS

Cristina Hernandez-Gomez
STFC, UK

Emerging new laser infrastructures in high power lasers and their applications

Andrés-Fabián Lasagni,
Fraunhofer IWS, Germany

Large area functionalisation of surfaces using Direct Laser Interference Patterning, new approaches and perspectives

Yasuhiro Okamoto
Okayama University, Japan

Recent topics of laser applications in Japan and high-quality Cu/Al laser welding

ATTEND ILAS

- Register now before the 10% Early Bird Discount ends on 16 December 2022
- 100% of delegates surveyed at ILAS 2019 said they would recommend ILAS to colleagues. Attending ILAS allows you to keep abreast of the latest developments in laser technology and applications in the company of your peers
- ILAS delegates are a 50/50 split of academic and industrial sectors; ILAS is a great place to meet potential collaborators and make business connections.
- 27 Exhibitors will provide laser sources, hardware, optics, motion systems and turnkey solutions

PRESENT AT ILAS

- We have a few spaces in the programme for oral presentations and lots of space for Poster Presenters. Contact AILU now if you have missed out on the opportunity to make an oral or poster presentation.

SOCIAL PROGRAMME

- A drinks reception alongside Posters presentations will be followed by our sumptuous Symposium dinner, at which we will be presenting 4 AILU awards to honour some of our members.

EXHIBITORS

Aerotech	Ekspla	Laserline	PowerPhotonic
Amplitude	Flow 3D	Lasermet	Pro-Lite
Brinell Vision	Hamamatsu	LBP Optics	SMC
Carrs Welding	IPG Photonics	Optoman	TLM Laser
Civan Laser	Laser Lines	Photonic Solutions	TRUMPF
Coherent	Laser SOS	Photonics Express	Woodrow Scientific
Cyan Tec Systems	Laser Trader	PI (UK)	

PROGRAMME

Wednesday 22 March	Thursday 23 March
Opening Plenaries	Beam Delivery
Laser Welding	Discussion Panel
Laser Marking & Ablation	Laser Cutting
Additive Manufacturing	Additive Manufacturing
Systems & Automation	Laser Cleaning
Surface Engineering	Surface Engineering
Microfabrication	Microfabrication
Poster Drinks Reception	Laser Sources
Symposium Dinner & Awards	Closing Plenaries

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Register now at https://ilas2023.co.uk/registration

METAL BINDER JETTING VS LASER POWDER BED FUSION: A COMPARISON

Additive manufacturing technologies build high value products layer-by-layer, allowing manufacturers to generate customised, relatively complex geometries with less material wastage and shorter lead times. Among the most promising metal-based additive manufacturing methods are Laser Powder Bed Fusion (L-PBF) and Metal Binder Jetting (MBJ).

The key difference between the two technologies lies in the mechanism used to form successive layers. While L-PBF employs a laser beam to selectively melt and fuse the powder to form successive layers, MBJ is a method of selectively binding together powder particles in a powder bed by using a liquid binding agent in room temperature atmosphere condition. MBJ is gaining popularity as an alternative powder bed AM technology, not only because of recent advancements in reaching high densities for metallic components, but also because of its ability to create parts without any support structures. Table 1 below shows the major pros and cons between MBJ and L-PBF technologies.

Binder Jetting (BJ) is a multi-step process in which post-processing steps (curing and sintering) are required. Wider choice of materials compared to other PBF technologies, however, post-processing, for most of the materials is still under development. BJ has no issues related to oxidation, residual stresses, elemental segregation, and phase changes as parts are sintered close to the material's melting point.

One of the major advantages of this process is the high production rate, capable of producing a high volume of parts hence cost-effective. BJ printers can produce green parts as much as 100 times faster than L-PBF systems. With a native resolution of 1200 dpi, the Desktop Metal Shop System (Figure 1) is the highest resolution single-pass binder jetting system available and can produce up to 670 million drops of binder each second. A similar system is installed at The University of Birmingham.

A major issue of BJ is the inability to predict a large amount of distortion that occurs when sintering metal alloy to full density. A common misconception about the BJ process is that it has relatively high build rates, around fifty times higher than PBF base processes. Although this is partially correct, given the higher build volume as compared to PBF processes, the BJ process itself is slightly more challenging.

One of the major challenges in the BJ process is managing and compensating for the large amount of shrinkage that occurs during the sintering step, where parts shrink 30-40% and linearly by 15-20%. The green parts are generally porous (50%) with low strength which adds complexity during the depowdering stage as manual handling by the operator can result in part breakage. Hence, MBJ is not preferred for parts of very large size, and it is limiting for very thin wall thicknesses (less than 0.5 mm) or very thick (upper than 3 cm).

Furthermore, MBJ is a multi-step manufacturing process that necessitates the employment of various types of equipment (printing machine, mixer, sieve, ovens, sintering furnace, and post-processing equipment), hence the entire system may require considerable financial expenditure including space. Although having a very satisfactory resolution, the parts experience high surface roughness and lower resolutions (0.5 to 50 μm) limited to tolerances of ±0,5% compared with some PBF AM processes.

Table 1. Pros and Cons between MBJ and L-PBF processes.

	Pros	Cons
MBJ	• Choice of wide range of materials • High scalability • No support structures are required • Being a so-called "cold" AM process, doesn't generate residual stresses • Relatively high powder recyclability • Can produce parts as much as 100 times faster than other PBF processes	• Relatively low density • Laborious depowdering step • Necessity of debinding, sintering processing • Potential distortion of the part's geometry during sintering • Currently less researched technology • Fewer machine choices
L-PBF	• High accuracy • Relatively less post-processing steps • Fully dense parts • Good mechanical properties • Ideal for bespoke part manufacturing	• High cost (machine depreciation & operation) • Significant residual stresses • Support structure (usually required) • Limitation in materials choices & part sizes • Low production rate • Large scatter band in mechanical properties

Figure 1: Desktop Metal Shop System similar to that installed at University of Birmingham (Courtesy of Desktop Metal).

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WMG
THE UNIVERSITY OF WARWICK

WMG, THE UNIVERSITY OF WARWICK

By working across the entire research and innovation cycle - from fundamental research, through applied research, to technology development - the Laser Beam Welding team at the Warwick Manufacturing Group (WMG) is enhancing understanding of the laser-to-material interaction, creating new welding strategies, and delivering in-process closed-loop control systems.

Key research findings include the elucidation of laser beam shaping on the microstructure properties of similar and dissimilar materials, and development of real-time control systems for high process capability. The breadth of industry applications includes e-vehicle manufacture and lightweight structures for the automotive and aerospace sectors.

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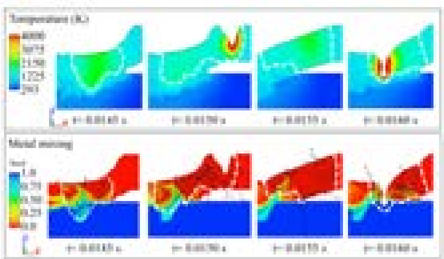
https://warwick.ac.uk/fac/sci/wmg/

FLUID DYNAMICS OF METAL MIXING DURING REMOTE LASER WELDING

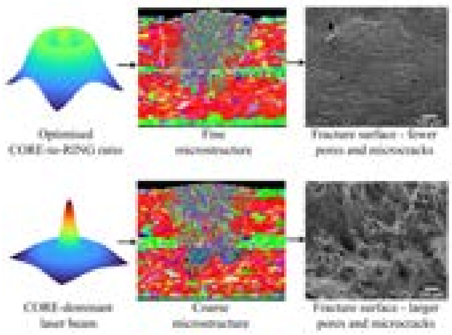


Simulated thermal field and metal mixing during remote laser welding of copper to steel

Remote Laser Welding (RLW) of dissimilar metallic thin foils has fundamental importance in battery pack manufacturing where high repeatability is a strict requirement. WMG researchers implemented a combination of CFD (Computational Fluid Dynamics) multi-physics modelling and experiments to study the metal mixing behaviour during lap welding of 300 µm copper to 300 µm nickel-plated steel, with circular beam wobbling.

The CFD model provided information about temperature fields, fluid flow and metal mixing, all of which are difficult to measure directly via physical experiments. The study highlighted that the part-to-part gap leads to uncontrolled metal mixing. Researchers concluded that laser beam shaping is a viable approach for controlling the metal mixing and hence for weld quality improvement.

GRAIN REFINEMENT OF 6XXX ALUMINIUM ALLOYS



Impact of laser beam shaping on refinement of weld microstructure

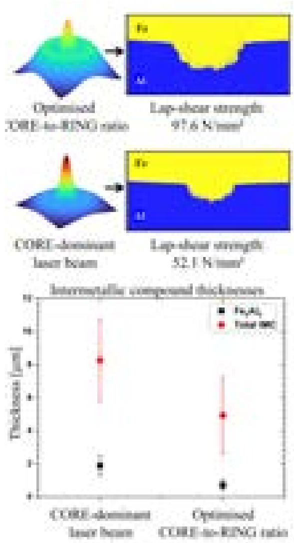
The notorious crack sensitivity of 6xxx series aluminium has prevented its wide-spread application in welded structures. Current practice in industry is to modify the chemical composition of the molten pool using filler wires, but this is limited to specific joint geometries and adds complexity and costs. WMG researchers studied the impact of an adjustable-ring-mode (ARM) laser beam to optimise the microstructure and mechanical performance of laser welded 6xxx high-strength aluminium alloy without filler wires.

Findings showed that both core-dominant beam and ring-dominant beam lead to low thermal gradient and cooling rate at the solidification front. Researchers noticed that only a proper selection of core/ring ratio restricts the formation of columnar grains near the interface boundary and allows wider formation of equiaxed dendrites and better grain refinement. The study achieved approximate 40% improvement in joint strength. This research is a first step towards fully autogenous laser welding (no filler wires) of 6xxx high-strength aluminium alloy.

ADJUSTABLE RING-MODE EFFECTS ON INTERMETALLICS

Dissimilar joining of steel-to-aluminium is undoubtedly one of the most challenging combinations that has attracted interest from researches and practitioners for decades. However, the notorious low miscibility of aluminium alloys and steel, caused by very large differences in their thermophysical properties, and the presence of brittle intermetallic compounds (IMCs), have prevented the wide-spread application.

WMG researchers implemented the adjustable-ring-mode (ARM) laser beam and explored the influence on the weld pool and metallurgical properties during remote laser welding of IF steel to 1050 aluminium alloy. Researchers found that the use of a ring-dominant beam significantly reduces the amount of the brittle Fe_2Al_5 IMC, in contrast to a core-dominant beam. The findings are significant to accelerate adoption of dissimilar material structures, across a wide range of applications, from structural parts in automotive bodies to tabs and connectors in battery systems.

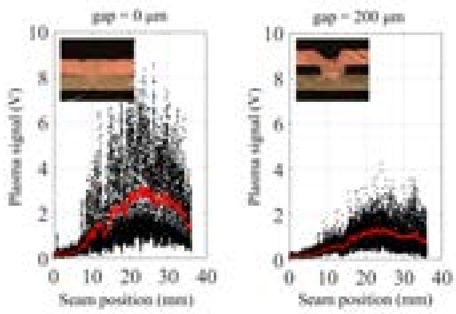


Impact of laser beam shaping on intermetallics

AUTOMATIC CLASSIFICATION OF LASER WELD DEFECTS

There is undoubtedly a gradual transition towards autonomous laser welding systems brought on by tools from Industry 4.0 such as Machine Learning (ML) / Artificial Intelligence (AI). Sensor technologies play a pivotal role since they serve as the surveillant of the process. WMG researchers studied whether photodiodes and supervised ML algorithms are sufficient to automatically classify weld defects caused by simultaneous variation of part-to-part gap and laser power during remote laser welding of thin foils, with applications in battery tabs assembly.

Researchers obtained up to 97% classification accuracy. The study highlighted the importance of further investments in ML/AI and sensor fusion, along with real-time multi-physical simulation, to enable safe and trustable intelligent decision-making systems.



Photodiodes data streams used to train ML/AI algorithms. Application in battery tabs welding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ECR COMMITTEE UPDATE: NEW MEMBERS

MARTIN BUCKTHORPE
UNIVERSITY OF SOUTHAMPTON

Martin is currently studying for a PhD at the Zepler Institute, University of Southampton. The aim of his research is to investigate power scaling methods of Thulium-doped silica fibre lasers emitting at two-micron. He is also studying the application of this technology to several industrial applications.

Martin has previously worked in the UK defence sector, developing and testing optical and laser-based platforms for a range of defence applications.

DANIEL WILSON
UNIVERSITY OF MANCHESTER

Daniel is a specialist technician who has worked in the LPRC at the University of Manchester for the previous eleven years. His role in the University is to build and maintain lasers systems, as well as to support students with the analysis of their samples.

Daniel is currently working towards completion of his PhD on the theme of analog control methods for lasers with the view to manufacturing stereo audio records for turntables using a single laser beam.

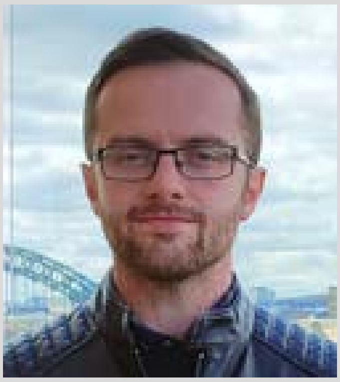
TIANZHU SUN
UNIVERSITY OF WARWICK

Tianzhu is an assistant professor at WMG, the University of Warwick. Prior to joining WMG, he received his PhD in Metallic materials from the University of Manchester.

His research activities are focused on advanced joining techniques for automotive alloys. In particular, he is interested in understanding relationships between microstructure and properties in laser welding and friction stir welding processes.

Tianzhu has worked extensively with the automotive industry on developing new welding strategies across the entire research and innovation cycle- from fundamental research, through applied research, to technology development.

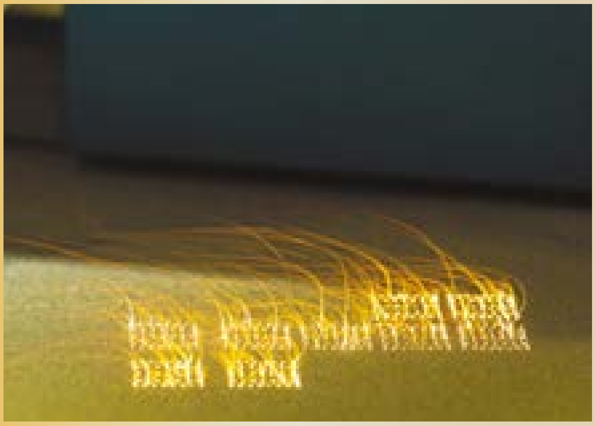
DONALD RISBRIDGER
HERIOT-WATT UNIVERSITY



Donald graduated from Heriot-Watt in 2017 with a MPhys degree.

His ensuing PhD project at Heriot-Watt investigated ultrafast laser resection of biological tissues using various beam geometries.

Donald is currently undertaking a research position within Heriot-Watt looking at implementing a robotic arm to automate the alignment of various laser systems. He has also worked within NHS Medical Physics departments and been awarded a Carnegie Scholarship for optical tweezing work.



EARLY CAREER RESEARCHERS SEMINAR

Wednesday 30th November

University of Nottingham

The ECRs are holding a morning seminar followed by a tour of the Additive Manufacturing facilities at the University of Nottingham's Institute for Advanced Manufacturing. Members of the Committee will give short presentations highlighting the current focus of their research or application area.

Free to AILU Members

Register at www.ailu.org.uk/events

FINE FOCUS ON SEMICON & PHARMACEUTICAL MARKETS

AN INTERVIEW WITH MARTYN KNOWLES

CEO AT OXFORD LASERS

Q. Can you tell us a bit about Oxford Lasers?

Oxford Lasers is a solution provider in micromachining and imaging applications. It was founded in 1977 by Colin Webb and his PhD student Andrew Kearsley based on excimer laser technology they were developing at the University of Oxford. During this period Andrew invented the pre-ionisation technique, which is still used today by excimer laser manufacturers, but unfortunately did not patent it!

In the early 80s the focus switched to developing copper vapour lasers (CVLs) for uranium enrichment for nuclear power. CVLs were our core business for the next 15 years and we supplied the UK, French and Japanese nuclear power programmes. At the end of the Cold War, with enriched uranium becoming available from the weapons programme, the need for new fuel enrichment plants disappeared so we focused on high-speed imaging and micromachining as markets where we could use our CVL technology. When I joined OL in 1993 my task was to set up the first micromachining lab.

We have evolved from being a laser manufacturer to a solution provider using all laser types. We are a growing business with 65 UK employees and a US office providing systems and subcontract services for micromachining and imaging applications.

Q. You have just celebrated a 45-year milestone, what are the biggest highlights and changes?

As a company we have been privileged to have been involved with some particularly important programmes and prestigious customers. Most of this we cannot talk about because of NDAs but back in the 90s our 2 kW installation at British Nuclear Fuels was the world's highest power commercial visible wavelength laser system. Also in the 90s, one of the fun things that we did was to provide the lasers for Pink Floyd's Division Bell Tour, we also sent 2 engineers as roadies for the world tour! Today we are humbled to know that our micromachining technology plays a significant role in the manufacture of the chips for mobile phones and computers and our imaging technology in the development of pharmaceutical drug delivery systems.

> *"We have seen wall plug efficiency improvements from 2% to 20%"*

Q. You operate both subcontract processing as a service and system sales, how does that work?

It works well having both. In the early days, until about 1996, we were only offering laser sources for research and subcontract laser processing. As we focused on micromachining, it became necessary to learn about motion systems, beam delivery and software – so we could build our own systems. Supplying them to customers was a logical progression.

Offering both systems and subcontract services has advantages for us. We have a large subcontract facility with 15 micromachining systems. We process thousands of jobs through them and this experience feeds back into our system designs. Being able to develop our own systems means that we can optimise our in-house subcontract systems for the markets we work in. This is advantageous to both us and our customers.

Q. What are the biggest challenges at the moment?

Supply chain shortages and delays are the biggest issue today. Some motion control components are on 6-12-month lead times, but that extends to other components too, especially in electronics. The recruitment market is also very tight, and we have about 4 open vacancies, in engineering and software design.

Space had been a challenge for us because of the business growth. In the last few years, we have added a mezzanine to our original building and then acquired a second building and more than doubled our floorspace. This has allowed us to expand our subcontract services and R&D labs and replan our manufacturing facility to meet the next stages of our growth.

Q. Have you taken any steps towards reducing your carbon footprint recently?

With technology developments (going from CVLs to diode pumped solid state lasers), we have seen wall plug efficiency improvements from around 2% to 20%. Also, when we took on the additional factory unit, we had extra insulation added to the roof space to make it better able to retain heat in winter. We have not gone as far a solar yet, but we have replaced internal lighting with LEDs.

Q. What do you predict for the business outlook in 2023?

Next year should be extremely exciting for Oxford Lasers. We are coming to the key point in a programme with a leading semiconductor manufacturer that will result in a huge ramp up over the next 10 years, and the build of a large volume of systems.

We also have a new imaging product, the VisiSize P15+ which is attracting interest in the evaluation of spray characteristics and droplet sizes for the future application of crop-spraying by drone. Our expansion came at just the right time for our business – and facilitated better social distancing through the pandemic. We have doubled in size in the last 7 years and that rate of expansion looks set to continue.

Q. What is the best thing about AILU membership for you?

The UK industrial laser community is a small but incredibly talented group of companies and universities. In my opinion, AILU is the glue that pulls together the UK laser community and helps it to be greater than the sum of the parts – and punch above our weight. The workshops are great and provide excellent focused events with great networking opportunities. We are looking forward to ILAS again next year where industry and academia meet.

> *"AILU is the glue that pulls together the laser community"*

Contact: Martyn Knowles
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www.oxfordlasers.com

INSPIRING SCHOOL-LEAVERS TO CHOOSE APPRENTICESHIPS AS THEIR CAREER PATH

Back in July 2022, the BBC published an article entitled “Vocational qualifications: 'Societal stigma putting young people off'”. This was the conclusion of research carried out by the Department of Economy in Northern Ireland to assess public perception of apprenticeships and Level 4 and 5 qualifications.

As a company that employs many apprentices each year, it was quite shocking but also not surprising to read that undertaking an apprenticeship is seen as either failure or a ‘lesser’ choice than university. We believe that this view is outdated and is a serious issue that needs addressing both at industry sector level as well as company level.

Hutchinson Engineering posted about this on our social media in July and it obviously struck a chord with our audience as many people commented on what their experience had been as a school-leaver. The problem is complex: a lack of awareness persists regarding what an apprenticeship is, at all levels, from careers teachers, through to parents and to the students themselves. There is still a ‘snobbery factor’ in that schools and parents are proactively pushing students towards the university route. We are also competing against other industries such as tech that are seen as being more aspirational to work in.

As an industry, we need to get the message out there that apprenticeships can provide an alternative route to building a successful career, and that you earn while you learn. Students can graduate through a defined path of education, from NVQ to an HNC, HND and on to a degree. The question is, how as an industry do we inspire school-leavers to make an apprenticeship in engineering their ‘Plan A’ rather than a fall-back ‘Plan B’?

According to Statista (www.statista.com), the average student debt on graduation in the UK ranges from £13,890 to £40,280. That’s a huge amount of debt to be saddled with as you start your career. By the time the average university student graduates with this debt, an apprentice can have earned a cumulative £80,000.

It is also interesting that many university students are graduating in degrees that do not actually qualify them to do anything, so they will end up either joining a graduate programme after university, or doing a conversion course, so their training effectively lasts 5+ years, all while running up more debt.

Just this week it has been in the news that due to the cost of living, there has been an average increase of 23% in the number of undergraduates dropping out of university. Figures from the Student Loans Company show that more than 18,000 students in England, Wales and Northern Ireland withdrew from university courses and stopped receiving loans by February this year, an increase of more than 4,000 compared with the same point in 2021. Could this help tip the balance between university and apprenticeships?

How should we address the problem? At Hutchison Engineering we run different initiatives to raise awareness of careers in engineering. We recruit apprentices twice a year for our Welding Academy, where school-leavers are taken through a defined programme of training, both practical and academic. We carry out a proactive outreach programme, seeking to build long-term partnerships with local schools and attend Careers Days. This year we advertised an Open Evening across our social channels and held information sessions and factory tours as part of an increased recruitment drive. This was highly successful and something we will repeat more regularly.

We would be interested in opening up the discussion with other AILU members, to exchange ideas on what initiatives we could run at industry level and what has worked for them at a company level.

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https://hutchinson-engineering.co.uk/

CHAIR'S MESSAGE

MY FINAL CHAIRMAN'S REPORT

We seem to be going through an increasingly volatile economical period. With each Chairmans report I've written of late, there appears to be a new drama unfolding with the potential to destabilise the economy. What I would say though is, despite the latest predictions of the Bank of England saying that we may be entering into a 2 year period of recession, Job Shops are always one of first to feel the pain but also the recovery.

The latest political turmoil has of course had a dramatic effect on various markets, namely the financial markets, which will inevitably cause a ripple effect into the manufacturing sector. However all signs at the moment show sales are stable. The situation was already tough, but that is the norm for the Jobshop industry, so little has changed and therefore little to worry about for the short term at least, I hope.

Now is the time to announce that, after nearly 8 years, it is finally time for me to pass on the baton of the AILU Job Shop Chair. Over the years I have met lots of wonderful and interesting people with a passion for lasers and manufacturing plus I have managed to visit many interesting facilities and have some great experiences.

Through AILU I have had the privilege of visiting the production facilities of JCB, MINI, Mazak and SPI Lasers (now TRUMPF Lasers) to name just a few. I even got to go all the way to Westminster to help support a bid for more funding for Lasers in the UK. I have enjoyed all these experiences very much.

You may have seen me at the AILU Job Shop annual meetings, at Steering Committee meetings or read these articles in the AILU magazine. Hopefully I have managed to keep you interested and informed. I wish the best for the next willing victim who takes on the honour of becoming Job Shop Chair, but most importantly I hope that you, the members, continue to be engaged and take an active interest in the Association.

AILU is a great association with many people behind the scenes who willingly give up their time to help it develop and grow, serving as members of AILU's Steering Committee. I'm proud to have played my part, no matter how small, to help contribute to AILU's legacy and I would say to all members that the more you engage and participate with AILU the more you will get out of your membership. I hope that I will still see many of you at future AILU events but for now I wish you a fond farewell.

Mark Millar

INTRODUCTION TO THE SAFETY AND SAFE USE OF INDUSTRIAL LASERS

NEAL CROXFORD

The reduction in cost of low to medium power industrial lasers has lead to a significant increase in their use and ownership. However, understanding the safety aspects and their safe use has not kept pace with this proliferation. Most industrial lasers are no more or less hazardous than any other machine tool found in a typical workshop and they can be used perfectly safely if their hazards are known, understood and correctly controlled. However the hazards of using, say, a lathe have been highlighted from early days at school or college whereas familiarity with industrial lasers is much less common, even amongst teachers and lecturers, and the potential hazard of a large piece of spinning metal is far more obvious than those associated with a laser system.

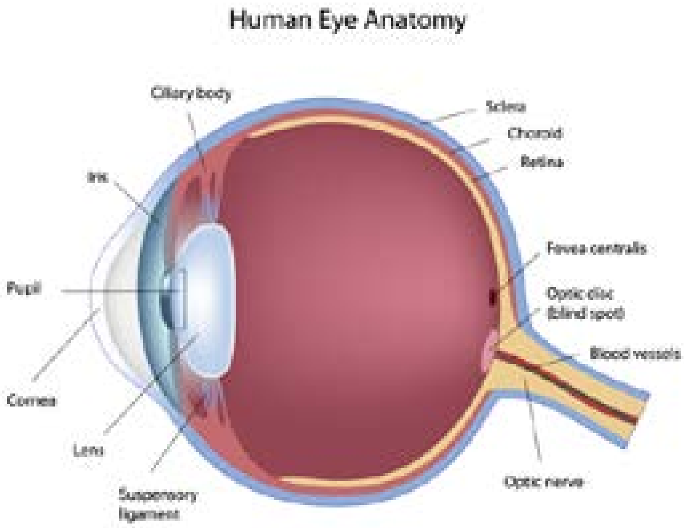

Figure 1: Anatomy of the human eye.

What are the hazards of a laser system?

The type of hazard presented by a laser system depends on its power and its wavelength. The greatest hazard is normally to the eyes because of their greater sensitivity to light compared to skin.

The two most common types of industrial lasers are fibre and CO_2. These lasers have wavelengths of 10^{-6} m (1000 nm) and 10^{-5} m (10 µm) respectively (legacy YAG and vanadate lasers have wavelength very similar to fibre lasers). Both of these wavelengths are in the infrared so it is not possible to see them with the naked eye. This makes them potentially more dangerous than even the much lower power laser pointers because it is not possible see the light or to take any avoiding action.

The fundamental quality that distinguishes lasers from other sources of light is their ability to be focused to very small spots and be collected into beams that expand (diverge) very little over large distances. This means that the intensity of light can still be harmful at significant distances from the source of light.

Fibre lasers present one of the highest hazards of any laser because the light is transmitted through the cornea and lens at the front of the eye, through the vitreous liquid which fills the eyeball and onto the back of the eye known as the retina (see Figure 1). The cornea and the lens both focus the laser light, increasing its intensity at the retina but, as it is not visible, the usual protective responses like blinking or looking away do not occur. Therefore very high intensities of light can be present on the back of the eye without the observer being aware of the danger.

Just like staring at the sun or a welding arc, light entering the eye can cause permanent damage to the retina causing blind spots, or worse still to the optic nerve which can lead to total blindness. There are currently no treatments to reverse retinal blind spots or optic nerve damage.

Long-term exposure to the light from fibre lasers can also cause cataracts in the lens of the eye, causing the lens to become cloudy and eventually causing total blindness. Cataract surgery is possible and involves replacing the lens with a clear plastic one.

The light from CO_2 lasers is heavily absorbed by the cornea, causing the surface of the eye to heat up. Long term exposure to low levels of CO_2 light causes premature ageing due to drying out of the eye's surface. Drying the surface can cause it to crack and peel in the same way as sunburn affects the skin, causing irritation which feels like rubbing sand into your eyes. In the most extreme cases the light can cause corneal burns. Damage to the cornea makes it less transparent and changes its shape causing distorted and unclear vision.

Corneal surgery is the most common type of organ transplant involving removing the damaged cornea and replacing it with a donated one.

Where are the hazards?

Because laser beams can travel large distance without expanding greatly, the intensity of the light remains high over very long distances. The laser safety standards provide methods to calculate the levels of exposure to laser light which are not hazardous, based on biological observations. For example the raw beam from a typical 20 W fibre laser remains an eye hazard for up to 3 km. This is known as the Nominal Ocular Hazard Distance (NOHD). The NOHD for a typical 80 W CO_2 laser is less than 1 km because of the lower hazard of its wavelength and its greater divergence. A raw beam must be controlled or contained in some way to allow the safe use of the laser.

Most lasers use a lens to focus the beam to a small spot which also increases the effective divergence of the beam (Figure 2). When fitted with a typical lens the NOHDs are reduced to about 25 m for a 20 W fibre laser and less than 5 m for a 80 W CO_2 laser. So, the laser beam remains a hazard for several metres from its focus, meaning that either personnel access must be prevented or the beam must be blocked in some way.

Completely enclosing the laser processing volume will obviously ensure the hazard is contained but this often is impractical or incompatible with the production process requirements.

Beam stops and diffusely reflecting panels are the most common method of creating a safe work volume. If the laser beam reflects off a part or panel in a specular (mirror-like) manner, the total beam path length would have to be the NOHD calculated above, tens of metres.

LASER SAFETY

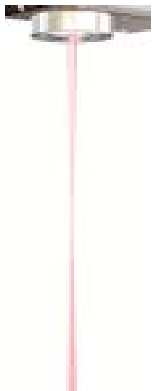

Figure 2: Divergence increases when a lens is used.

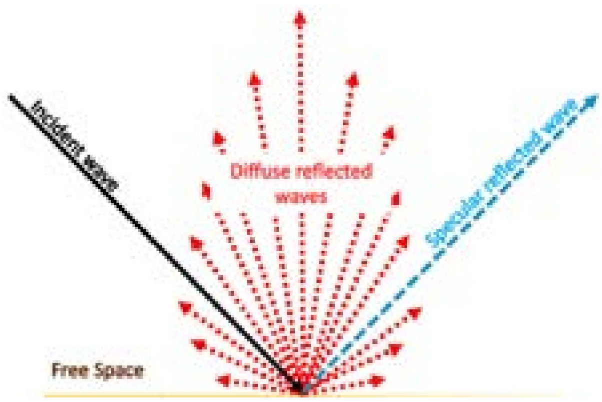

Figure 3: Effect of a diffuse reflection.

If, however, the reflection is diffuse, the power of the laser is distributed out in all directions, like the light from a light bulb. Diffusely reflected light spreads in all directions with the highest intensity being directed normal to the surface of the reflector, irrespective of the angle the laser beam hits the surface, with increasingly less power when viewing the reflection at a glancing angle to the plane (Figure 3).

The NOHDs for diffuse reflections are approximately 350 mm and 200 mm looking normal (straight down) onto the surface for our 20 W fibre and 80 W CO_2 examples, falling to less than 100 mm looking side-on to the point of reflection.

Therefore, with carefully designed beam stops, guards and panels, combined with suitable interlocks and working procedures, it is possible to design safe working cells for most laser processes.

Laser safety classification system

International safety standards' committees have developed a laser Class system dependant on the risks posed by the laser. For Europe this is given by EN60825-1, using Classes 1 to 4

The American standard ANSI Z136.1 does not give such a qualitative guide but essentially follows the same ideas. Following is a summary of Classes 1-4:

Class 1, Class 1M, Class 1C: Safe under reasonably foreseeable conditions of operation. Class 1 also includes high power lasers that are fully enclosed so that no potentially hazardous radiation is accessible during use.

Class 2, Class 2M: Emitting only visible light. Eye protection is afforded by aversion responses including the blink reflex.

Class 3R: Exposure could cause injury but injury is unlikely. Prolonged or deliberate ocular exposure is hazardous.

Class 3B: Viewing raw beams is always hazardous. Viewing diffuse reflections is normally safe. May produce minor skin injuries and ignite flammable materials.

Class 4: Even diffuse reflections are hazardous May cause skin injuries and could be a fire hazard. Their use requires extreme caution.

Most industrial lasers are Class 4 lasers BUT can be treated as Class 1 when suitable safety systems and precautions have been implemented.

Safe laser work enclosures and cells

Safety standards recommend that all lasers in excess of Class 2 are used in Class 1 enclosures. Laser system suppliers often offer Class 1 laser systems which contain a Class 4 laser, containing the hazard with suitable guards and interlocking systems.

Any company selling a Class 1 laser system takes on the responsibility of ensuring that the laser is safe to use in all reasonably foreseeable circumstances, but it is recommended that anyone purchasing a Class 1 system requests a Certificate of Conformity from the vendor which details the standards that have been considered when designing and building the laser system. If the purchaser has any doubts about the system they can also request a risk assessment from the laser system vendor which should follow the format detailed in EC standard EN ISO 12100 or equivalent and covered by the Machinery Directive 2006/24/EC.

Many laser system suppliers offer Class 4 laser systems for integration by the purchaser into a safe working environment or system. It is essential that anyone purchasing a Class 4 system requests a Certificate of Incorporation which details the standards that have been considered, and a risk assessment which will allow them to incorporate the laser into a safe working system.

Note that any person, company or organisation purchasing and/or operating a Class 4 laser system MUST appoint a Laser Safety Officer (LSO) to oversee its operation, which can be an external person or company.

There are many important considerations when designing a suitable safe enclosure including interlocking, the integrity of the materials used and their reflectivity/diffusivity, which can be very different at the wavelength of the laser compared with what is observable in the visible wavelengths.

Laser Safety Officer and Standard Operating Procedure

The Laser Safety Officer (LSO) has, amongst others, the following responsibilities:

- Coordinate acquisition of laser devices and systems.
- Coordinate and assure compliance of all lasers with standards.
- Implement appropriate engineering and administrative controls including personal protective equipment using a Standard Operation Procedure (SOP) and laser safety manual.
- Keep records of accidents and report them.
- Carry out periodic safety inspections of laser areas and laser devices.
- Provide basic training, educational material and proficiency tests for personnel
- Maintain up-to-date inventory of all lasers in the company.
- Participate in accident investigations involving lasers.

More focused laser safety topics will be covered in future articles.

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Neal Croxford of Dovecote Technologies is the AILU representative on the BSI laser safety technical committee.

SEE OBSERVATIONS P30

METAL 3D PRINTING OF STANDARD DEVICES IN THE MEDICAL INDUSTRY

LAURA KASTENMAYER

Most medical device manufacturers already have experience with 3D printing, either with metals, plastics, ceramics or biological materials (such as tissue). From this perspective, AM is not regarded as a new technology. Compared to the vast field of conventional processes, however, it is still relatively new, and it has yet to prove itself as a serious alternative in many application areas. Nevertheless, it is no longer accurate to see additive manufacturing technologies only in terms of "rapid prototyping", as within the last decade the technology has developed quite rapidly into a production solution for finished parts.

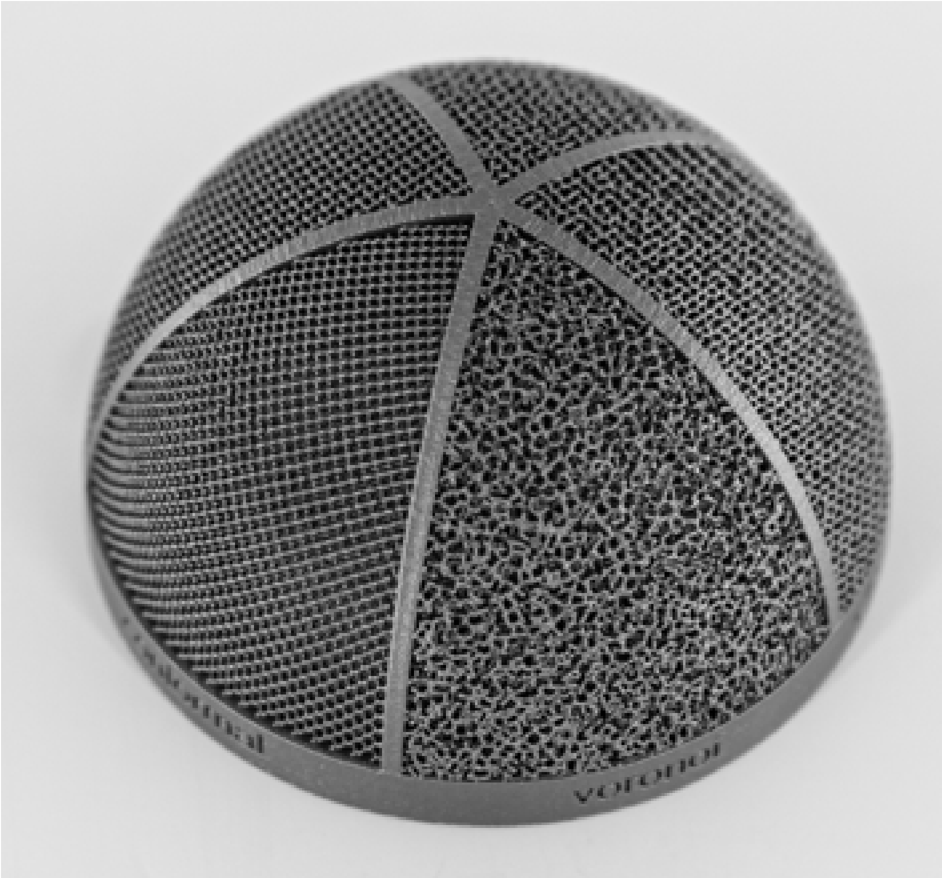

Figure1: Acetabular cup with various lattice structures to showcase the design possibilities with metal 3D printing.

This development was driven by early adopters and printing enthusiasts, but also by machine manufacturers such as TRUMPF, which entered the additive manufacturing field back in 1999. Companies becoming familiar with the medical market have launched machines that meet the needs of medical device manufacturers and some also offer advanced services to help customers with their qualification and validation process.

Additive manufacturing is best known for its design freedom, which has made the technology ideal for the production of patient-specific devices. But this is not the limit of its potential. A large number of off-the-shelf devices have proven to be a sufficient and reliable solution for patients all over the world and do not necessarily need to be replaced by a customised solution. Nevertheless, or precisely because of this, the question arises as to how 3D printing can add value to the production of these standard medical devices.

Opportunities for mass production: acetabular cups

The design flexibility afforded by additive manufacturing technology, makes it possible to significantly shorten the entire process chain by integrating the surface modification or component functionality into the printing process step.

Acetabular cups used in hip replacement procedures provide an example of the mass production of parts with integrated surface designs. These are flagship products for metal additive manufacturing in medical technology and have been printed with different surface structure characteristics since 2007 (Figure 1).

Meeting the mass production market requires an approach that significantly reduces cost per part and time to market, while maintaining a high level of quality. There are several critical process parameters that impact on a reliable and efficient production process, and many of these can be addressed through engineering improvements to the machine.

Prudent investment in advanced and robust machine designs is essential. For example, TRUMPF has focused on efficient gas flow concepts, parameter settings and stable process conditions. The company also equips its machines with state-of-the-art monitoring solutions that help additive manufacturing operators better understand their process and monitor the quality of their parts.

One technical machine development is the 500°C preheating option. This feature raised the limits of production capacity in metal powder bed melting to a new level without the need to add further laser sources. Using the acetabular cups as an example, the effects of 500°C could be optimally exploited by significantly reducing the number of support structures and stacking the components in multiple layers (Figure 2).

Optimising the production process saves material costs and reduces part costs in series production when the system is utilised to the maximum. The use of 500°C preheating for titanium and advanced parameter setting also ensure that quality is not compromised at maximum production capacity.

Mould inserts for plastic injection moulding

It is not only titanium, widely used for orthopedic implants, that has benefitted from the advances in printing technology in recent years. For example, preheating the build plate to 500°C allows the processing of high-carbon materials such as hot work tool steels 1.2343 (H11) and 1.2344 (H13). One might initially think that this is of no interest to the medical technology industry, but hot work steels, as well as stainless steels

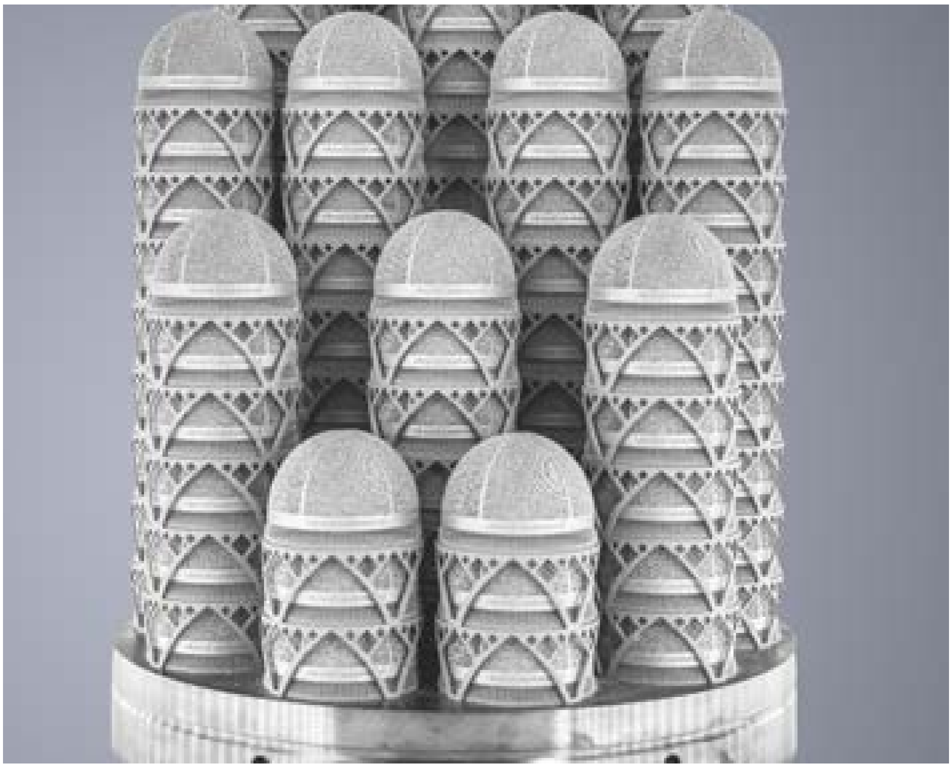

Figure 2: Stacked acetabular cups made of titanium and printed on the TruPrint 5000 machine with 500°C preheating.

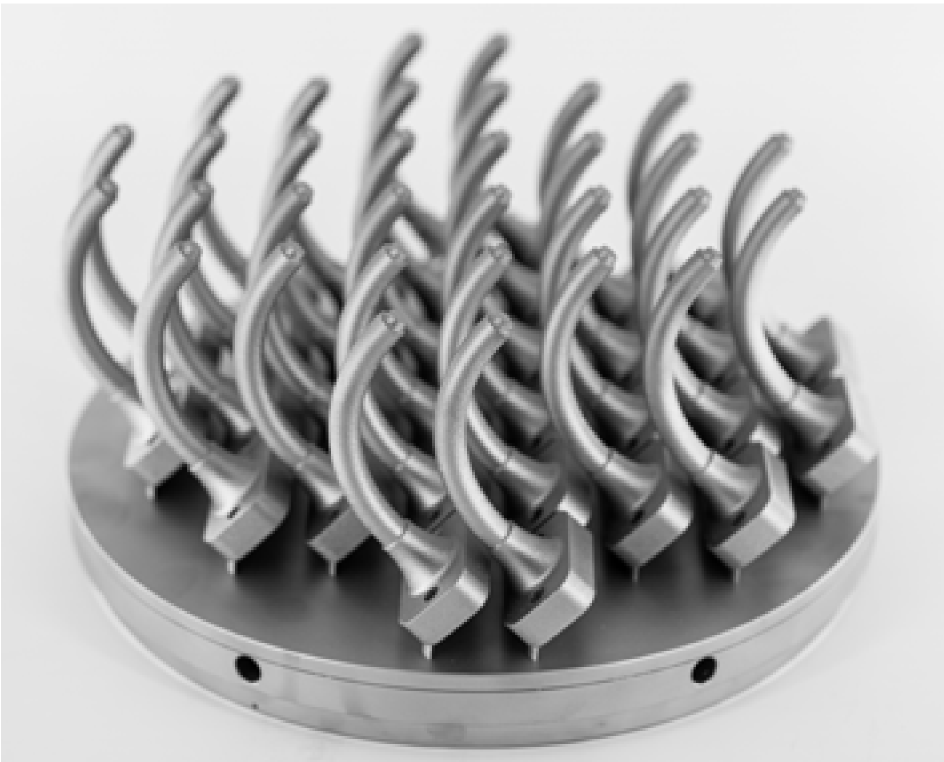

Figure 3: Tooling inserts made of 1.2709 for plastics injection moulding of tracheal tubes on TruPrint 3000. Source: Roechling Direct Manufacturing GmbH, Germany.

such as 1.2709, are often used for mould inserts in plastic injection moulding.

Considering the huge amount of disposable plastic products in the medical industry, plastic injection moulding plays an important role. Combined with additive manufacturing, mould inserts can be designed with near-contour cooling to improve cooling rates and plastic quality in ways that would not be possible with conventionally manufactured inserts (Figure 3).

However, it is rarely the case that additive manufacturing can do without one of the conventional processes. For users, machine suppliers and the manufacturing industry, it is crucial to bring the additive and conventional worlds together in the best possible way. Each technology should be used where it brings the greatest benefit, for example in the dental market individual geometries can be printed on a conventionally manufactured part. This approach is called printing on preform and medical applications such as shoulder or dental implants and surgical instruments can also benefit from this solution in an economical way.

Summary

The potential of metal 3D printing for medical device products has been recognised by manufacturers, from major OEMs in the medical industry to new, emerging contract manufacturing companies. The challenge is to use the technology in a profitable way. The initial time spent evaluating the potential of additive manufacturing, as well as the right machine solution and the right machine supplier to support along the way, are key to success.

The benefits of the technology are obvious, even if only a fraction of the potential of additive manufacturing has been exploited to date. Currently, the focus of metal additive manufacturing is on orthopedic devices and implants, which are primarily made of titanium or CoCr. But the technology offers so much more. Even exotic materials such as copper, tungsten, tantalum, nitinol, precious metals and amorphous metals have already been successfully processed, opening up future improvements in areas such as cardiology, electrosurgery or imaging and diagnostics. Those who neglect the emerging technology of additive manufacturing could lose touch with the market and the competition in the medium to long term.

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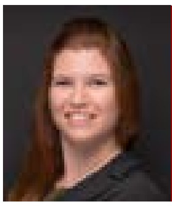

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SEE OBSERVATIONS P30

BLUE DIODE LASERS REVOLUTIONISE COPPER PROCESSING

LUISA-MARIE HEINE & MATHIAS SCHLETT

Lasers have proven themselves repeatedly for welding processes in industrial metal processing. Diode lasers particularly impress, producing outstanding stability of the melt pool, which leads to better-quality weld seams. However, when processing non-ferrous metals such as gold, copper, and copper alloys, near-infrared (NIR) lasers with wavelengths between 900 and 1100 nm repeatedly reach their limits. The reason is the low absorption rate of NIR radiation in non-ferrous metals. As a result, high energy input is usually required to melt a component. Welding processes therefore often run unstably and result in welding defects, spatter formation, and production scrap.

High reflection complicates copper processing

Infrared lasers are only partially suitable for copper welding because NIR radiation is reflected by copper at room temperature by up to 95%. This means only 5% of the laser energy input is used for melting, which has an extremely negative effect on the energy and CO_2 balance of the production process.

Copper is becoming increasingly important in manufacturing due to its outstanding electrical conductivity when used, for example, in the production of electric motors in the automotive sector. Therefore, industrial users and laser manufacturers are striving to find new solutions for the laser welding of copper components.

Optimising production processes

The motivation for a solution led to the development of blue diode lasers at Laserline with a wavelength of approximately 450 nm. Laser radiation with this wavelength is absorbed by copper at around 60% at room temperature.

Therefore, the material can be penetrated by 12x the energy than with a NIR laser—an average absorption rate of around 5%, considering the same output power. As a result, the energy requirements of laser welding are drastically reduced. And almost all machining processes can be implemented with moderate heat input.

In 2019, Laserline launched the first blue continuous-wave (CW) diode laser with up to 1 kW output power. As part of the Efficient High Power Laser Beam Sources funding program launched by the German Federal Ministry of Education and Research, development is being driven forward. Output powers of 1.5 and 2 kW were achieved just one year later. For the first time, blue industrial lasers enabled controlled heat conduction welding of highly reflective metals such as copper or gold. Seams with a perfect appearance can be realised on copper foils and copper sheets almost independent of the surface finish of the material. This means new and more efficient joining solutions are now available, especially for welding thin copper battery technology for electric vehicles.

Since spring 2022, blue CW diode lasers have been available with an output power of 3 kW, at an average wavelength of 445 nm, a beam quality of 33 mm-mrad, and typical spot sizes of 0.45 to 0.6 mm. A socket efficiency of approximately 25% is currently the highest for a laser in the visible wavelength spectrum. Although this efficiency is slightly lower than the power outlet efficiency of some NIR lasers, it does not affect the overall energy balance of the process. A blue 3 kW diode laser can easily be used for welding processes where a NIR with the same output power would cause difficulties. Since less output power is required than for copper processing with NIR lasers, energy can be saved despite the lower socket efficiency. Process efficiency is the decisive factor in the end. The power class of 3 kW enables new opportunities for various welding applications, especially in e-mobility (e.g. copper hairpins) as well as for additive manufacturing of copper components.

Hairpin welding of larger surfaces

Welding of smaller copper hairpins was already possible in 2021 using a blue 1.5 kW diode laser. Very smooth and homogeneous welds were achieved during the welding process without spattering at medium intensity and a spot size of 1 mm.

With the 3 kW laser, hairpin welding is now possible without size limitations. Extensive tests prove that diode lasers can weld hairpin twins with sizes of up to 20 mm² at speeds ranging from 20 to 270 ms (see Figure 1). Analysis of the cross-section images also showed remarkable seam qualities, promising high conductivity and stability. Even with gaps, rotations, height differences, or lateral displacements, the new 3 kW diode laser provides excellent contacts.

Welding, cladding, and additive manufacturing

Further welding applications such as overlap, fillet, or butt welding can also be reliably

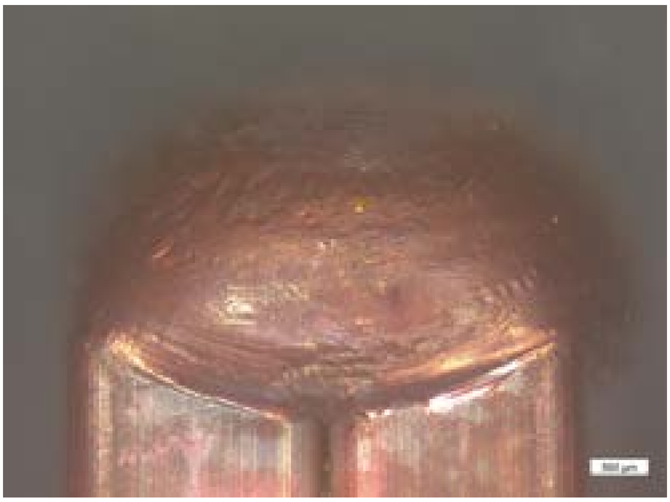

Figure 1: Welding of copper hairpins with a cross-section of 9.9 mm² each in approximately 250 ms. ©Laserline

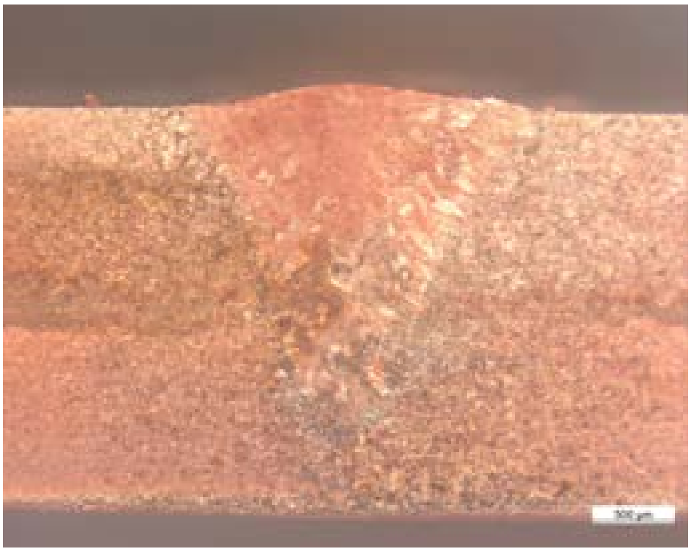

Figure 2: Overlap welding of 1.2 × 1.2 mm thickness (copper sheet) by a 3 kW blue diode laser. ©Laserline

Figure 3: Additive Manufacturing using copper powder by directed energy deposition and a blue diode laser ©Laserline

implemented in the copper sector with blue 3 kW diode lasers. The power increase enables processing of larger cross-sections and faster welding processes with lower heat input, which very effectively compensates the high thermal conductivity of copper. In addition, when joining sheets, the common welding depth can be doubled to some extent. In overlap welding of 1.2 mm x 1.2 mm with 2.9 kW laser power and a speed of 2.4 m/min, a weld penetration depth of 84% is achieved (see Figure 2).

In additive manufacturing of copper components, the power increase to 3 kW also opens up other interesting options. Recently, Laserline has been able to present samples of a copper tube that was manufactured using a blue 800 W diode laser on a powder basis (see Figure 3). With 3 kW of laser power, even more efficient additive manufacturing of large and high-volume copper components will be possible in the future.

Components made of two different materials are particularly interesting because copper material is often used to enable efficient cooling in a component, whereas tool steels are built up as the outer shell for rough industrial use. The blue laser can process both materials well, but NIR lasers can only process one. Likewise, significantly higher area rates can be achieved in copper-based deposition welding with blue 3 kW diode lasers.

Simpler processes, better results

The new 3 kW diode laser is not only versatile, but also simplifies production processes. The use of a shielding gas such as argon or helium is not necessary, which reduces production costs. If needed, the beam sources can be combined with common systems for process monitoring or an optical coherence tomography (OCT) system (see Figure 4). For the greatest possible flexibility in the application, individual beam shaping can also be realised.

Outlook: Higher laser power, more opportunities

With highly reflective metals such as gold and copper, blue diode lasers have revolutionised a wide range of new opportunities overall. Increasing the output power to 3 kW opens up additional application options. In joining and cladding processes, much faster welds and higher deposition rates can be achieved. Even larger cross-sections can be handled reliably when deep welding electrical conductors such as copper hairpins. The efficiency of copper plating and additive manufacturing of large copper components also increases significantly.

Reaching the threshold of 3 kW output power certainly does not mark the end of the development of this type of laser. In the future, significantly higher power classes will be achieved.

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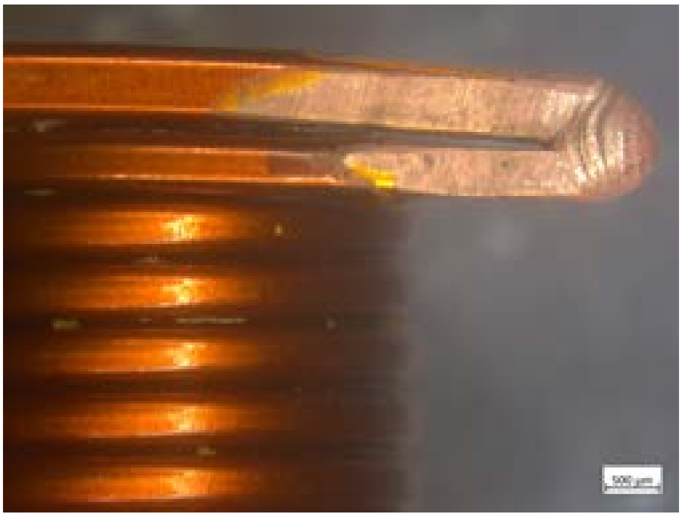
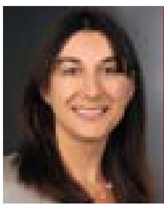


Figure 4: Welding of copper connections in electrical coils without vision systems ©Laserline



Luisa-Marie Heine is an application engineer at Laserline and has extensive expertise in the blue wave spectrum.

SEE OBSERVATIONS P30

IMPROVING AL ALLOY PROPERTIES USING ULTRASONIC LASER WELDING

JOHN SILVA & AHMED TEYEB

Welding high strength aluminium alloys is generally a delicate operation due to the degradation of mechanical properties in the heat affected zone (HAZ) and the presence of porosities in the molten metal. Furthermore, the formation of compounds that solidify before the rest of the base alloy during welding operations, act as stress concentration points that lead to the hot cracking phenomenon. This article investigates the process of applying ultrasonic vibrations to the molten pool of aluminium alloy AA6082 as to improve both its microstructure and mechanical properties. Conventional and ultrasonic-assisted laser welding processes were analysed to assess the sonication effect in the ultrasonic band 20–40 kHz. The study achieved a 26% increase in the tensile and weld yield strengths of laser welds in the aluminium plates via the power ultrasonic irradiation under optimum ultrasonic values during welding. Cavitation activity was significant and sometimes a main contributor to the achieved improvements.

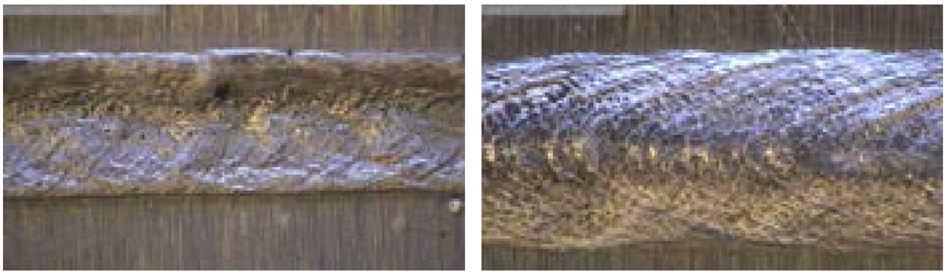


Figure 1: Examination of the surface of the welds achieved without ultrasound (left) and with ultrasound (right).

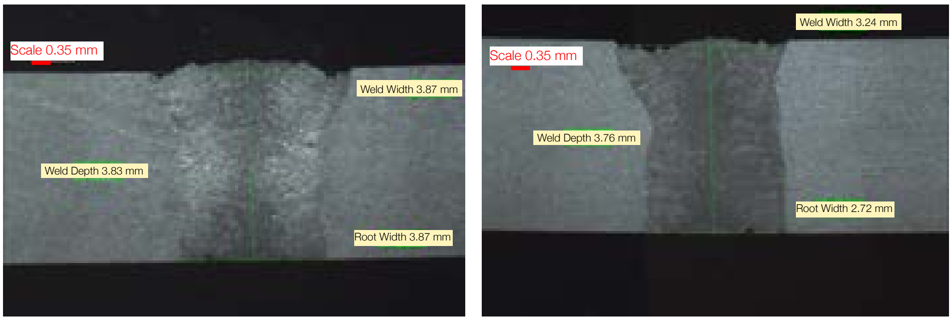


Figure 2: Aspect ratios (surface width to root width) of welds achieved without ultrasound (left, AR=1.38) and with ultrasound (right, AR=1.19).

Laser welding technology is extremely reliant on the reflectivity of the materials to be welded due to its dependency on the light coupling effect. Additionally, the laser can provide a concentrated heat source, however materials with high thermal conductivity tend to partially disperse the heat and affect the profile of the resulting weld, (i.e., shallow welds). Materials such as aluminium and its alloys pose additional challenges, as they have a strong tendency for crack formation due to several attributes such as an extensive solidification range, a high thermal expansion coefficient, and large solidification shrinkage which greatly affect the mechanical properties of the resulting welds. Hence the use of ultrasonic waves, which when applied during welding operations limit the growth of grain structures and lead to grain multiplication due to vibration impacts, shocks, or fluid flows acting as new nuclei. This phenomenon is called ultrasonic grain refinement. Grain refinement is an essential tool used to improve material tensile and yield strengths, as implied by the Hall–Petch equation, relating yield strength to mean grain size under assumed spherical grains.

The aluminium alloy AA6082 is highly crack-sensitive because it contains around 1% of magnesium silicide (Mg_2Si). To temper these effects, slower speeds can be used in conjunction with lower power, but this reduces one of laser welding's major advantages—its speed. As a result, there are significant economic impacts which prevent laser welding from being used in highly sensitive applications.

The project focused on the butt welding of two 300x150mm plates with variable thicknesses (1.5, 2 and 4mm) with the aid of distinct transducer frequencies.

Results

Examination of the surface quality of the welds confirmed the overall effectiveness of using ultrasonic power during the welding process. In Figure 1, microcracks that are likely to be a crack initiation zone can be easily identified in the middle of the weld. However, these lines completely disappeared when ultrasound was used.

The visible reduction of the plasma cloud was another noticeable improvement when using ultrasound. The ultrasonic waves help to balance and stabilise the keyhole, which minimises the pressure build-up and stops material ejections leading to a reduced plasma cloud.

The effect of the ultrasonic waves also led to different weld aspect ratios (i.e., the ratio of surface weld width to root). For thinner plates (1.5 and 2 mm), the use of 40 kHz transducers led to smaller aspect ratios, whilst on thicker plates (4 mm), the converse was observed (i.e. 28kHz transducers). The wave penetration decreases along the axis of the plate thickness with increasing frequency because both wave absorption and scattering in the weld melt increase with frequency. Thus, to achieve complete coverage of the weld joint, the frequency must be reduced commensurately with increasing plate thickness.

Microscopy images showed that at a plate thickness of 1.5 mm, the straightness of the weld profiles improved, i.e., the aspect ratio was smaller when ultrasound was used at a given laser power and welding speed. The weld profile became 43% straighter when the 40 kHz transducer was used. With the plates that were 4 mm thick, the use of ultrasound at 28 kHz decreased the aspect ratio even further by 62%. However, 40 kHz ultrasound led to a reduction of only 14% when compared to the baseline. Compared with the thinner plates, the 28 kHz transducer achieved smaller aspect ratios on the thicker plates (Figure 2).

The reflected light microscopy images of the samples showed that without ultrasound, dendritic growth was evident in several locations throughout the weld zone and an unevenly distributed grain structure could also be seen. On

Figure 3: Reflected light microscopy images (×200 magnification) of cross sections of welds without ultrasound (left, arrows indicating some dendrites) and with ultrasound (right, arrows indicating some solidification fronts).

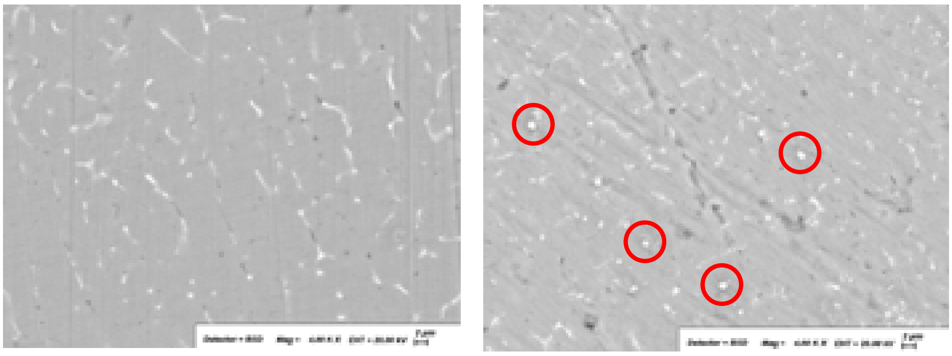


Figure 4: SEM analysis of cross sections of welds without ultrasound (left, linear intermetallic structures) and with ultrasound (right, spherical nature of the intermetallic structures).

the other hand, when ultrasound was used, no agglomerations were noted in the analysis and the grain structure appeared evenly distributed. However, a higher concentration of grains could be seen in the zones where different solidification fronts met.

Without ultrasound, the number of grains per area appeared higher than that obtained with ultrasound. It was also possible to identify dendritic growths and an increased concentration of grains around these growths. In the trials with ultrasound, the grain structure appeared to be more homogenised and evenly distributed, and it was also possible to identify a boundary with different grain sizes (solidification front), see Figure 3.

Further SEM analyses showed that linear intermetallic formations could be seen over the entire samples welded without sonification. These are more likely to act as crack initiators when compared to the spherical nature of the intermetallic structures seen in the sample where ultrasound was used. In that case, the intermetallic formations were smaller and appeared mostly in the shape of spheres (Figure 4).

During tensile testing, when ultrasound was used, an average increase of 10% was seen in both ultimate tensile strength and the load required for failure. The maximum values were achieved at a frequency of 28 kHz.

Despite the inevitable decrease in local strength due to the fusion process, in a trial with a power of 80 W, a frequency of 28 kHz, and a welding speed of 25 mm/s, the ultimate tensile strength was 25% higher than the baseline trial. This increase could be explained by the homogenisation of the molten pool and the consequent reduction in crack initiation zones (e.g. dendritic growths).

The strongest mechanism of ultrasonic action on fluid phase materials, especially grain refinement, is cavitation where local forces, large enough to rupture chemical bonds and raise local temperatures up to 10,000 K, acting on solid particulates in a melt, are generated by collapsing bubbles. Cavitation forces are strong enough to break up the large and agglomerated grains in melts into smaller structures, and such structures will usually appear accidentally during melt cooling. The times for bubble growth and subsequent collapse to release cavitation forces are ~1 ms and 150 μs, respectively, so these forces can be effective in weld melts produced by rapidly moving laser spots.

It was concluded that the cavitation threshold was well exceeded at the antinodes and cavitation, thus making a significant or even dominant contribution to the ultrasonically improved ultimate tensile strength of the welds.

High power ultrasonic waves are known to disperse alloying compounds, such as magnesium silicide, towards the weld boundary, thereby minimising the risk of cooling residual stresses, leading to the hot cracking phenomenon. Additionally, ultrasonic waves improve weld quality by reducing overall imperfections due to porosities and oxide formation. It is possible that high power ultrasound forces could mitigate the negative effect of Marangoni flow. Marangoni forces arise from surface tension gradients and can adversely affect weld strength by introducing spatial variations in the microstructure. Ultrasound could agitate the flow of the liquid melt at different solidification phases which would result in an even heat distribution.

Conclusion

Mechanical analysis and tensile testing identified an average increase in the ultimate tensile strength of 10% across the study whereas the best trial improved the ultimate tensile strength by 25% compared to the baseline, where no ultrasound was used. The weld profile became straighter when ultrasound was used, with the difference between weld width and root width being reduced by 14–62%.

The use of high-intensity ultrasound effectively disrupted the epitaxial growth of the dendrites, refined the grain structure, reduced the plasma cloud, and transformed the shape of the intermetallic compounds from linear to spherical. It also improved weld stabilisation and decreased the spatter levels, which are critical to weld quality and weld strength.

The resistance to crack propagation–crack initiation due to grain refinement and disruption of the epitaxial growth of dendrites is linked to the increase in ultimate tensile strength and the load required for failure.

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SEE OBSERVATIONS P30

BEAM SHAPING IMPROVES METAL MOULD MACHINING

GWENN PALLIER

Lighting is a field of photonics that is a ubiquitous part of our daily lives – take headlights and night lighting for example. It is also one of the oldest fields: lighthouses have been guiding ships for thousands of years. There are several methods of manufacturing optical components to obtain the desired lighting for a specific application, and they often all have one thing in common – they incur significant manufacturing costs.

One effective technique for producing Fresnel lenses (Figure 1) is by injecting polymer into a metal mould. Although manufacturing the mould can be a complex process, the parts can then be mass produced by injection moulding, which helps solve the cost problem. Lenses produced with this method can be used to project information onto floors or walls, such as for emergency exit signage.

Figure 1: Fresnel lens

Improving the mould manufacturing process would enable the production of even more competitive lenses: if the moulds have finer and more precise details, smaller and lighter lenses can be produced.

How to manufacture a complex metal mould

The metal mould for polymer injection moulding has a complementary shape to that of the lens. In order to improve lens quality, two main criteria must be considered: the possibility of producing finer, micrometric structures on the mould, and enabling the production of complex shapes, especially non-linear and asymmetric shapes.

Femtosecond laser machining makes it possible to perform cold ablation on a very small scale, which is useful for machining the finer details of a mould. However, the output beam of a femtosecond laser has a Gaussian profile, which cannot be reduced to the desired size. The type and size of beam therefore limits the size of the finest details that can be obtained.

When producing a mould for a Fresnel lens, multiple triangular grooves need to be machined with different inclines and transverse positions at the bottom of the groove. The typical minimum beam size obtained with a femtosecond laser processing machine is 10 µm. To create a triangular groove with reasonable precision using a Gaussian beam, the width of the groove should be about 5 times the size of the spot, or 50 µm.

Beam shaping makes it possible to machine grooves with the same width as the beam size while maintaining an acceptable degree of accuracy on the transverse position of the bottom of the groove. By converting the Gaussian beam into a triangular beam, the energy can be focused on selected areas during the scan: if the beam is scanned perpendicular to one of the sides of the triangle, the bottom of the groove will be in the centre, while if the scan is parallel to one of the sides, the bottom will be closer to that side (Figure 2).

The Femtolens project

The aim of the Femtolens project – a Eurostar project involving CEIT, Laintec, Lasea, Multitel and Cailabs – is to implement this type of process. Cailabs developed the solution to be implemented and the process was then optimised by CEIT. The shaping system will be integrated into a Lasea production machine.

MPLC technology enables complex beam shaping

The laser beam shaping module developed for this project is based on Cailabs' Multi-Plane Light Conversion (MPLC) technology (Figure 3). This unique beam shaping technology involves analysing the mode propagation of a laser and passing the beam through successive phase plates with sufficient propagation between each phase plate. MPLC is a compact technology thanks to its completely reflective design: the beam travels back and forth between two mirrors, one of which is textured, while the other is a simple mirror. MPLC can stack multiple phase plates, making it possible to

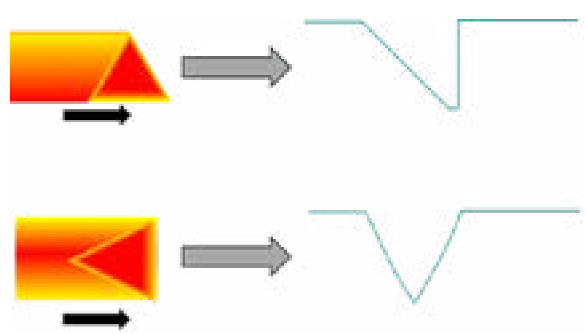

Figure 2: Adjustment of maximum depth of the V-groove by rotating the triangle versus the scanning direction

Figure 3: Multi-Plane Light Conversion system [1]

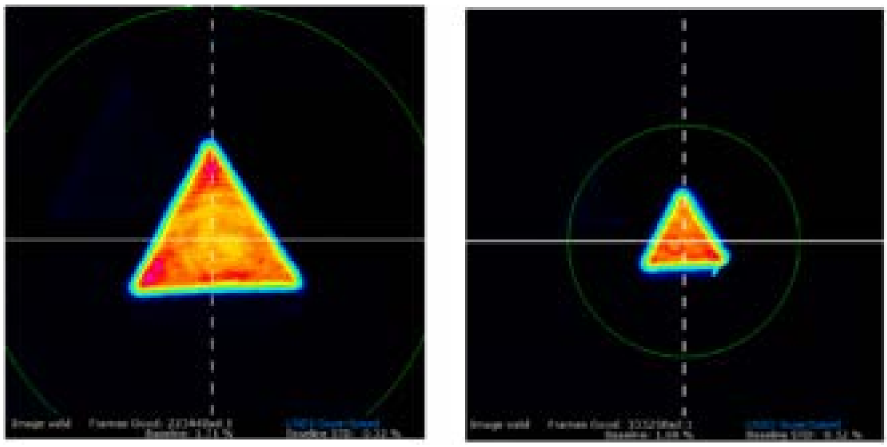

Figure 4: Measured intensity profile of the 1000 µm and 500 µm side triangles

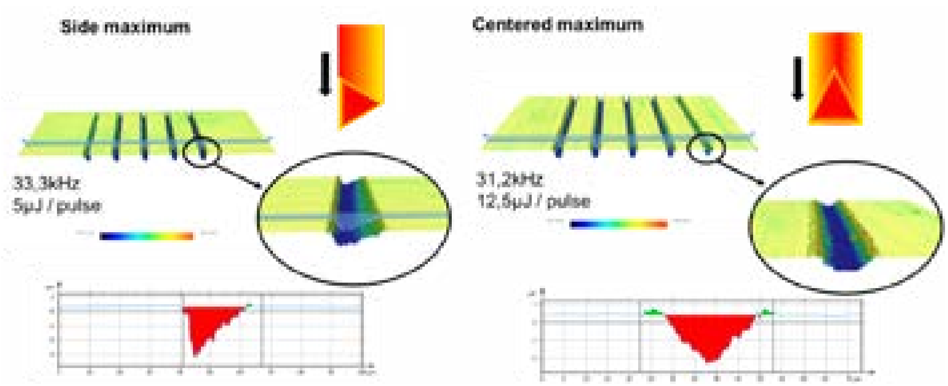

Figure 5: Process tests results by scanning parallel and perpendicular to one side of the triangle

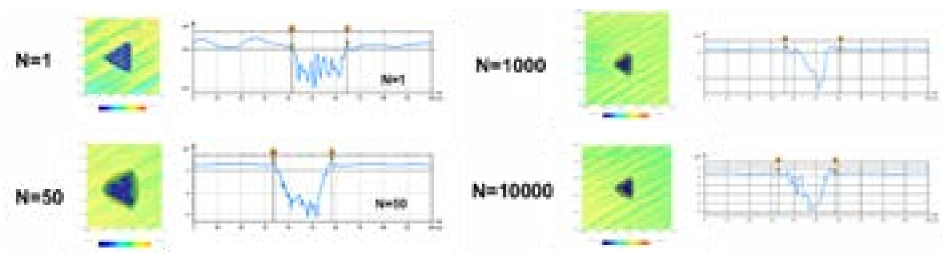

Figure 6: Process tests results by drilling without scanning and variating the number of pulses

generate any kind of shape with excellent control of the intensity and phase profiles. Unlike its competitors, this beam shaping solution can generate a flat phase in the process plane, producing a large depth of field.

A custom beam shaping solution

Within the framework of the Femtolens project, Cailabs developed modules that can create two different beam shapes: a 500 µm and a 1,000 µm sided triangle at the module output (Figure 4). The beams are reimaged to the process plane, where their sides measure 10 µm and 20 µm, respectively. The 20 µm-sided triangle has a slope (transition zone from 90% to 13.5%, divided by the length of the build plate at 90%) of 0.1, which is 17 times steeper than a Gaussian beam of the same size, and a depth of field of 20 µm in the process plane! The 10-µm sided triangle has a slope of 0.2 and a depth of field of 9 µm. In both cases, the slope value is limited by the numerical aperture of the entire optical chain, but primarily by the focal length of the F-theta lens and the aperture of the scanner used.

Finally, to perform complex machining, the beams need to be rotated on their propagation axis. This was achieved by positioning a Dove prism after the beam shaping module.

Implementation

Process tests were performed on an optical table at CEIT. The optical chain used to perform the process testing contained the following components: Yuja Amplitude laser, injection beam expander, MPLC modules (beam shaping and stabilisation), tube lens, periscope and Thorlabs 20x microscope objective. The sample to be machined was positioned on an Aerotech translation stage.

The beam stabilisation module uses a unique mode-cleaning feature that stabilises and cleans the laser beam: the output shape is always preserved, regardless of changes to the input beam's shape or focus. This feature ensures constant high-quality beam shaping without requiring realignment.

Results

Micro-engraving of steel injection moulds to manufacture Fresnel lenses was performed at CEIT. V-shaped grooves 20 µm wide and 2-4 µm deep with adjustable angles and depth were produced (Figure 5).

Tests were also performed to assess whether the number of pulses affected product quality, demonstrating a constant triangular profile over a wide range of pulse numbers: the triangular shape of the groove was well preserved throughout (Figure 6).

Conclusion

Within the framework of the Femtolens project, a study was conducted on improving the manufacturing of metallic moulds for injection of polymer lenses. Using a triangular beam, an improvement of a factor of 4 was obtained on the transverse positioning accuracy of the bottom of the groove.

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SEE OBSERVATIONS P30

X-RAY EMISSIONS IN ULTRASHORT PULSE LASER MICROMACHINING

JÖRG SCHILLE ET AL.*

Ultrashort pulse lasers (USPL) feature excellent beam performances for flexible and high-efficient material processing. For example, using USPL in micro machining allows highly-localised and defined energy inputs, resulting in reduced heat load to substrates for almost melt-free and high-precision material ablation and microscopic surface feature production. This, in turn, holds great promise for USPL as a fascinating tool for advanced micro machining and surface engineering with innovations in research, industry, medical engineering, and daily life. As another key feature, the continuing trend towards high-average power USPL reaching kilowatt class levels has made upscaling of processing speeds possible [1].

The increase of the available average laser power during the last 3 decades is amazing. Weber and Graf (IFSW Stuttgart, Germany) recently stated: "the average power is subject to a kind of Moor's law: the average power doubles every three years and there is no limit in sight yet" and further, "the average power attained by USPL in research laboratories precedes the average power applied of standard industrial lasers by about 10 years" [2].

The availability of such high laser powers at industrial standards offers prospects for high throughput machining at high-quality and over large areas. This new technology readiness level (TRL) evolves laboratory-grade USPL into advanced industry-grade solutions ready for deployment. However, the reported emission of undesirable laser-induced X-ray photon radiation, even for industrial USPL processes, constitutes a secondary laser beam hazard potentially causing serious health risks for laser operators. It could also be a drawback for industrial USPL machining [3].

Laser-induced X-ray emissions

X-ray emissions can arise when high-intensity laser beams interact with solid surfaces by producing hot and dense thermal plasma states, see Figure 1, including highly excited electrons of several keV kinetic energy. During laser processing, a stream of such laser-excited and ultrafast accelerated electrons release X-ray photons when they lose kinetic energy by scattering, acceleration and recombination with other charged particles. This can occur, for example, by (i) Bremsstrahlung arising from free-free transitions of accelerated free electrons, (ii) recombination continuum from free-bound electron transitions, and (iii) characteristic line emissions originating from bound-bound transitions of the inner-shell electrons of ionised atoms.

Figure 1: Monitoring of USPL induced X-ray photon emissions by using the X-ray Guard SILIX.

A typical X-ray photon spectrum is presented in Figure 2, such as is released from an ultrashort laser pulse of 2.7 x 10¹³ W/cm² intensity irradiating AISI 304 stainless steel substrate. The X-ray photon flux was monitored with the X-ray Guard SILIX, provided by Ingenieurbüro Prof. Dr.-Ing. G. Dittmar (Aalen, Germany). The spectrum shows X-ray photons in the soft-radiation regime between 2 keV and 10 keV and two clearly distinguishable X-ray emission characteristics; firstly, a broad Bremsstrahlung continuum following Maxwell-Boltzmann distribution, and secondly, characteristic line emissions referenced to AISI 304 alloying elements. The released X-ray emission dose can be approximated by integration over the entire spectral X-ray photon flux. The X-ray dose induced by a single laser pulse ranges typically from only a few picosieverts (pSv) to several nanosieverts (nSv), and the potential risk for laser operators is fairly low.

For a higher number of irradiated pulses however, the X-ray photon emissions accumulate from pulse to pulse. As a consequence, in particular when high-intense USPL pulses irradiate at high pulse repetition rates (PRF) and high average powers, X-ray dose levels will greatly exceed the threshold dose levels established in radiation protection. In Figure 2, this is shown by the X-ray photon spectrum captured for a USPL beam of 22.4 W average power and 506 kHz pulse repetition frequency. The corresponding X-ray emission dose rate is $\dot{H}'$ (0.07) = 1.1mSv/h which is about three orders of magnitude above the legal limit of 1 µSv/h at a distance of 0.1 m from the accessible surface. In radiation protection, these dose limits are set to reduce the risks of

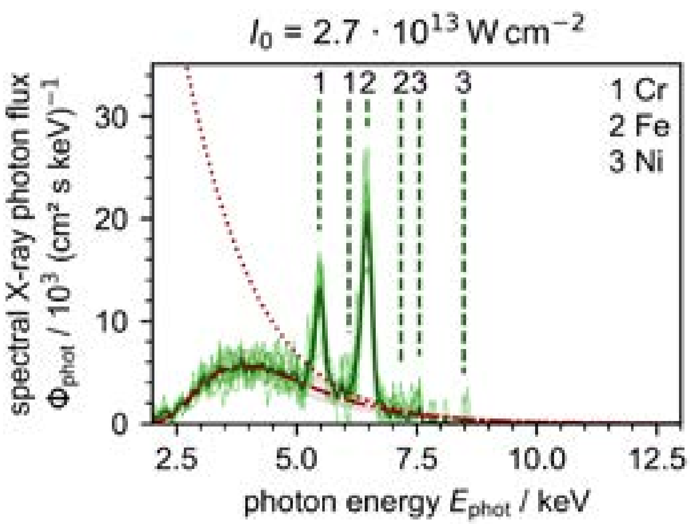

Figure 2: Typical USPL-induced X-ray photon spectrum on AISI 304 showing Bremsstrahlung continuum and characteristic line emissions for the alloying elements. The Bremsstrahlung emissions follow Maxwell-Boltzmann distribution (red line), the dotted line indicates the computed undamped spectrum. The corresponding X-ray dose rate is $\dot{H}'$ (0.07) = 1.1 mSv h⁻¹

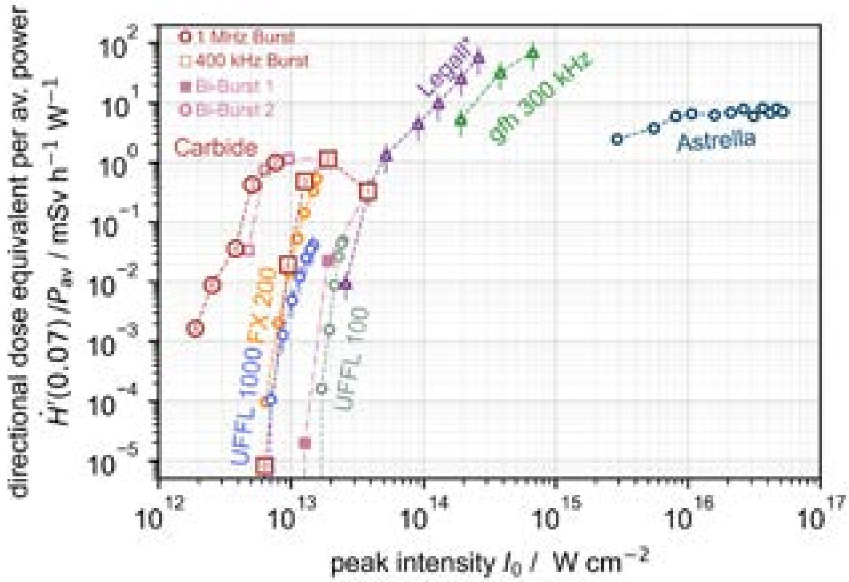

Figure 3: X-ray emission dose rates as function of peak intensity shown for different processing regimes and laser systems. Data provided by R. Giedl-Wagner (GFH GmbH) and H. Legall (Bundesanstalt für Materialforschung und –prüfung (BAM) Berlin) are included in this figure.

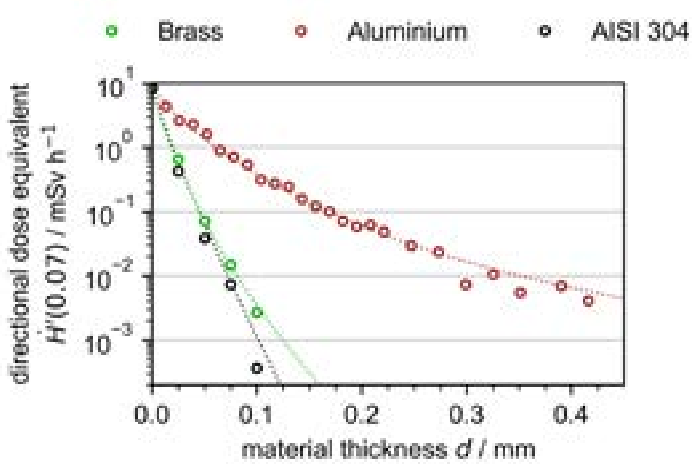

Figure 4: Shielding effect of Brass, Aluminium and AISI 304 housing walls from X-ray radiation

stochastic health effects caused by ionising radiation and also have to be complied during USPL processing.

Influencing factors

In fundamental research, more than 20 influencing factors on the laser, process and material-side were identified for increasing X-ray emission doses, and the specific parameters can have direct impact on each other [4]. Among others, this can be pulse energy, spot diameter, pulse duration, average laser power, polarisation direction, suction flow speed, etc. Nevertheless, the peak intensity is the most likely variable. As a general rule, X-ray emissions start at peak intensities above 10^{13} W/cm², which can be delivered, i.e. by ultrashort pulses of 1 ps pulse duration and 10 J/cm² fluence. However, X-ray photon emissions above the legal limit can also arise below this peak intensity threshold under specific processing conditions, i.e., when MHz-PRF pulses irradiate at small spatial distance below 1 µm. Furthermore, it has been shown that the X-ray emission dose rate increases tenfold when peak intensity doubles (Figure 3). On one hand, ultrashort pulses far above the optimum peak intensity for material ablation, or rather irradiated at small spatial distances at MHz-PRF, are not the best choice for micro machining and may result from incorrect parameter settings or operator failure. On the other hand, with a view to the near future with high-average power USPL at kilowatt level in industrial micromachining, X-ray emission dose rates can potentially reach dangerous levels in the range of extremely high Sievert per hour (Sv/h) as X-ray photon emissions scale-up almost linearly with the applied average laser power. As a matter of fact, special attention should be given to the high X-ray emission dose levels arising from USPL burst mode machining. In this regime, the intra-burst pulses irradiate at nanosecond to microsecond time delay, which results in strong pulses with plasma interaction, in turn, inducing a disproportionate high increase of X-ray emission as a secondary effect.

Effective safety precautions

In conclusion, X-ray photon emission arising in USPL material processing is based on highly complex laser pulse-plasma interactions. This work identifies a secondary laser beam hazard where high X-ray dose rates greatly above the legal limits can be reached, in particular when applying USPL at high average powers or in the laser burst mode regime. As a consequence, effective X-ray protection strategies have to be implemented for safe and risk-free operation when using powerful USPLs in industrial and academic research applications.

An effective precaution to protect users from X-ray radiation is to operate USPL in shielding enclosures. In order to provide a basis for the correct selection and dimension of the housing walls, the shielding effect of different housing materials from X-ray photons is shown in Figure 4. As a rough estimate, by a factor of 20 and above higher shielding from X-ray photons can be obtained when using AISI 304 instead of aluminum as housing material for interlock-monitored Laser Class I systems. In addition, adequate safety distance from the processing area is another effective safety measure as soft X-ray radiation is strongly attenuated in air.

In summary, adequate protection from X-ray photons can be achieved by using steel enclosures and operating at suitable distances, as well as taking into account the processing conditions for the specific situation. These practices pave the way for risk-free laser operation and ensure the safety of everyone involved with USPL in modern micro fabrication.

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[3] H. Legall et al. Appl. Phys. A 2018, 124, 407.

[4] J. Schille et al., Materials 2022, 15, 2748

*** Jörg Schille, Sebastian Kraft, Udo Löschner** (Laserinstitut Hochschule Mittweida, Germany)

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SEE OBSERVATIONS P30

OBSERVATIONS

METAL 3D PRINTING OF STANDARD DEVICES IN THE MEDICAL INDUSTRY

LAURA KASTENMAYER

Laura's article demonstrates the versatility of metal 3D printing, particularly the laser powder bed fusion (LPBF) process. Every day, OEMs achieve new applications and levels, and I completely agree that the TRUMPF systems are among the best in the world for not only lasers but also additive manufacturing. I agree with the author that some L-PBF machines are better suited for medical applications than others, and choosing the right machine is crucial to success.

It is difficult to manufacture complex shapes like the acetabular cup with various lattice structures using the L-PBF process, and I am grateful that the author not only did so in high quality but also in the most efficient way possible by stacking many of them together, which is a really cost effective way of doing it and opens the door to mass production. Finally, I'd like to thank the author for writing such an informative article on the state-of-the-art in laser metal 3D printing.

Prveen Bidare, University of Birmingham

BLUE DIODE LASERS REVOLUTIONISE COPPER PROCESSING

LUISA-MARIE HEINE & MATHIAS SCHLETT

This is an excellent article which confirms our findings at NUBURU that blue wavelength enables processing of copper without the need for complex beam profiles and wobbling that are required in typical infra-red processing systems for copper. As documented in the article, the simple approach with blue wavelength gives the customer a robust and tolerant process with excellent quality.

As power levels and beam quality of the blue wavelength sources are developed, and scanner integration becomes possible then welding and other applications will grow in e-mobility, energy storage and electronics applications.

Andrew Dodd, Nuburu

INTRODUCTION TO THE SAFETY AND SAFE USE OF INDUSTRIAL LASERS

NEAL CROXFORD

With lasers becoming more prevalent within the workplace for traditional and newer applications where people may not be aware of the potential hazards, laser safety requirements cannot be understated. As Neal explains, the NOHD of beams can be significant and pose a danger even at long range, so not only do operators need to be aware of the dangers, anyone working in and around the area should also be aware of the hazards that lasers can pose. The majority of lasers used within industry will be Class 4 and legally require a laser safety officer to be appointed.

Preetesh Mistry, Pro-Lite Technology

BEAM SHAPING IMPROVES METAL MOULD MACHINING

GWENN PALLIER

Beam shaping has been around for years as a means to manipulate laser beam energy density profiles to assist in achieving better quality processing and in some instances assist in achieving challenging processing requirements as highlighted in this article. Having a desirable beam profile for a specific processing requirement is critical especially when it requires high precision and accuracy.

Gaussian shape laser beam is no longer the optimum configuration for some of the most challenging machining operations and therefore requires beam shaping technology to modify the energy distribution of the beam for tighter and better control.

There are plenty of beam shaping techniques and technologies in the market that comes with their pros and cons but ultimately, a laser application engineer or system integrator would dream of having a dynamic beam shaping capability which can modify and change the beam shape on the fly to adapt the laser to fit specific manufacturing requirement.

Tian Long See, MTC

Cailabs' Multi-Plane Light Conversion (MPLC) System has been demonstrated on the challenging task of producing small-size V-shape grooves into a metal mould. Using this unique technology in combination with a femtosecond laser, two types of V-shape grooves were produced with a width of 20 µm and depth of 2-4µm. It is not possible to produce these types of grooves by just using a femtosecond laser. MPLC is enhancing the capability of selective ablation of ultrashort pulses, which will open a significant number of new types of applications.

Danijela Rostohar, Coventry University

IMPROVING AL ALLOY PROPERTIES USING ULTRASONIC LASER WELDING

JOHN SILVA & AHMED TEYEB

The excellent ratio of strength to mass, easy machinability and good corrosion resistance make the aluminium alloys among the most advanced engineering materials available. If only welding of it was easier, it would have been the best metallic material. The authors present very interesting results of ultrasonic enhanced laser welding. The influence of ultrasonic cavitation is evidenced in a better weld profile, reduced porosity and most importantly improved grain structure. It would be interesting to see more results and perhaps modelling work to understand how the propagation of ultrasounds changes with the material thickness, process conditions and joint configuration.

Wojciech Suder, Cranfield University

X-RAY EMISSIONS IN ULTRASHORT PULSE LASER MICROMACHINING

JÖRG SCHILLE ET AL.

Jörg Schille et al. make a salient point about high power laser processing and the generation of x-rays: as laser intensities increase on average, we start to reach intensity thresholds that generate x-rays. Precautions such as using steel chambers and being sufficiently far away from x-ray sources are incredibly effective.

In general, having passive detectors permanently installed in operation areas also helps to safeguard against unintentional x-ray generation and is a good practice to adopt. With this combination of knowledge and know-how, the increase of laser processing powers and stronger subsequent laser-matter interactions can remain safe for all using ultra-short pulses lasers in modern micro fabrication.

Simon Hutchinson, AILU

TACKLING THE ENERGY CRISIS THIS WINTER

The energy crisis remains a concern for businesses as winter approaches. The inflated energy prices we are seeing are largely due to Putin's weaponisation of energy, which has caused an excess demand.

The Energy Bill Relief Scheme will grant businesses some protection against the increase in energy bills over the next six months, but the crisis may still cause irreversible damage to some industries.

The Energy Bill Relief Scheme

The scheme aims to ensure businesses will pay wholesale energy costs well below half of expected prices for this winter. On 1st October, it was amended by Business, Energy and Industrial Strategy (BEIS), with changes to the initial proposals made for businesses on fixed or variable tariffs.

As a result of this late change in support, energy suppliers are advising that it is unlikely you will see the expected discount on your October energy bills, as energy suppliers have yet to be provided with full details to ensure the discount is correctly applied. Our advice is to pay outstanding invoices whilst you wait for these discounts to be applied.

There is no need to sign up for the scheme - be vigilant of fraudulent messages and scams that urge you to do so.

How the scheme will affect energy bills

Energy bills are comprised of three main components: energy cost - or the commodity element as it's often referred to, distribution and transmission charges, and green taxes and levies.

Many businesses may expect their bills to be halved, however, the scheme will provide businesses with a discounted price for the commodity element of their energy bill. Non-domestic customers who receive support under the scheme will also have their green levies charge removed.

Government support will be the same across suppliers but will vary for individual bills across different contracts and tariffs.

For fixed contracts signed after 1st December 2021, the discount will reflect the difference between the government supported price and the relevant wholesale price for the day the contract was agreed. For variable, deemed and all other contracts, the discount will be applied in the same way, but be subject to a 'maximum discount' as mentioned earlier. On 10th October, the detail was released for the discounts to be applied to fixed contracts. It can be viewed here: https://www.gov.uk/government/publications/energy-bill-relief-scheme-discounts-for-fixed-default-and-variable-contracts.

Don't wait to renew

We are seeing a high proportion of businesses delaying their decision to renew their energy contracts and waiting for the storm to pass in the hope that prices will fall if they hold out until the last possible opportunity.

However, this carries significant risk, as there is a far greater chance we will see further increases as we continue to move through an ongoing period of uncertainty in the energy sector and could leave you vulnerable to punitive out of contract rates.

A flexible approach to the energy crisis

While those on variable tariffs will be receiving a smaller discount on wholesale energy prices, we would advise businesses to consider a flexible energy contract.

As opposed to fixed contracts, you won't be required to make a decision based on the market position on one day which can help mitigate further risks to your business. It will also enable you to spread risk when the markets are high – a crucial advantage in the current climate.

As you are able to purchase energy for up to four years in advance and build a price made up of multiple purchasing decisions, flexible purchasing allows you to take advantage of wholesale market fluctuations and move quickly when the market is favourable. The longer the purchasing framework, the greater the prospect of minimising risk and exposure to volatility.

Both small businesses and large corporates can benefit from a flexible contract. If you would like to explore flexible purchasing as an option for your business, you can download our free eBook by visiting cec.uk.com/flex.

Next steps

Many businesses will still be vulnerable to soaring energy prices, even with Government support. In addition, there are concerns that the UK could face gas shortages this winter.

Another way to manage your energy costs is to invest in more energy efficient measures to reduce your consumption and set you on the right path to managing your energy bills long-term. If you need help with starting your journey to net zero, you can find helpful resources and information by visiting the Green Hub on our website.

We're here to help

The energy support measures provide some hope over the coming months; however, they are only a short-term solution to a long-term problem.

It's understandable that many businesses will be unsure how to navigate these uncertain times. If you need help or an opinion, please get in touch with us and we will explore the best options for your business.

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PRODUCT NEWS

SYSTEMS & SOURCES

ELEVATED PERFORMANCE IN 2D LASER CUTTING

BLM introduced the LS7 - the innovative 2D laser-cutting system that allows processing a wide range of metals - at EuroBLECH. The machine integrates into production processes with all the advantages of fibre lasers, including lower energy consumption, low maintenance and cutting of highly reflective materials.

Contact: Paul Lake
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NEW COST-EFFICIENT LASER CUTTING MACHINE

LVD introduces Puma, a new cost-efficient fibre laser cutting machine designed to provide high-technology features and performance at a lower total cost of ownership. Offered with 3-, 6- or 12-kW laser in 3050 x 1525 mm, 4065 x 2035 mm, and 6160 x 2035 formats and automation ready, Puma provides the agility to handle a diversity of cutting applications.

Contact: Maryse McHale
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ENTRY-LEVEL MACHINING CENTRE

Mazak has responded to market demand for a high-specification entry-level machining centre with a large Y-axis stroke by launching the new VCE-600. Designed to deliver superior productivity at a competitive price, the new machine is ideal for subcontractors and jobshops looking to invest in machines that make them faster, leaner, greener and more intelligent.

Contact: Ian White
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COOL TOUCH LASER MARKING

FOBA has developed a 532 nanometers wavelength green laser marking system which offers new possibilities for industrial direct part marking. The low heat laser applies perfect marks on materials with extraordinary absorption properties. Such materials include white, transparent, or red plastics as well as highly reflective metals.

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PRODUCT NEWS

ANCILLIARIES

A TRIO OF NEW LASER OPTIC PRODUCTS

Knight Optical has revealed its latest product offering – a trio of components that are suitable for a wide range of laser varieties, particularly ultrafast laser systems. These include Broadband & Wide-Angle Laser Line Mirrors, Low GDD Ultrafast Laser Mirrors and Thin-Film Polarisers.

Contact: Mike Sharp
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UNIVERSAL LASER FUME PRIMARY/PRE FILTER

Labyrinth Filtration's new LF39U primary laser fume filter fits into both of the main branded 400 m³/hr laser fume extractors enabling laser users having a mix of extractors to stock just one filter. The new filter has three fabric layers each having graduated fibre density for increased operating life.

Contact: John Horsey
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www.labyrinthfiltration.com

PROCESSING MACHINE PRODUCTS UNVEILED

The AMADA Group is set to introduce fibre laser machines and bending machines equipped with the new AMNC 4ie NC control. The new unit is based on the concept of four Es: Easy (can be used by anyone), Efficiency (can be used anywhere, even remotely), Environment (environmentally friendly), and Evolution (developed with customers).

Contact: Anabela Lelis
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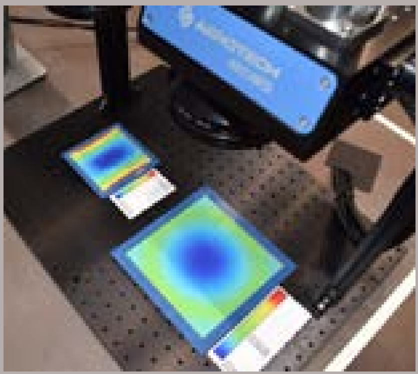
EXPANDING THE FIELD OF VIEW

At Photonex in December, Aerotech will demonstrate the innovative IFOV function for expanding the field of view during laser scanning, as well as the latest features of the Automation1 control platform.



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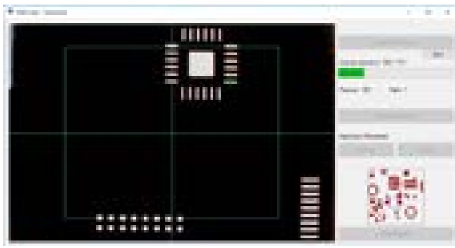
AUTOMATED OPTICAL INSPECTION INTRODUCED



Watt Laser has announced the addition of Automated Optical Inspection (AOI) to their SE12 stencil machine, furthering the efficiency improvements provided to SMT stencil manufacturers. AOI combined with the numerous laser processes possible on the SE12 allows a stencil manufacturer to double their productivity regardless of the age or brand of stencil cutter.

Contact: Fraser Shaw
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SOFTWARE FOR PROCESS DIGITALISATION

Bystronic launches BySoft Suite software allowing customers to completely digitalise their business, from quote to delivery – a step beyond Smart Factory. BySoft Suite is comprised of six software product families that collectively enable the customer to digitally monitor, manage and make decisions at each stage of their business process.

Contact: Caroline Wood
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NEW 30 kW LASER CUTTING HEADS

Coherent has released its next-generation BIMO-FSC3 cutting heads with three product variations, each optimised for one of the following applications: ultrahigh laser power delivery of up to 30 kW, efficient ring-mode laser beam management, and reliable operation in harsh environments.

Contact: Michael Batchelor
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NEW SCAN TECHNOLOGY FOR LASER WELDING

TRUMPF has launched a new solution to improve the quality and robustness of laser welding. Currently, the only way to guide the laser beam during the welding process is via the welding robot – but TRUMPF's new BrightLine Scan technology will also allow users to guide the laser beam using the laser scanner.

Contact: Gerry Jones
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NEW BEAM PROFILING CAMERA

MKS Instruments has introduced the Ophir® SP504S Beam Profiling Camera with small pixel size for higher resolution measurement of large and divergent beams. The SP504S camera accurately captures and analyses wavelengths from 340-1100 nm for beam sizes from 45 µm up to 23 mm x 23 mm.

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EVENT REVIEW

29 SEPTEMBER 2022

HIGH POWER LASER WELDING

CRANFIELD UNIVERSITY

The recent high power laser welding event was hosted by the Manufacturing Technology Centre (MTC) at their site on Ansty Park, Coventry. As fibre lasers continue to reach higher and higher average powers, new applications and technology transform the results in metal welding. Wojciech Suder of Cranfield University acted as the workshop chair, and the event had over 40 delegates. Event sponsors were Coherent and Civan Lasers.

Kevin Withers of the MTC spoke about some of the work being carried out currently – including laser welding with blue lasers, welding in a vacuum and hybrid arc/laser welding. Goncalo Pardal of Cranfield University described how and when to use laser welding (and when not to) and discussed beam shaping, wobbling and temporal pulse shaping. Pasquale Franciosa from WMG outlined welding for electric vehicles, including dissimilar materials and process monitoring for weld validation – especially important are reductions of cracking and porosity, especially in highly reflective materials.

Three industrial presentations followed. Meir Giladi from Civan Lasers described the coherent beam combining method which allows dynamic beam shaping with high flexibility and speed to achieve improved results in weld integrity. There was much interest in this technology especially in research. After this, Phil Carr from Carrs Welding Technologies described copper welding with and without the addition of ultrasonic vibrations and the SoniLaser project that is looking to characterise this technology for battery welding. Finally before lunch Peter Brown talked about a challenging application for drive belts in aluminium, one example of the subcontract welding and additive work that Laser Additive Solutions carries out.

After an excellent lunch and time to browse the 6 exhibitors, Tristan Tremethick of UKAEA presented some of the challenges of laser welding for nuclear fusion, and introduced the new 125 kW fibre laser they have recently acquired for the CHIMERA project. Then Max Nentwich from Cambridge Vacuum Engineering (CVE) compared electron beam welding and laser welding in a vacuum. Similar results can be achieved with both processes. Jihane Guenon from Welding Alloys presented the results of laser cladding with wire feed as compared with submerged arc welding – laser being more energy efficient and potentially quicker.

In the final session Callum Wreford of PowerPhotonic described how beam homogenising and shaping can be used to provide various results in high power laser welding, especially allowing the mapping of fields to achieve different output shapes. Finally Eurico Assuncao from European Welding Federation (EWF) highlighted the importance of training and qualification to allow the welding engineers required in industry to be trained and equipped. A tour of the MTC labs with about 8 different stops allowed the delegates to see live demonstrations of many of the welding processes.

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EVENT REVIEW

18 OCTOBER 2022

LASER SOURCES & BEAM DELIVERY

TRUMPF LASER UK, SOUTHAMPTON

At the recent workshop on Laser Sources and Beam delivery 55 people from 26 companies and institutes met at TRUMPF Laser UK. Eleven presentations were delivered on both laser sources and beam delivery from industry and academic experts, as well as 5 exhibitors, with attendees coming from the UK, Lithuania, Germany, Czech Republic, as well as UK representatives for companies from France, USA, and Japan.

The advancements of 2 µm sources, including commercially available systems, and their growing applications was explained by Daniel Esser from Heriot-Watt University. Ultrafast and high average power lasers were a hot topic, Deividas Andriukaitis from Ekspla explained a novel water-free cooling concept that will improve reliability of ultrafast lasers. Continuing on the topic of laser beam power management, Burly Cumberland from NKT Photonics described their use of micro-structured optical fibres which allows for high-average power, femtosecond pulses to be delivered by fibre.

There were three other laser developers presenting. Jiri Muzik from HiLASE gave a thorough description of the ultrafast thin-disk laser source development, their multi-beam and multi-wavelength techniques for high-throughput in drilling, cutting, and surface-structuring applications. A parameter that is increasingly controllable in laser processing is the pulse duration of the laser, and Matthias Mueller from TRUMPF explained the state of the art in their tunaeble pulse system and its benefits when it comes to surface roughness. Going right to the extreme short end of pulse duration, Ashley Crane from Amplitude detailed developments for increased average power, temporal agility, spectral ability and spatial agility for femtosecond pulses.

Beyond the source, beam delivery is what controls the effectiveness of laser processing. It is possible to shape beams to be the most effective for laser material processing, and Cailabs are doing just that, David Grosclaude told us, for applications such as micro-chip welding and hybrid laser arc welding of steel.

Other than spatial shaping, it's also possible to time multiple beams in order to coherently combine them. Ben Mills from Southampton talked about how he uses deep learning to coherently combine beams in real time. The possibilities seem almost limitless when neural networks are used, especially for the future of laser processing.

Coming back to the physical act of transferring the beam from the source to the application, we had talks from Holger Schlueter from SCANLAB and Wolfgang Lehmann from RAYLASE. Holger discussed their polygon scanner and multi-beam approaches to faster processing, and Wolfgang went into detail about beam delivery for photovoltaic wafers, laser powder bed fusion, electrode foil cutting for batteries, and welding. While SCANLAB and RAYLASE are freespace systems, fibre delivery systems are also used and we heard from Martin Udden from Coherent who explained their QD cables, which allow beam delivery as well as monitoring simultaneously. This technology is widely compatible with any process head configuration is an Industry 4.0 enabler.

In between sessions there was ample time for discussions, held around the exhibitors tables. The exhibitors were Aerotech, Hamamatsu, Kentek, Laser Trader and PowerPhotonic. We received positive feedback from the delegates, who heard about the latest state of the art in laser processing, and had access to every level of the laser processing supply chain during breaks.

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STEERING THE SHIP...

In my university days, I spent 2 years as the cox in a rowing crew, having had some experience doing the same in school. A rowing eight (as the boat is called) is almost 20 metres long and the oars (or blades) stretch out to a "wingspan" of almost 7 metres tip to tip. Unfortunately, the canal in Manchester we rowed on was only designed for craft up to 4.5 metres wide. To pass through the narrow bridges, you have to stop rowing and bring the oars halfway in (this makes balance tricky and these racing boats can easily capsize. The other fact is that you must go a long way up or down the canal until you get to a basin wide enough to turn around in, which involves a process of one side of the boat rowing forwards and the other side backwards. There are other hazards too in an urban canal, as they are generally rubbish tips for old shopping trolleys, used tyres, bicycles and the occasional motorbike. All of which can puncture the 3 mm thick carbon fibre hull of a racing boat. Another issue is that the canal has a speed limit of 4 mph, but in competitive rowing speeds of 10 -14 mph are reached.

Apart from rowing crews, the only people who come out in the rain are generally sitting on a stool with a fishing rod dipping into the canal in the hope that some living fish might be found. A rowing boat coming past at high speed is likely to result in grunts and shouts of abuse and sometimes a catapult load of maggots (fish bait) which isn't the friendliest welcome. I am pleased to say that now the club has moved to the Salford docks area where there is a lot more space and wider channels to row up and down.

The job of a cox essentially involves steering, monitoring the speed and stopping/starting the boat, coaching and encouraging the others in the boat. Only the cox is facing forwards, and even if the view is not great, it is vital to get the steering right. For example, if you have ever watched the boat race (Oxford and Cambridge) on the Thames in London, you will notice that although the river is very wide, there is a narrow band (not usually in the exact centre) where the river flows fastest – and the advantage of being on this conveyor belt of water is that it adds a few miles per hour to your speed. Now the cox is supposed to know this and put the boat in the exact spot where the maximum speed is found – not easy if you have only rowed on this stretch once or twice and don't have a good coach to teach you this.

For such a large boat, it is surprising how small the rudder is that steers the boat (controlled by a loop of rope which the cox pulls with both hands). Also, every time the rudder is used, the boat is slowed a little – so if you can go in a straight line you will go faster than if you continually correct the rudder in a zig-zag path. Visiting a race at York, I was warned of the need for one side of the boat to pull harder round the long and quite sharp right hand bend in the River Ouse, as the rudder alone was not enough to round this bend. In spite of the crew doing their best, we ended up in the bank and only when it was too late did I realise that the rudder string was broken and I was effectively pulling the rudder the wrong way! In spite of this, we did very well at other events and I have some trophies to show for it.

What is the moral of the tale? Perhaps there are 2 things to take away. Firstly, if you can look to the future and steer a straight path to your goal, you will find it easier and quicker achieved. And secondly, there are hidden obstacles that can derail your plans – the sooner you can find them and fix them, the better.

Dave MacLellan
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AILU'S ANNUAL JOBSHOP BUSINESS MEETING NEW TECHNOLOGY FOR YOUR BUSINESS

24 NOVEMBER 2022 - NATIONAL METALFORMING CENTRE

PROGRAMME

09:30 – 10:00 Registration & refreshments

Welcome & Introduction - Mark Millar (Chair of AILU Jobshop Group)

Current Challenges Facing Steel Supply in the UK - Gareth Stace (UK Steel)

Energy Cost Uncertainty: What is the best policy? - Liam Conway (Control Energy Costs, CEC)

Degree Level Apprenticeships – Finding & Retaining Future Skilled Staff
Rowland Travis (University of Nottingham)

11:10-11:40 Refreshments

R& D Tax credits – new legislation & opportunities - James Cameron (ABGI)

What's the Current situation with Commercial Solar Power? - Richard Wakeford (Evoenergy)

An Introduction to High Power manual laser welding in sheet metal - David Pope (IPG Photonics)

Laser Cleaning – a practical introduction to the process & equipment - Sinan Bilgin (SS Laser Solutions)

12:50-13:50 Lunch

What's new – short commercial presentations

Survey results feedback - Dave MacLellan (AILU)

Open Discussion Forum

15:45 Close

VENUE

National Metalforming Centre
47 Birmingham Road
West Bromwich
B70 6PY

AILU WORKSHOP ADDITIVE MANUFACTURING

15 DECEMBER 2022 - UNIVERSITY OF BIRMINGHAM

PROGRAMME

09:30 –10:00 Registration

Welcome - Moataz Attallah, University of Birmingham

Advanced Processing Routes for Netshape Manufacturing - Khamis Essa, University of Birmingham

Understanding & improving laser-material interactions in LPBF through high-speed imaging - Andrew Moore, Heriot Watt University

Process Control for the Creation of Porous Structures - Amanda Field, The MTC

11:10–11:40 Break

Design for Additive Manufacture and the rise of Gen3D - Vimal Dhokia, Bath University

Metal Powders for Additive Manufacturing - Raja Khan, TWI

RoboWAAM: an integrated hardware and software ecosystem for wire DED-Arc - Filomeno Martina, WAAM3D

12:40–13:40 Lunch

In-process quality monitoring: the power of sensor data fusion - Stephan Kuehr, Sigma Additive

TBA - Sarah Glanvill, Renishaw

Hybrid Additive Manufacturing Developments for Industry - Chris Austin, Mazak

14:40–15:10 Break

Putting Additive Manufacturing into Production - Emmanuel Muzangaza , Digital Manufacturing Centre

15:30 Optional Tour of Additive Manufacturing facilities at University of Birmingham

VENUE

University of Birmingham
Edgbaston
Birmingham B15 2TT
United Kingdom

Free places for Midlands-based SMEs
Contact AILU for more information

DATE	EVENT	LOCATION
15-18 November 2022	Formnext	Frankfurt, Germany
24 November 2022	AILU Job Shop Annual Business Meeting	TBC
30 November 2022	AILU Early Career Researchers Seminar	University of Nottingham
6-8 December 2022	SPIE Photonex	NEC, Birmingham
15 December 2022	AILU Additive Manufacturing Workshop	University of Birmingham
22-23 March 2023	Industrial Laser Applications Symposium ILAS 2023	Daventry