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AILU

THE LASER USER

IN THIS ISSUE:

FUTURE-PROOFING LASER APPLICATIONS: TECHNOLOGY IN TUNE WITH NATURE

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: Rotary cutting 0.04” stainless steel with a 1.5 kW fibre laser at 125 in/min.

Image courtesy of IPG Photonics

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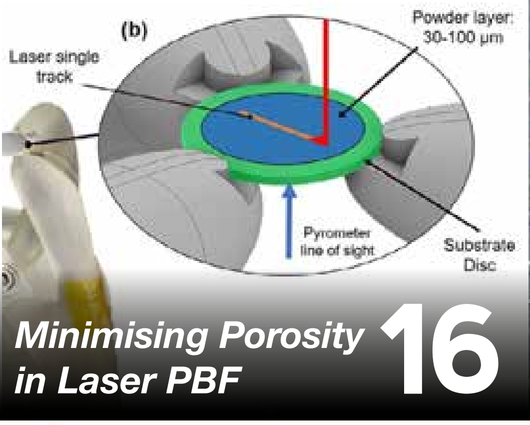

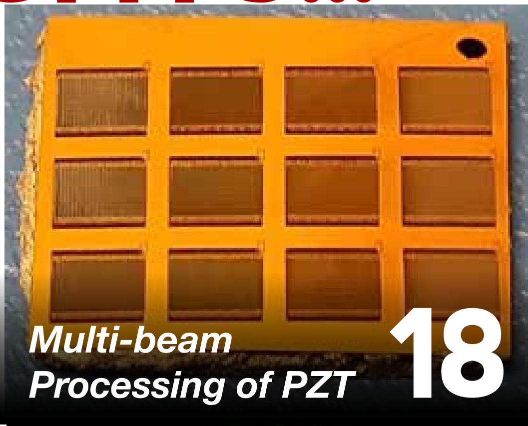

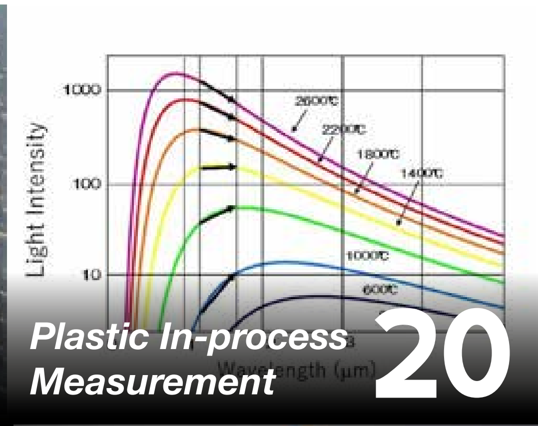

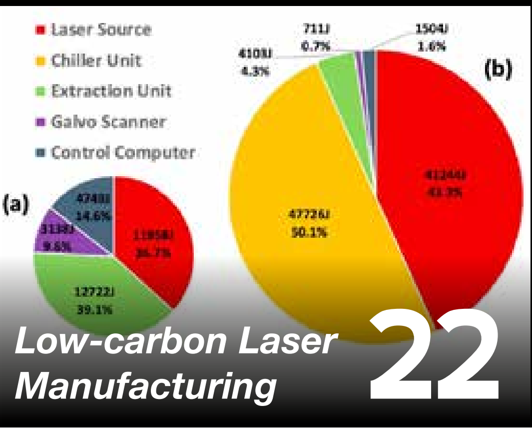

ASSOCIATION NEWS

FIRST WORD

Events are a major part of AILU's DNA as they are the best way to bring together the industrial and academic arms of our membership. We are right now putting together the programme of AILU events for 2022, as well as confirming the timing and location of ILAS 2023 (Daventry, 22-23 March 2023). Current favourites are surface texturing and additive manufacturing, but there is also a lot of interest in high power welding as well as laser sources and beam delivery. Look out for details, dates and venues as we try to fit in as many live events as we can.

In other news, the new AILU website is in the final stages of testing and modification and we will be going live imminently – we look forward to the new interactivity as it will include modules to book events directly (avoiding using Eventbrite) and it will be also possible to sign up new members too. The new website will be more responsive and rank higher in searches too - watch out for an announcement soon!

Dave MacLellan
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PRESIDENT'S MESSAGE

At the time of writing the great and good from governments around the world have converged upon Glasgow with the aim of 'fixing' the environmental challenges which threaten the future of our species. This is no small task! Developed nations have developed an addiction to the highly calorific and highly carbon emitting fuels and developing nations are developing an addiction of their own.

The solutions will require change at an unprecedented level and will challenge the way we configure industry. As such we must ask ourselves what the role of laser technology will be in driving towards a greener future.

I believe that the role of lasers will be tremendous in manufacturing the technologies which will underpin our race to net zero. E-mobility will continue to rise in prevalence with great opportunities in laser operations associated with welding and cutting to provide the staggering number of batteries that will be required.

Further, the laser has a pivotal role to play in additive manufacturing as we seek to manufacture ever more complex structures. While new part manufacture may currently be a focus for industrial laser users I predict a growing opportunity for the laser in reconditioning and repair of engineering assets. This will be driven in part by a shortage of engineering materials alongside an end to the availability of cheap energy.

Legislation will begin to force manufacturers to adopt new technologies alongside emergent business opportunities. The challenge is not only to survive but also learn to thrive in our very different energy future. A call to arms for the lasers community alongside our world leaders indeed!

Adam Clare
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RIC'S RAMBLINGS

There is a brave new world upon us, and it's… Hybrid.

We are encouraged to buy and drive hybrid cars (at least until we can get over our range anxiety and go full-on electric). Post-covid (probably not allowed to say that yet) we now also have hybrid working (sometimes at home vs sometimes in the office), hybrid events and hybrid meetings - all of which has, in my opinion somewhat complicated the world of work. Actually, I think there are definite advantages to holding a hybrid meeting or event, but there are also some definite downsides.

So what's the good bit? Well if you are organising an event, it is now somewhat easier to get speakers, especially if you are sourcing them from overseas. Rather than all the commotion of travel, they simply have to commit the time to writing the presentation and an hour or so on zoom being projected to a hall full of eager listeners. Also you can in general get bigger audiences for those speakers to present to. Some people who just can't, won't, or are still not allowed to travel to events can dial in and enjoy the day from the comfort of their own desk (does wonders for your delegate numbers).

To my mind though, there is still nothing like being "in the room" with all the peripheral benefits of coffee chats and lunchtime networking. I've talked a bit about this before – but that was mainly focused on "online only" events rather than our new hybrid friend. Difficulties come with that old chestnut – technology – why-oh-why do we still have trouble with internet connections and also with the fact that human nature is such that if you are not physically in the room – it is easier to be ignored or forgotten about – so Q&A sessions can be awkward and stilted.

Hybrid working also has challenges associated with being in the office (often a shared office) but still having to make zoom calls, especially if you have to talk about colleagues who share your office! Not sure if you have ever had to chair a hybrid meeting – I have and it is hard work. Making sure that in fact you don't ignore those lonely folks who dialled in, whilst having a jolly old time with those sitting around the table enjoying the full value of body language and non-verbal clues – that's really hard, and will take some getting used to. My plea to you all – imagine you are that person, sitting on zoom, away from the room, not able to engage like the rest of the team – and remember to include them in the conversation.

Ric Allott
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OBITUARY
VALENTIN GAPONTSEV

Image credit: Washington Post

AILU was saddened to hear of the passing of Valentin Gapontsev, "Father of the Fibre Laser Industry" and founder, Chairman and former CEO of IPG Photonics. We are honoured to publish two personal tributes to Valentin from Bill O'Neill, University of Cambridge, and Roy Taylor of Imperial College London.

It is with great sadness that we mark the passing of the mighty Valentin Gapontsev. Valentin's life is a true story of grit, determination, scientific discovery, technology innovation, and business success.

He once described himself to me as a frustrated spectroscopist. His frustrations led him to become an international expert in energy transition mechanisms in rare earth doped laser glasses and crystals. Following 25 years of research he became disillusioned with the difficulty of obtaining research funding and struck out on his commercial journey. This was an incredibly brave move for a 52-year-old academic with no business experience, starting from scratch, in the economic uncertainty of Russia in the early 1990s.

Like many stories of great business success, he started in a basement, with lots of ideas and little money. In his case it was a laboratory in the Institute of Radio Engineering in Fryazino, near Moscow. Working with his partner, Alex Schestakov from the Industrial Laser Institute, and a small team of laser scientists, he began selling novel glass and crystal lasers. His interest in fibre laser technology grew throughout the 1990s with his first commercial successes coming from contracts for high power fibre amplifiers.

The communications industry at that time was entering a boom phase, the internet was a burgeoning promise on the horizon, and there was much need for optics-based telecom solutions. IPG Photonics rode the wave and became an international telecom component manufacturing company.

One sector's loss is often another sector's gain. In this respect the downturn in the communications industry in the late 90s gave greater impetus for Valentin to focus on his long-held belief in high power fibre lasers for materials processing. In the early 2000s IPG spent heavily on R&D of high-power lasers and advanced manufacturing capabilities.

Those of us who attended Laser Materials Processing conferences at that time could not possibly forget the site of Valentin on stage. This larger-than-life Russian fella, running through 100 slides in 25 minutes, declaring the end of the laser industry as we knew it, and the promise of tens of kW of power from what looked like a piece of fishing line. We were quite simply shocked by the audacity of his vision and were in shear disbelief at his numbers. I was sitting in one of Valentin's presentations at ICALEO in 2004 where he declared his new lasers had a MTBF of 100,000 hrs. The person sat next to me said, "blimey that's longer than my career", and shook his head, as we all did.

Valentin's dream was to see lasers become a tool of choice in mass production. His success in science, technology and business has made this dream come true. His multi-billion-dollar corporation founded on a few thousand dollars of savings has delivered technology solutions that underpin trillions of dollars worth of manufactured goods. Valentin was a true genius, visionary and philanthropist. He was a people person who knew how to get the best out of others and was highly regarded by his workforce and colleagues across the world.

Professionally, he was a tour-de-force. In person he was warm, generous, and welcoming. I will miss our bear-hug greetings, and dinners that comprised of vodka toasts interrupted by food. He is an inspiration to us all and will be greatly missed on the laser stage.

Bill O'Neill, Centre of Industrial Photonics, University of Cambridge.

I first met Valentin Gapontsev in March 1991, when he visited our laboratory to see our then early work on short pulse generation with Ti:Sapphire lasers. The first thing that was apparent was his encyclopedic knowledge of non-radiative energy transfer mechanisms which was to be of vital importance in his latter development of high-power fibre laser schemes. In conversations with Valentin it was apparent that his principal interests lay in rare earth doped fibre lasers and amplifiers, and their potential commercialisation in a burgeoning fibre-communications marketplace.

In 1990, Valentin had reported 1 W from an end-pumped single mode and 4 W from a multimode Er-doped fibre laser. This was at a time when academics were simultaneously forecasting that up to 100 mW would possibly be achieved from fibre lasers, totally ignoring Gapontsev's achievements! Valentin placed particular emphasis on reliability and in fact, a diode-pumped, IRE Polus EFL-2 Yb:Er amplifier is still in operation in our laboratories at Imperial College after nearly 30 years.

Valentin recognised that there was substantially more to the fibre laser's potential and by the telecoms bust around 2001 he had already directed increased emphasis on power scaling, initially primarily with Yb-based systems. In addition to improvements in glass chemistry and through understanding and controlling the physics of rare earth ion doping, Valentin refined all the principal steps in high power fibre laser technology. The rest as they say is history. With each passing year IPG reported record average power achievements from their systems, breaking the kilowatt average power barrier by 2004.

Throughout his career Valentin was highly supportive of those around him. Even in the early days he established collaborations and student training programmes between the Company, Imperial College London and the Institute of Physics and Technology, Dolgoprudnyi, Russia. Valentin's support of the high-power fibre laser community was also very apparent in his sponsorship of the associated international conference on the topic held in St Petersburg every two years where he was an exceptionally generous host to the many invited international speakers and students.

There is no doubt that without Valentin Gapontsev's vision and drive, the high power fibre laser would simply not be in the world-leading dominant position that it is in today. It would have been a totally different product. His vision not only changed the technology but also changed the lives of the numerous people who were fortunate enough to interact with him on that wonderful journey of research and development. It was an absolute pleasure to have worked with and for him.

Roy Taylor, Department of Physics, Imperial College London

BUSINESS NEWS, EVENT REVIEW

OXFORD LASERS SECURES SECOND INDUSTRIAL UNIT

Oxford Lasers has signed the lease on a second industrial unit at Moorbrook Park in Oxfordshire. Despite completing an impressive expansion of the existing site in 2019/20, further space was required to support the continuing growth in its micromachining and imaging markets. The building will be the new home for the manufacturing, engineering and purchasing departments.

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XL PRECISION INVESTS IN THE FUTURE

Three new apprentices at XL Precision Technologies are embarking on a 44-month programme in laser and EDM manufacturing technologies. The apprentices are from the local Middlesbrough College. All three will start with a 12 month programme of rotating experience.

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II-VI POWERS SITES WITH RENEWABLE ELECTRICITY

II-VI Incorporated announced that it is powering all its facilities in Europe with 100% renewable electricity sources. The renewable electricity is supplied to II-VI's manufacturing operations, research & development sites, and sales offices throughout six European countries, including the UK. II-VI is purchasing approximately 38 million kilowatt-hours (kWh) per year of renewable electricity, and thereby eliminating about 5,800 metric tons of CO_2 emissions each year.

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IPG Photonics

Micrometric

Rainford Precision

TLM Laser

TRUMPF

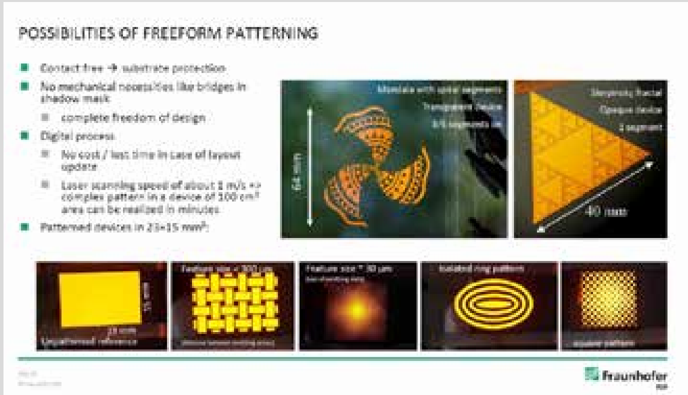
Aura concept EV

OLED TECHNOLOGY FOR LIGHTING MANUFACTURE APPLICATIONS WEBINAR: 15 SEPTEMBER 2021

This mini-webinar in September debuted a new format event for AILU. Featuring one sponsor (3D Micromac AG), teamed with a research organisation (Fraunhofer FEP) and free-to-attend for delegates, the webinar was a 60 minute format and attracted 93 delegates (nearly 60 live) from 17 different countries.

OLEDs are a fast-developing lighting phenomenon, and Jacqueline Hauptmann of Fraunhofer FEP gave an overview of the applications including automotive and domestic lighting. Thin flexible glass can be structured and cut with lasers and the LAOLA project outcomes show how the process is applied especially in roll-to-roll production.

The second half of the webinar allowed Hendrik Steinmetz from 3D-Micromac AG to go into more depth concerning the cutting with zero gap of thin and flexible glass using femtosecond pulsed lasers and highlight the system solutions that have been developed to prepare the process for volume manufacturing. There was a good engagement from the audience, who offered interesting questions, and this format of webinar is something that is well worth repeating.



Examples of OLED applications

DIGITAL TECHNOLOGY IN LASER MANUFACTURING WORKSHOP: 6 OCTOBER 2021

In our first live event since 2019, this workshop was also a first for AILU as a hybrid event. Combining live presenters and a live audience with several online presenters (from around the world) with an online audience could have been complicated, but the set up at Cranfield University enabled this to be carried off in a very successful manner.

Chaired by Cliff Jolliffe, and sponsored by Physik Instrumente (PI) UK, the event was forward looking and combined developments in laser sources, processing applications, automation and optics as well as motion systems and assembly verification.

The facilities at Cranfield University made this hybrid event very interactive and allowed remote delegates and presenters to fully participate in the activities (except for the lunch and networking which was reserved for the live attendees!).

Remote presentations from TRUMPF and Precitec covered the monitoring solutions for multiple laser systems in production (Markus Brieger, TRUMPF), and real time monitoring of laser welding performance for quality assurance (Jens Reiser, Precitec) – both under an Industry 4.0 regime. Krste Pangovski from Vision Intelligence then moved the topic to Artificial Intelligence (AI), where remote monitoring of process steps in assembly and machining operations can detect defects more reliably, efficiently and effectively than a human inspector and prevent sub-standard parts from being further processed.

Presentations from Oxford Lasers and University of Southampton looked at laser micromachining to improve the accuracy of beam location (Chris Wright, Oxford Lasers) and using Neural Networks to model and predict the performance of laser engraving or ablation (Ben Mills, University of Southampton). In the last presentation before lunch Branislav Timotivejic of Optotune described how auto-tunable lenses achieve accurate focus and in-process inspection in laser marking with a single optic.

After lunch Steve Kidd (PowerPhotonic) presented an all-digital design and manufacturing process for custom homogenisers and beam shapers that are laser machined parts with a very smooth surface. Two presentations from Universities, covered deep learning for defect detection (Hang Geng, Brunel University) and process temperature monitoring (Wojciech Suder, Cranfield University). The other two presenters were both remote speakers from USA, showing how motion systems within laser machines can have adaptive control with look-ahead functions (William Land, Aerotech) and optimised pulse positioning for high speed and tight radii (Nikta Jalayer, PI).

Delegates welcomed the return of face-to-face networking over lunch

Remote presentations were relayed to the live audience over Zoom, including Nikta Jalayer (PI, USA)

LASER LINES FORMS STRATEGIC PARTNERSHIP WITH THE DIGITAL MANUFACTURING CENTRE

Laser Lines has formed a strategic partnership with the Digital Manufacturing Centre (DMC) in Silverstone, which will see Laser Lines install Stratasys Additive Manufacturing (AM) machines in the DMC's live production environment.

The DMC is a sector agnostic digital production facility with a focus on engineering-led solutions. The first machine to be installed as part of the partnership is the Stratasys F770 – the first installation of the printer in the UK.

Mark Tyrtania, sales director at Laser Lines, said: "Working so closely with the DMC will enable our customers and prospects to see Additive Manufacturing printers in a live, digital manufacturing environment, which will help them to understand how they can be used for production parts within the whole digital workflow.

"The collaboration also enables us to highlight the benefit of AM and show Stratasys machines in volume production, printing real parts in a live environment."

From a variety of AM systems and materials, through to finishing and inspection services, the DMC has been designed from the ground up with full traceability throughout the entire production pathway.

Kieron Salter, CEO at the DMC said: "We are bringing together world-class engineering with industry-leading additive manufacturing systems to solve the real-world challenges of our customers. Our partnership with Laser Lines is an integral part of this pursuit, providing us with state-of-the-art AM equipment backed by exceptional support and a spirit of collaboration.

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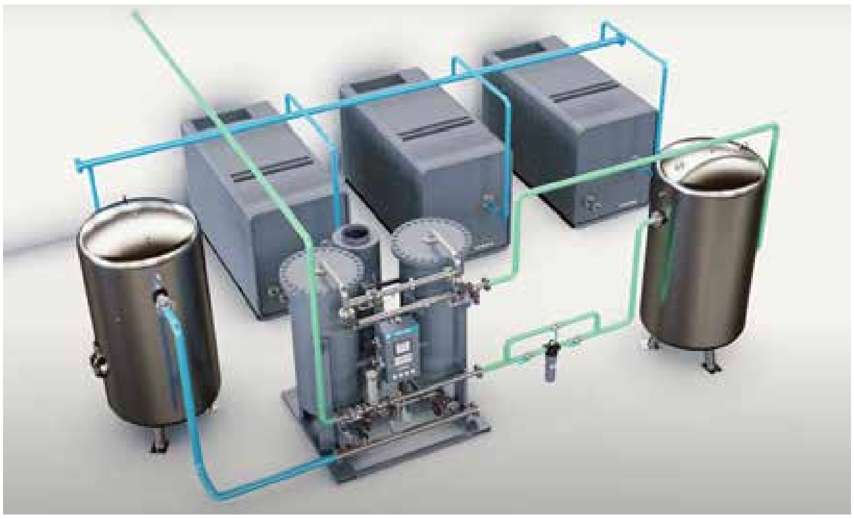
ATLAS COPCO'S ON-SITE NITROGEN GENERATOR SAVES THOUSANDS

Laser metal cutting and fabrication specialist LaserMaster recently switched from bulk delivery of nitrogen to an Atlas Copco on-site, high pressure nitrogen generation container unit.

Located in Cornwall, LaserMaster offers metal cutting services to industries ranging from private customers to local, national, and international manufacturing companies. For the past seven years, LaserMaster has had a bulk nitrogen supply agreement in place and was renting an on-site storage tank. However, rental costs were in the order of £8,000 p.a.

LaserMaster looked for a one-stop facility, one company to could deal with providing the nitrogen system and be responsible for its maintenance. The company was recommended an Atlas Copco HPN2 skid 8, on-site, high-pressure nitrogen generation containerised package. This was to be rented for an initial three-month period in order to compare performance and costs against the current supply facility.



The switch to on-site nitrogen generation is estimated to save around £2500 per month when compared to the previous bulk supply method, and now the total cost of nitrogen has been reduced dramatically – down to 4p per Nm^3.

Commenting on the performance and success of the installation project, MD John Gotts said, "We have invested for the future, firstly by taking delivery of one of the first Bystronic 4kw fibre optic lasers in the UK. This has enabled unparalleled high-speed parts production and first-class cutting quality. Now with a continuous supply of nitrogen, we have the capability to cut metal 24/7."

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TRUMPF TRULASER ELIMINATES TIME/COST ISSUES FOR TW METALS

TW Metals, a supplier of high-performance metals with a global turnover of £710 million, has invested in a new 10 kW TRUMPF TruLaser 3060 fibre for one of its UK facilities.

The company describes the large 6 m bed laser cutter, which is the first of its type in the UK, as a “game changer” as it has eliminated the time/cost issues associated with using subcontract resources and is now fulfilling next-day delivery demands.

The market segment occupied by the Speciality Distribution business unit of TW Metals has particular focus on materials for critical and hazardous environments, often in sectors such as nuclear, petrochemical, oil and gas, medical and automotive.

“We’re far from a standard stockholder,” explains Mike Street, Vice President Europe - Speciality Distribution. “We talk to our customers about their pain points and issues, from which we create material proposals that include service provision to manage flow through their supply chain.”

Explains Mr Street: “The provision of machined or first-stage components is becoming an increasingly common request. We had a plasma cutter for this purpose, but knew a laser cutter would be ideal for our corrosion-resistant and heat-resistant nickel alloys, which extend from thin gauge sheet up to 30 mm thick. It would also help us introduce other product ranges, like thin gauge sheets in stainless steel and aluminium.”

Selecting the 6 m bed option for the TruLaser 3060 fibre provides TW Metals with a market advantage as it can handle much larger raw material. In addition, the company can get preferential pricing from the mills as they have less processing to undertake, while the large bed also means TW Metals can accommodate four or five large offcuts simultaneously for overnight cutting, should the need arise.

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WDA SHARPENS UP ITS ACT WITH NITROGEN GENERATION FROM MSS NITROGEN.

WDA Machine Knives in Sheffield have recently upgraded their high pressure nitrogen generation system with the latest generation MSS Nitrocube. Having had many years of reliable supply from their previous MSS system WDA decided that it was time for an upgrade. Paul Harris, MD at WDA comments "the old nitrogen system has given us excellent system but required some refurbishment work as the cutting quality had started to reduce so we contacted MSS about making some improvements for us".

The new Nitrocube 1 system provides high pressure nitrogen at 99.9975% purity which is ideal for high quality laser cutting, especially for stainless steel. The new system is very compact and features integrated high pressure storage tanks together with MSS’ own touch screen control panel. The latest generation Nitrocube is more efficient than ever, using 25-40% less energy to generate higher purity nitrogen than the older systems were capable of.

Paul commented that "the installation work went extremely smoothly, MSS planned all aspects of the work to minimise disruption and got us back up and cutting again more quickly than I expected. The new Nitrocube has really improved the quality of our products and gives us great confidence in our nitrogen supply. The control panel gives me really useful operating data, I can clearly see the status of the entire system and production data at the touch of a button – I look at it regularly".

MSS Sales Director, Chris Smith commented "this was a challenging installation and I’m very pleased how well it went, we were able to provide WDA with a really flexible purchasing option that allowed them to upgrade their old system without any significant impact on their current capital budget".

Chris also comments "the latest generation MSS Nitrocube is the most compact and most flexible system available anywhere, we have over 400 systems like this installed in the UK already and the popularity of this product is growing very quickly in a number of important overseas markets. This latest product incorporates all we have learnt from high pressure nitrogen systems for laser cutting applications over the past 20 years’.

Contact: Chris Smith
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LASER INTERACTION WITH WOOD TISSUES

Low carbon construction is one of the potential ways to achieve the goal of net-zero by 2050. The UK Climate Change Committee (CCC) has suggested the use of timbers in construction to reduce carbon emissions. Timber is an alternative to other structural materials, mainly steel and concrete, due to its high strength-to-weight ratio and reduced energy in manufacture. The constituent polymers of wood (cellulose, hemicellulose and lignin) are not resistant to weather, insects or fungi which is a critical concern when the moisture content exceeds approximately 20% in service. Chemical (preservative) treatments are widely used to protect the wood polymers against structural degradation and overall failure of timber components. The effectiveness of preservative treatments and some wood modification techniques depends on a suitable depth of penetration of chemicals into the wood structure.

Laser incising is beneficial for increasing the penetration and retention of chemical preservatives due to its ability to incise deeper, use smaller hole dimensions and, due to it being a non-contact method, with lower wear on tooling. However, the laser interaction with the wood tissues (earlywood and latewood) is complex. The complex wood structure results in different sized holes at different locations. The structure of wood predominantly contains alternate layers of earlywood and latewood. The density of latewood is on average 1.9 times (for Southern Yellow Pine) higher than the earlywood value. The differential density results in different incision rates at different locations depending on the presence of earlywood/latewood tissues on the surface and its size and shape. The growth rings within the wood are not always perfectly circular as depicted by Figures 1(a), 1(b) and 1(c). Further research is underway at Coventry University, in collaboration with Bangor University and Millenium Lasers Ltd., to better understand this phenomenon.

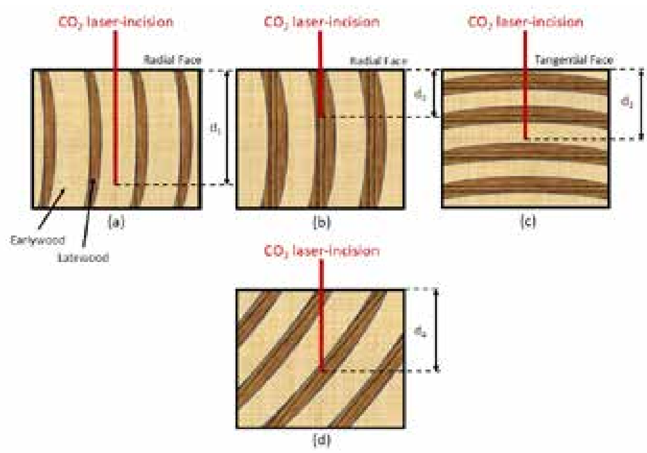

Figure 1: Schematic diagrams of CO_2 laser-incision strategies with CO_2 laser interaction with earlywood and latewood tissues in the structure of wood.

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USING LASERS TO 3D PRINT MAGNETS

Laser powder-bed fusion (L-PBF), as an additive manufacturing (AM) technique, has demonstrated excellent capabilities in achieving degrees of freedom in manufacturing that are otherwise unattainable. The potential of combining Nd-Fe-B as a permanent magnet and the manufacturing capabilities of L-PBF promises new prospects for functional AM in applications such as electric motors. In a study by researchers at the university of Nottingham's CfAM, NdFeB permanent magnets were manufactured using L-PBF elucidating the process-structure-property relationships concerned. High density parts (91%) with remanence of 0.65 T and maximum energy product of 62 kJ/m^3 were successfully fabricated, comparable to the state-of-the-art in the field.

One of the key findings of the study was the correlation between the rapid cooling rates associated with laser processing and the unique nanocomposite microstructure developed in the material. Nevertheless, the rapid solidification led to significant micro-cracking, attributed to the residual stresses due to the brittle nature of the material as a consequence of the laser-material interaction. The sizes and geometries of the printed magnets played an important role in the formation/minimisation of defects (Figure 1). For example, larger parts were easier to print with less defects. As for the geometries, it was found that avoiding extruded sharp corners in the designs allowed successful production of various shapes, such as columns, rings and cylinders. It has been demonstrated in the article (doi: 10.1016/j.matdes.2021.109992) that combining laser-based additive manufacturing techniques with interesting functional materials allows 3D printing of functional parts, paving the way for more multi-functional additive manufacturing opportunities and applications.

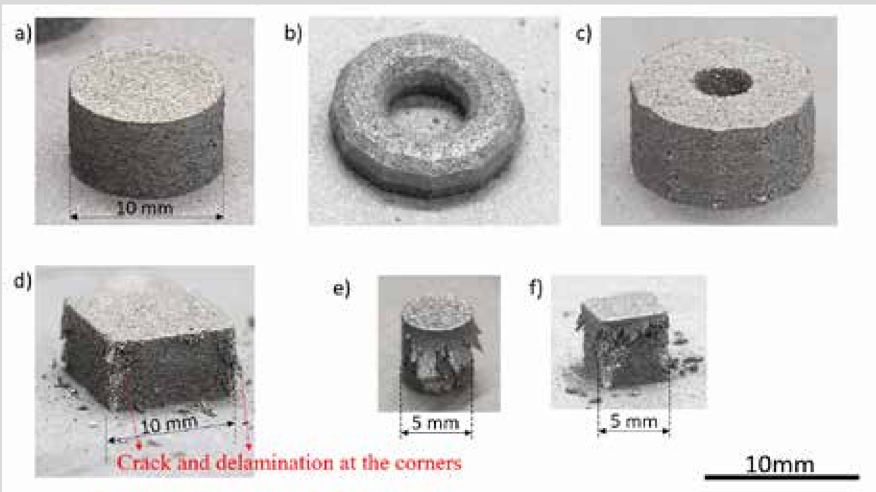

Figure 1: Printed demonstrators showing the design freedom capabilities and limitations when using laser powder bed fusion to process NdFeB magnets

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HARNESSING THE POWER OF THE PERIODIC TABLE

AN INTERVIEW WITH HOLLIE DENNEY

SALES MANAGER, II-VI

Q. Can you tell us about II-VI?

The Roman numerals II-VI in our company name refer to group II and group VI of the periodic table of elements. By chemically combining elements from these two groups, II-VI produced infrared optical crystalline compounds to be used in optics for CO_2 lasers.

Founded in 1971, the company's co-founder, Dr. Carl J. Johnson, paid homage to these so-called "II-VI" materials by calling the company II-VI Incorporated. From there, we have never stopped innovating in materials, processing and quality, and now we work with most of the elements in the periodic table.

In our 50 years of growth, we have continued improving and expanding our portfolio and are now a global leader in engineered materials, optoelectronic components, and optical systems, offering vertically integrated solutions for several exciting end markets.

With revenues of $3.1 billion (FY21), II-VI is growing year on year. Headquartered in Saxonburg, Pennsylvania, and with 22,000+ employees worldwide in 73 global locations in 18 countries, our mission is "Enabling the world to be safer, healthier, closer, and more efficient."

Q. How does laser processing fit into the overall structure of II-VI?

II-VI was founded to provide optics for industrial lasers. This market is still an important part of the II-VI business, although the company is continuing to expand into new markets and other technology platforms.

Q. How has the shift from CO_2 to fibre lasers altered your business? Does CO_2 have a promising long-term future in your opinion?

Low-power CO_2 lasers are still very much favoured in many applications, for example, in automotive with plastics and fabrics, due to the efficient light absorption of these materials at 10 micron wavelength. However, the high-power lasers purchased and deployed today are mainly one-micron-based systems. We anticipate a significant market for service work and spare components for the deployed base of CO_2 lasers for maybe another 10 years or longer. I conducted an investigation in 2020 into sales of CO_2 lasers and found that the median age of CO_2 machines being resold in the EMEA area is 14 years. When we compiled this survey back in 2018, we found the median age to be 12 years old. Of course, II-VI also supplies consumable parts for fibre laser machines and is looking at different ways to support the service of fibre heads in the future.

> "Being in sales, meeting customers was a huge part of my job"

Since 2013, II-VI has developed an important GaAs technology platform, which underpins the semiconductor lasers that power fibre lasers. It's one of the world's very few 6-inch GaAs optoelectronics platforms. As it happens, we are expanding that platform right here in the UK, at our Newton Aycliffe facility, where we are significantly ramping up our hiring.

Q. How have you and the business been affected by the pandemic? Do you see a strong bounce-back of business in 2021-22?

Personally, COVID-19 has affected life quite significantly. Working from the office has now turned in to working from home, social interaction decreased significantly in social and work settings, and a new 'hybrid' way of working seems to be the new norm. Being in sales, meeting with customers was a huge part of my job, also the part I loved. Lockdown has made me question things I used to take for granted, and made me look at life in a new, unfamiliar way.

II-VI has been working hard to mitigate the effects of the pandemic, giving priority to the safety of our employees. Establishing new pandemic protocols across our 73 locations worldwide has been a gigantic internal effort, but we've pulled together to do everything we possibly can to serve our customers.The bounce-back of the business appears to have already started. As we recently reported, growth was strong in the last quarter for our CO_2 and fibre laser components.

Q. Do you feel the laser industry is moving fast enough in recruiting women?

I believe the laser industry is going in the right direction, but there is always more that could be done. The industrial laser cutting industry, in particular, is quite traditional in the sense of once you are in, due to it being quite niche, it's quite hard to come away from. I come across men all the time who float between different laser job shops, but they always stay in the industry. Maybe 80% of my customers in this industry are male; as a woman, I must be self-confident to be in sales in a hugely male-dominated environment.

At II-VI, on the other hand, I have several female colleagues in senior positions whom I look up to as role models. I see AILU in particular as an excellent conduit to push the progress of women in the industry.

Q. Anything new and exciting in the pipeline you can talk about?

As ever, II-VI is working on many new and exciting projects. For example, we recently announced a turnkey laser welding solution for the e-mobility market. The combination of Coherent's ARM fibre lasers with our RLSK and HIGHmotion 2D remote laser processing heads ensures maximum productivity on customers' manufacturing lines.

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

AILU offers excellent networking and learning opportunities through its meetings and particularly its ILAS events. Also, its job shop meetings are a great way to bring together the laser cutting industry under one roof: customers, service companies, and OEMs.

> "AILU is an excellent conduit to push the progress of women in the industry"

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MODERN TOOLS SUPPLY THE VINTAGE MARKET

Many job shops offer more than laser cutting, but few have 5-axis capability. GF Laser is co-located with Moseley Brothers who are equipped with press tool manufacturing capabilities and a range of press tools that can operator coil fed or single load operation, as required. The image above shows a bumper overrider for a vintage Jaguar which is in the process of being laser cut on one of the two TRUMPF 5-axis machines at GF Laser.

This part is first pressed and then trimmed to final shape on the 5-axis machine. Pressings are sometimes free issued for finishing, or the full service of manufacturing can be provided by GF Laser in combination with Moseley Brothers.

Parts like this can be reverse engineered where drawings are not available – this is especially useful when using the 5-axis machine. Finishing operations like powder coating are also available.

In case other laser cutting subcontractors have a need for 5-axis cutting and are not equipped to do it, GF Laser is ready to work in partnership. Its 5-axis machines can process spinnings, formed tube or hollow section parts, pressings and straight tube. The most recently installed machine, shown in the picture, is the TRUMPF 5030 installed in July 2019, the first one of its type installed in the UK.

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CHAMPIONING YOUNG PEOPLE AT MICROMETRIC

It has always been one of Micrometric's goals to support the future careers of young engineers, and as part of this they've been working with students from the University of Lincoln and Lincoln University Technology College to help them expand their engineering knowledge and experience.

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MIDTHERM LASER UP FOR COVID AWARD

Midtherm Laser is proud to have been nominated to receive the Made in the Midlands Manufacturing Hero award for our ongoing efforts to support the NHS throughout the pandemic.

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ESSEX LASER'S ONE-OFF ANGEL SCULPTURE

Although Essex Laser mainly produces large quantities of laser-cut and folded items for practical applications, once in a while they are asked to work on one-off projects that are a bit special. In this case, the brief was to create an angel sculpture inspired from a small brooch using CAD files that had been supplied by the client.

The Essex Laser team had to heavily modify the CAD files then started by making a laser cut and welded mild steel mock-up of the angel sculpture. Once this had the customer's approval, the real thing was created by laser cutting and welding it using mirror polished stainless steel and is approximately 600 mm high. The team was extremely pleased with the finished result as was the client.

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CHAIR'S MESSAGE

FORCE MAJEURE

"The world is literally burning, on fire" said Greta Thunberg while protesting at the COP26 recently. Whilst she was specifically referring to the global climate crisis, there is a underlying feeling that we are living in very challenging times at the moment.

About 3 years ago, if you were to read our company's "threats to the business" and "disaster recovery" plans, they said tame things such as "potential policy changes which could affect the economy are a threat" and "in case of fire, sub-contract work to our sister sites or even competitors". How naïve not to have seen the issues from Brexit, a pandemic and now the looming energy crisis coming!

Natural gas supply is being propped up by Russia, our electricity supply was threatened when a cable from France caught fire, materials have rocketed in price and now we are struggling to source items due to the lack of drivers. We have been battling with the shortage of materials for a few months now, but electricity and nitrogen supplies are next on the list to give me a headache.

I'm jealous of those of you with your own nitrogen generators right now, because today we received a letter from our nitrogen supplier declaring a "Force Majeure event" - due to "supply chain constraints" our supplier may not be able to deliver the contracted level of service for nitrogen supply. Whilst it is not clear if this is down to electricity supply issue, lack of drivers or both, our sister site has already lost a few days production due to lack of nitrogen and I can see that is a similar threat for us.

Next is the cost of electricity - right now we are being quoted 3 to 4 times our current price. Hopefully this will settle down, but I can't see prices in the near future being close to what we are paying now.

Finally, to add the cherry on top of this humble pie, the Bank of England have apologised about the increased cost of living as both interest rates and inflation are set to rise above predicted levels. Well, whilst I'm no economist, even I could see that coming after the amount of money the pandemic and furlough scheme must have cost the country.

Looking on the positive side, we are all in the same boat. Yes, so it's currently sinking but... at least it is the same for everyone! I would suggest most of these issues will ease or, better still, disappear over time. Don't fear and take solace in the fact that the best thing about Job Shops is that we are very dynamic and can react quickly to the changing and challenging conditions, something the large incumbent corporations find much harder to do.

If you want answers from real experts on these issues and what we can do right now, I strongly encourage you to come to the AILU Job Shop meeting at Mazak on 2nd December 2021. I look forward to seeing you there; you can't afford to miss it!

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LASER CALORIMETRY AS POROSITY MINIMISATION METHOD IN L-PBF

GIUSEPPE DEL GUERCIO ET AL.*

The interaction between the scanning laser beam and the powder bed is one of the most studied phenomena in Laser Powder Bed Fusion (L-PBF). The ability to process a material with L-PBF highly depends on the powder absorptivity, which is the fraction of the laser beam's energy transferred to the material. An adequate energy deposition is required to guarantee optimal consolidation of the printed part with minimum porosity. When this condition is not met, macro-porosities (such as lack-of-fusion (LOF) and keyholes) arise, impacting negatively on the structural reliability of the print. Analytical models have been proposed to predict the presence of defects as a function of laser-related parameters such as power (P), scan speed (v) and absorptivity (A) [1–3]. Nevertheless, it is often assumed that the powder absorptivity is constant, leading to erroneous predictions of the optimal L-PBF processing window.

In this work, we use 2024 aluminium alloy (AA2024) as an exemplar material to measure the variations in absorptivity via in-situ calorimetry as a function of the power and the laser scanning speed. The obtained values of absorptivity are then applied to analytical models to predict the presence of macro-pores in a large process parameter range. Based on these calculations, an optimised window minimising the occurrence of the cited porosities is selected and validated by inspecting cross sections of the corresponding printed parts.

Laser calorimetry measurements

The absorptivity of AA2024 was measured using the laser calorimeter shown in Figure 1(a). An aluminium disc with a layer of AA2024 powder on top was held parallel to the pyrometer aperture and perpendicular to the laser beam (Figure 1(b)). During operation, single tracks were deposited consolidating the powder on the disc. The energy delivered by the laser beam melted the powder and caused an increase of the disc's temperature which was recorded by the pyrometer over the duration of the track deposition. The raw trend of temperature (T) over time (t) was measured until the disc's temperature returned to the nominal starting temperature. The raw T-t curve was linearly fitted to evaluate the characteristic temperature profile and cooling rate associated to the laser scan track (Figure 1(c)). The absorptivity of AA2024 was evaluated for selected powers and scan speeds using the method proposed by Trapp et al. [4], then linear interpolation was used to evaluate the A-P trend.

Absorptivity and melting modes of AA2024

The measured absorptivity variation as a function of laser power is shown in Figure 2 for the three scan speeds analysed. In the low-power regime, absorptivity has relatively low average values with large variances for each considered scan speed. This happens due to incomplete melting of the powder bed and discontinuities in the track formation (specifically at lower scan speeds) causing inconsistent light scattering and poor energy absorption. Laser powers exceeding 150 W were required to form continuous tracks and in turn, more accurate absorptivity measurements. In the high-power regime, the average absorptivity values plateau and have much lower variances. This trend is clear for a scan speed of 0.5 m/s. In between the low and high-power regime, a progressive rise of absorptivity values was noted which is more accentuated for lower scan speeds.

Absorptivity is directly associated with the interaction between the powder and the laser source that is the melting mode. Moreover, fluctuations of the layer thickness and powder inhomogeneities may influence the energy absorption and cause the scattering of the absorptivity values. When considering Al-based materials, this behaviour is strongly influenced by the laser power intensities. In the low-power regime, the cited interaction is dominated by the specular reflection between powder particles. In these conditions the conduction melting mode dominates. On the other hand, in the high-power regime, keyhole mode melting prevails. The high energy associated with the laser causes metal evaporation and the formation of deep V-shaped melt pools. This condition is associated with a higher interaction between the laser source and the powder bed, which results in the greater values of absorptivity of Figure 2. The detected rise of absorptivity in between the two considered power regimes is associated with the gradual change of melting mode from conduction to keyhole. This behaviour is more

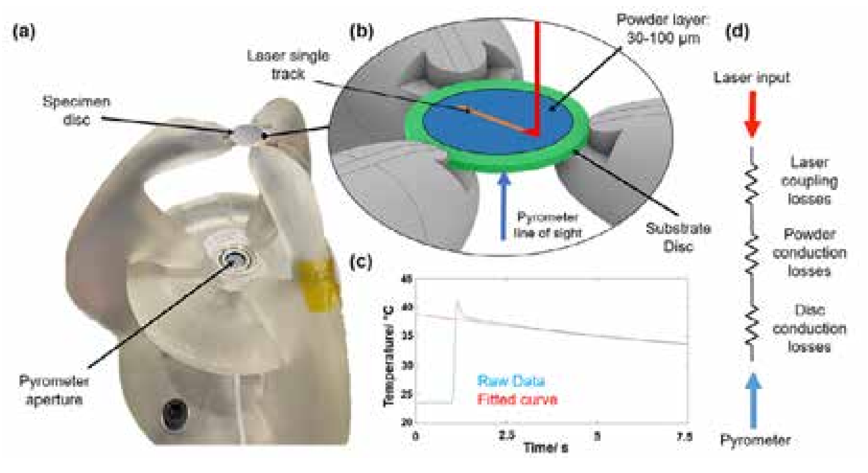

Figure 1: (a) Overview of the laser calorimetry system used to measure the absorptivity of AA2024 powders during L-PBF; (b) Detail of the disc's holding mechanism; (c) Curve fitting from raw data to evaluate temperature decrease over time; more information about this calorimetry system can be found in [5].

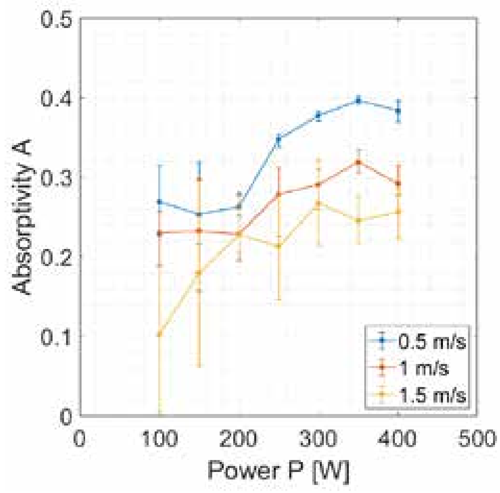

Figure 2: Laser absorptivity of AA2024 powders during L-PBF as a function of laser power and scan speed.

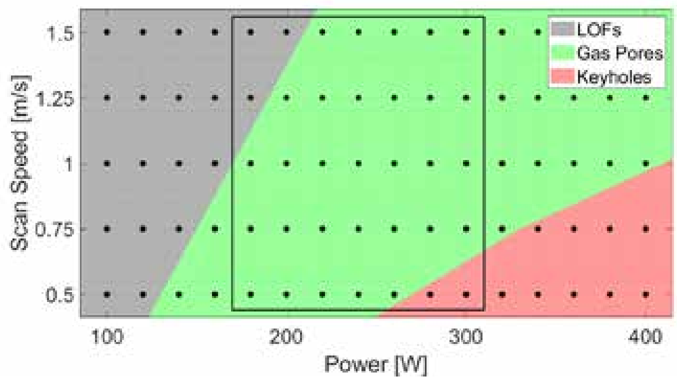

Figure 3: Graphical output of the prediction of the presence of LOFs (grey region), keyholes (red region) and gas pores (green region). The refined process window is enclosed by the black box.

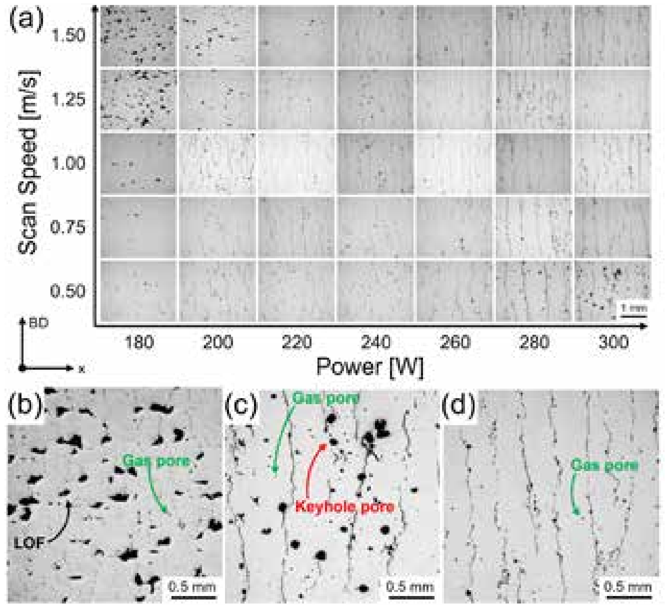

Figure 4: (a) Optical micrographs of all the P-v combinations experimentally investigated within the optimised process window; (b) Typical microstructure of a sample in the LOF region; (c) Microstructure obtained in P-v combinations predicting the presence of keyhole pores; (d) Typical microstructure of a sample in the gas pores area.

accentuated for low scan speeds since these are characterised by a higher energy deposition.

Prediction of the presence of pores in AA2024

Porosity in L-PBF is thought to arise from distinct mechanisms leading to the formation of gas, lack of fusion and keyhole pores. These last two types of porosity are larger than the first one and their presence can be predicted using the methodologies proposed by Tang [1,2] and King [3] as a function of power and speed. Based on these approaches, computations were conducted using the measured trend of A (Figure 2), a power range of [100-400] W and a scan speed range of [0.50-1.50] m/s. In case no macro-porosity was found, the presence of gas pores only was predicted.

Figure 3 graphically depicts the output of the calculation. In order to validate these predictions, an optimal processing window characterised by minimal porosity was selected and samples were manufactured using each P-v combination within these optimal ranges.

Densification behaviour of AA2024 in the optimised process window

Figure 4.(a) shows representative micrographs corresponding to the specimens obtained with the optimised process parameters illustrated in Figure 3. Within this window, samples produced with high speed and low power showed the presence of LOFs (Figure 4(b)). Conversely, samples produced with low speed and high power were characterised by keyhole porosities (Figure 4.(c)). The rest of the optimised process window showed only the presence of gas pores (Figure 4.(d)). Due to high cracking susceptibility of AA2024, all the P-v investigated showed the presence of long cracks aligned to the building direction.

The micrographs presented in Figure 4 confirm that, despite relative simplistic assumptions, analytical models can be effective tools to predict porosity in Al alloys processed by L-PBF. However, in order to correctly capture the mechanisms causing the formation of both LOFs and keyhole pores, A needed to be implemented as a function of both laser power and scan speed.

The presence of LOFs at high scan speed and low power is caused by the poor energy exchange between the laser source and the powder bed which additionally results in low absorptivity values. In these regimes, the correct overlapping of melt pools is not guaranteed causing the formation of a LOF. On the other hand, at low scan speed and high power the interaction between the energy source and the powder bed is higher resulting in great absorptivity values. These conditions favour the nucleation of keyholes.

Conclusions

Laser calorimetry enabled the measurement of the absorptivity of the AA2024 powder as a function of laser power and scan speed. In the low-power regime, the absorptivity has lower values due to the limited energy exchange between laser source and powder bed. On the contrary, in the high-power regime the absorptivity is higher due to the change of melting mode from conduction to keyhole. Intermediate values of power are characterised by a progressive rise of absorptivity. This behaviour is more emphasised when a low scan speed is used.

The computation of the trend of absorptivity as a function of laser power and scan speed, coupled with the use of analytical models, enabled the correct prediction of the presence of pores in AA2024. This accelerated the identification of an optimal process window characterised by low porosity.

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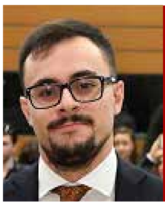

Giuseppe Del Guercio is a PhD student at the University of Nottingham. His research aims to design and develop new high-strength Al-alloys for L-PBF.

SEE OBSERVATIONS P28

MULTI-BEAM PROCESSING OF ULTRASONIC MEDICAL SENSORS

DANIEL ARNALDO

Precision laser micromachining of heat-sensitive materials acts as an enabling technology for creating novel high resolution and high frequency ultrasonic probes. These constitute the heart of miniaturised sensors that are employed to gather real-time acoustic images during complex endoscopy-based surgical procedures. One of the key advantages of using an ultrasonic sensor is the possibility of discerning between different types of human tissue in real time. This is a critical advantage that greatly enhances standard procedures, which are commonly based on offline pre-surgical MRI brain mapping. In fact, the human brain moves during a surgical procedure.

Acoustic images are created after processing reflected acoustic waves generated by an ultrasonic probe. The acoustic waves are focused down on the target area, then they partly penetrate into the tissue before bouncing back to the sensor, according to several mechanisms. Travel time, remaining acoustic energy or entry angle of the reflected wave are all examples of the information that is collected by the sensor and then processed in real-time to create the acoustic image. The reflected acoustic waves include additional in-volume information of the living tissues they have travelled through. This in turn allows forming an image that shows different types of human tissue. The surgeon may now be able to selectively remove a certain malign brain melanoma while avoiding damage to surrounding "healthy" tissue, for example.

Piezoelectric ceramic material

At the core of the ultrasonic sensor is a laser micro-structured piezoelectric lead zirconate titanate (PZT) ceramic material, which is responsible for the generation of the correct acoustic waves. The PZT material is micro-structured according to a design with tight geometrical tolerances, which enables the piezoelectric ceramic to generate pulsating sound waves at a given desired frequency and bandwidth, typically at several tens MHz.

The bulk of a piezoelectric ceramic material like PZT consists of dipolar molecules which are physically arranged in space following a determined unique and common orientation. If the material is heated above a certain temperature, then its dipoles lose their initially shared orientation and become random. This ruins the piezoelectric response of the material, together with any ability for producing sound waves. This loss of piezoelectric properties due to dipole orientation disturbance is referred to as depoling.

Challenges

Residual laser heat is usually a major limiting factor when attempting laser micro-structuring of piezoelectric PZT, even when using an ultra-short, pulsed laser source. As much reduction of residual thermal impact that can be expected from using laser pulses in the pico- or femtosecond regime, residual heat is by no means absent nor negligible [1,2]. This residual heat input will be sufficient to easily cause complete depoling of the PZT unless adequate heat management strategies are adopted.

Aside from residual heat mitigation, very tight geometrical specifications and laser etch tolerances also need to be achieved. The PZT piezoelectric material has an additional electrically conductive, thin topcoat that needs to be selectively removed first. This process will generate a predefined number of PZT elements, which will be electrically isolated from each other. Once the topcoat has been removed, the material in between the elements needs to be completely removed to achieve mechanical isolation between them. In this way, each individual PZT element can "resonate" at the desired frequency upon electrical excitation.

The available gap in between elements is only 8 µm by design, so this length establishes the upper limit for the laser cutting kerf maximum width. Typical PZT thicknesses of about 50 –70 µm are employed, so the required aspect ratio of the cut can also be a challenge. One needs to consider the substantial limitation on laser power that the PZT material can withstand before depoling. The absolute positional tolerances of the cut kerfs are also quite demanding at typical ±1 µm.

Process development

Process development is vital to achieve a functional ultrasonic device. The use of IR thermal cameras with high frame rates allows monitoring of the thermal input during the laser process, and has proved to be an essential tool that helps to identify the right processing conditions. Due to the restriction in applied laser power, the PZT cutting speed can be slow to a point of becoming uneconomical. However, by taking advantage of the large available power of modern pulsed laser sources in the picosecond regime, the use of beam splitting techniques for parallel processing has greatly improved effective cutting speeds, and therefore decreased cost per unit.

We have demonstrated that parallel laser beam processing speeds up the fabrication of

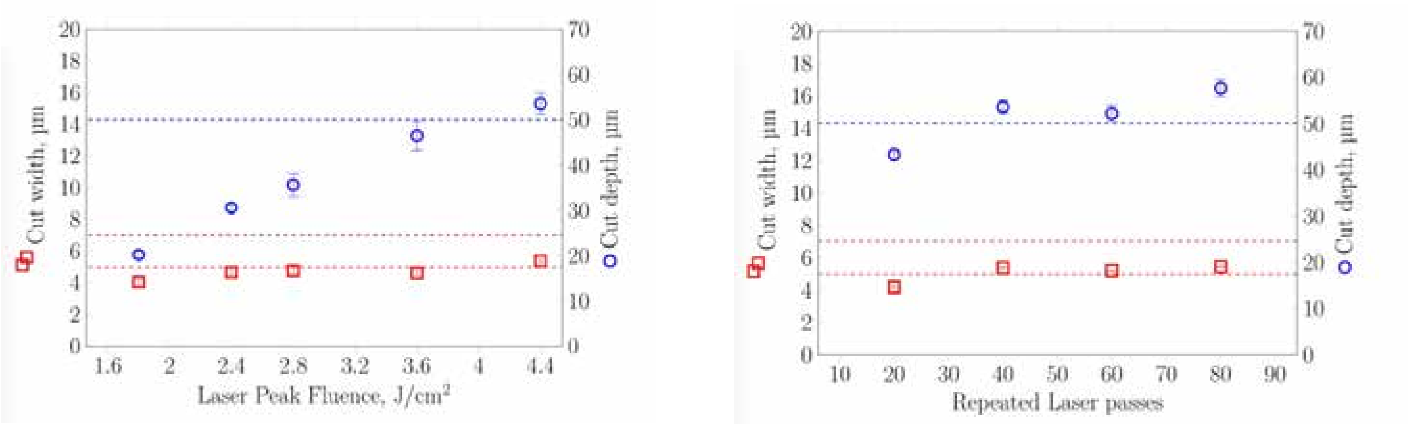

Figure 1: Single beam process development. Moderate fluences and many passes are required for achieving precise element singulation of 50 µm thick PZT substrates with cut street width below 8 µm.

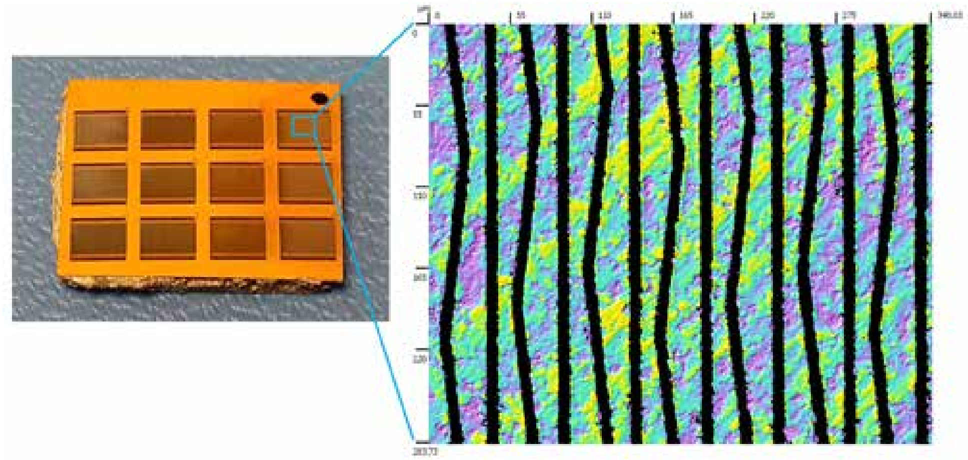

Figure 2: Photograph of an acoustic panel showing 12 individual arrays directly after laser processing at OL (left) and confocal microscope image of the resulting cut elements (right).

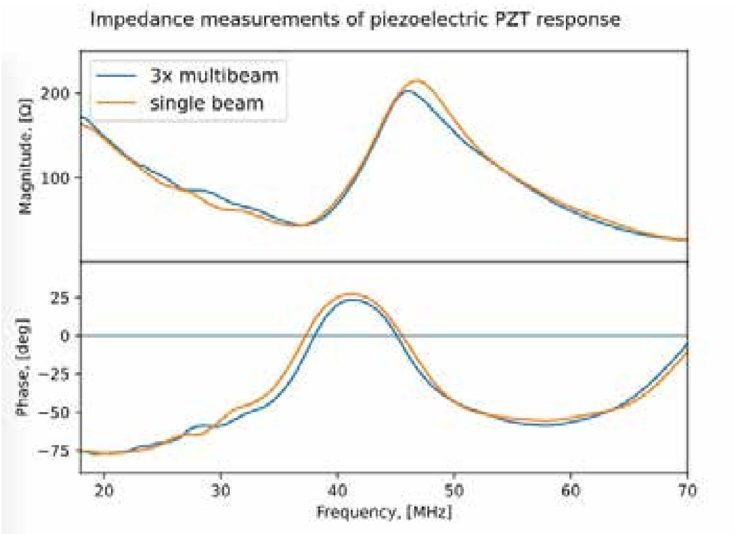

Figure 3: . Impedance measurements of multi vs single-beam processing showing identical piezoelectric response directly after laser processing. Introducing a multi-beam approach speeds up the process without compromising the high-frequency piezoelectric response at around 40 MHz.

functional ultrasonic probes to at least 3 times the original single beam benchmark. This in turn will soon enable the fabrication of disposable single-use ultrasonic probes, whose cost would otherwise be prohibitive if adopting a single-beam strategy instead.

Once a PZT probe is micro-structured, conventional confocal microscopy is used to determine whether the geometrical tolerances have been achieved, while also examining the quality of the cut tracks. It is important to avoid any recast or redeposited material being accumulated at the sides of the cuts, since the probe will be part of a vertical multi-stack layered sensor. The laser cut quality and cleanliness achieved when using the right laser source with the right process parameters is remarkable, see Figures 1 and 2.

The piezoelectric response of the probes can be determined directly after laser processing by means of impedance measurements. To this end, a vector network analyser (VNA) can be used to scan and look for the corresponding piezoelectric resonant peaks to confirm the device is operating at the desired frequency.

A PZT element array may be completely compliant with the geometrical specifications and tolerances (of the array design) whilst being completely depoled and therefore not functional. This would be readily exposed by the disappearance of the resonant impedance peaks from the VNA measurements, see Figure 3.

Summary

We have shown here that implementing a successful laser micro-structuring process of challenging piezoelectric materials can be accomplished by the right choice of laser source (picosecond pulse duration), process diagnostics (IR thermal camera) and quality evaluation tools (VNA impedance measurements and confocal microscopy).

Our results show so far that functional PZT probes can be accomplished at least 3 times faster than the single beam benchmark when using our new multibeam laser parallel processing strategy. This speed up-scale has been accomplished without compromising any of the already demanding geometrical specifications.

Further, our on-going process development which has received financial support from the Innovate UK Eureka project PA64 (contract No 105609), is currently exploring the upper limits for this speed scale-up. We have identified potential for achieving even faster scaled up speeds of 9 times that of the single beam benchmark, possibly even beyond. We plan to demonstrate this further jump in process speed from 3 to 9 times by taking advantage of custom-made diffractive beam splitters.

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SEE OBSERVATIONS P28

IN-PROCESS TEMPERATURE MONITORING FOR WELDING PLASTICS

SATOSHI MATSUMOTO

The laser welding of plastics has been developing since the 1980s. This technology utilises the property that some plastics are transparent to near-infrared rays, while other plastics absorb it. Laser-transparent plastic is positioned above the laser-absorbing plastic, and the laser beam is directed onto the transparent material side. The heat generated by the laser absorbing material is transferred back into the laser transparent material, and both are melted, the two materials being clamped together. Once the laser irradiation ends, the interface cools, the plastics solidify and a weld is formed. As laser welding has matured, new material additives have been developed to improve the conditions of transmission and absorption required to improve the process utilisation.

Temperature measurement by light

Effectiveness of temperature measurement by light

The plastic to be laser welded is heated to its glass transition (softening or melting) point, and this state can be verified by accurate temperature measurement. For example, Nylon 66 at 280°C could be assumed be in a molten state. Therefore, in laser welding, measuring the interface temperature is very effective in predicting the state of the interface.

However, although contact-type thermometers can be used for experiments, in actual production lines, they are not practical. Therefore, it is necessary to measure the temperature in a non-contact manner, and the author investigated the measurement of temperature by light.

Temperature measurement principle

Every substance emits light according to its temperature. In this way, matter emits light as shown in Figure 1 according to Planck's radiation law.

A radiation thermometer is a piece of equipment that measures the temperature using this principle. A typical radiation thermometer can be used for calculating temperature from radiation intensity. In order to obtain the temperature from the radiation intensity, the emissivity must be known. Emissivity has a value particular to the substance and varies with temperature and wavelength. This property is further affected by surface conditions. For these reasons it is difficult to measure temperature accurately using radiation intensity because of the uncertain emissivity. In addition, it is important to stabilise the measurement state because the output of the optical sensor is susceptible to error, for example: Misalignment of focus = Decreased output = Decreased measured value.

The authors adopted a two-colour method in which the radiation intensity of any two wavelengths is measured and the temperature is determined from the ratio of the radiation intensity, instead of a method in which the temperature is directly determined from these radiation intensities.

The radiation intensity ratio of the two wavelengths as shown in Figure 1 corresponds to the slope of the arrow in the figure. Since it is uniquely determined for each temperature, it is possible to determine the temperature from the radiation intensity ratio. The reasons for adopting the two-colour method are: as follows: it is applicable to objects with unknown emissivity (using the gray-body assumption); it has good reproducibility.

Application of radiation temperature measurement to laser welding of plastics

Thermopiles have been investigated to measure the processing point temperature using radiation thermometry in the laser welding of plastics. By considering which part of the temperature is effective, it is referred to as the temperature of the bonding interface. Usually, large wavelengths of optical absorption of plastics are utilised to measure the surface temperature of plastics with light. Such a method is used because it is equivalent to the fact that the absorption is large and the emissivity is high. However, in this method, it is possible to measure the temperature of the laser-transparent material surface, but the temperature of the interface cannot be measured. The reason is that the thermal radiation generated at the interface is absorbed by the laser-transparent material, meaning the use of a thermopile is not an effective way to collect accurate thermal data. Therefore, we measure temperature using relatively high transmittance wavelengths in plastics.

Outline of the experimental method

Polycarbonate (hereinafter PC) was used as an amorphous material. The welding was carried out by scanning the laser using a 4-axis stage with a laser processing head. The experimental conditions used to create PC samples with a fibre-delivered diode laser were: wavelength, 808 nm; processing spot size, 2.4 mm diameter; observed spot size, 1.6 mm diameter; welding speed, 10-50 mm/sec; applied pressure, approx. 30 kgf; tensile test speed, 10 mm/min (PC).

Results and Discussion

Temperature measurement of polycarbonate

Figure 2 shows that, when welding in ideal conditions, the plastics can be welded at an

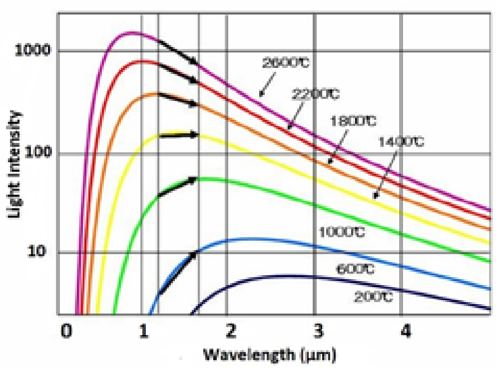

Figure 1: Planck's radiation law

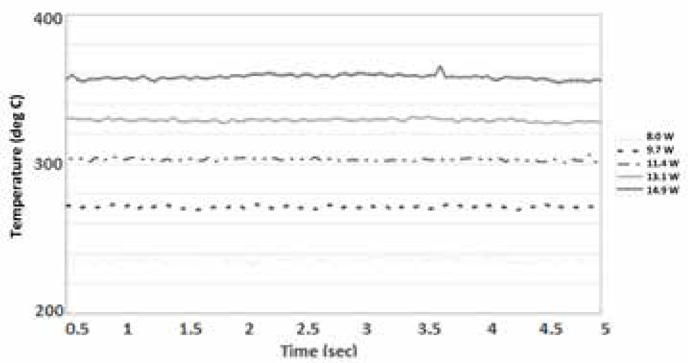

Figure 2: Measurement temperature at the time of laser welding when scanning at 30 mm/sec.

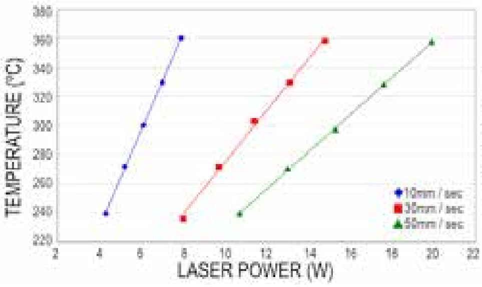

Figure 3: The relationship between power and temperature at different processing speeds

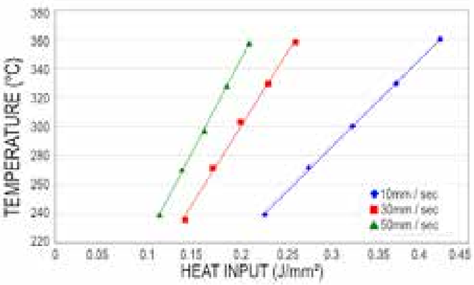

Figure 4: The relationship between heat input and temperature at different processing speeds

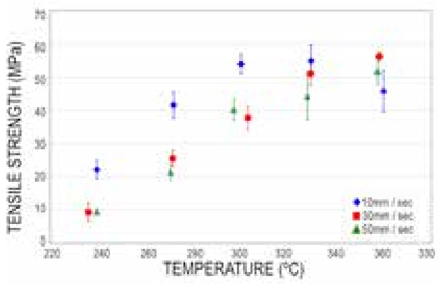

Figure 5: Relationship between the processing point temperature and welding strength

almost stable temperature regardless of the power. Since the stability of the temperature was confirmed, the average temperature of the welding point averaged over the full time range is compared with the irradiated laser power in Figure 3.

As can be seen, the processing point average temperature and the laser irradiation power at each processing speed shows a proportional relationship. The phenomenon that the inclination decreases as the machining speed increases was also measured.

Next, the heat input calculated from the irradiation power was compared with the processing point temperature. Figure 4 shows when the irradiated laser power is converted into heat input based on the processing parameters.

As can be seen, the relationship between heat input and temperature is not constant when using polycarbonate. Characteristically, as the processing speed increases, the welding point temperature is easily increased even at a low heat input. When the welding cross-section of each sample was observed, it was noted that the heat-affected layer became thinner (the melting depth is shallower) as the processing speed increased. That is, as a result of the processing speed being increased, the volume of the plastic being melted is reduced, and therefore the temperature of the interaction in the thinner material is likely to rise.

Figure 5 shows the relationship between the processing point temperature and the welding strength, clearly showing the correlation between temperature and intensity. Polycarbonate has a softening point of 200°C to 240°C, and the temperature shows that it is starting to be welded. In the case of non-crystalline plastic, there is a tendency that the welding strength gradually increases when increasing the processing point temperature, as shown in Figure 5.

Beyond the maximum strength, the welding strength is reduced by thermal decomposition. As for the maximum strength, since the base material strength is 71MPa, it was about 80% of the base material strength. Further, it was observed that the welding strength is different even at the same processing point temperature as a result of the processing speed.

Detection of gaps

Welding of plastics relies on the heat transfer from the absorbed material to the transparent through heat conduction of the molten material. Hence, when a gap is present at the interface, the temperature accumulates (increases) in the absorbing material as compared to the case where it is welded. In Figure 6 a gap has been introduced intentionally to investigate this phenomenon. The larger the gap, the higher the temperature rise measured when the laser is scanned across it. In the narrowest gap (10 microns) the gap has been bridged by molten material which means that a temperature rise is not detected.

Conclusion

The following have been shown by the measurement of the welding point temperature:

- Prediction of welding strength is possible by welding point temperature
- Prediction of contact conditions in welded materials is possible
- Gaps can be detected

Since the contact state in the welded material can be predicted, it is possible to make extremely small variations of weld tooling and workholding for optimum weld repeatability.

Next, since the welding point temperature is sensitive to the amount of heat input, it is possible to keep the temperature stable during processing (e.g. corners). In addition, the welding strength can be predicted by this temperature measurement.

Furthermore, the temperature data obtained so far will be the reference data for quality control in further parts. It is possible to establish the control standard by temperature, and to manage the welding state in real time. In addition, the real-time welding condition control is performed by monitoring the welding system itself at the same time. As the laser power decreases, the processing point temperature decreases. It is possible to know the change of material and system by the change of temperature, for example due to an abnormality in the clamping. The identification of the cause becomes easier.

Thus, processing point temperature monitoring has various advantages in laser welding of plastics. We hope that this technology will contribute to the expansion of the application of laser welding of polymers.

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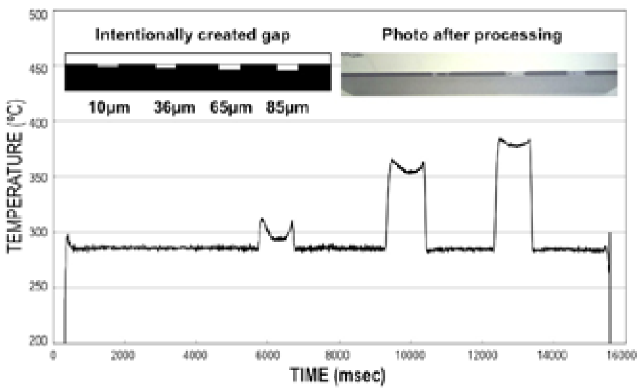


Figure 6: Experimental results of gap detection

Satoshi Matsumoto joined Hamamatsu Photonics K.K. in 1998 and is engaged in the development of high-power semiconductor laser applications.

SEE OBSERVATIONS P28

LOW-CARBON LASER MANUFACTURING

LEWIS JONES ET AL.*

Laser manufacturing technologies for cutting, welding, and cleaning are often explicitly used to increase the processing rate over traditional methods, although laser-based manufacturing processes are generally more energy-intensive than conventional alternatives [1]. For energy effectiveness and the drive towards net-zero carbon emissions, it is essential to improve the current limited understanding of the energy efficiency and carbon intensity of these processes. This work introduces the energy consumption and environmental assessments of complete laser systems to enable low-carbon manufacturing with lasers.

Defining the energy consumers to inform net-zero manufacturing

To evaluate the energy-derived emissions for a manufacturing process or system (Scope 2 emissions as defined in the Greenhouse Gas (GHG) Protocol), one needs to model and understand energy consumption. Many companies pursuing or contemplating net-zero emissions in manufacturing need to evaluate and reduce Scope 1 (direct on-site emissions) and Scope 2 emissions. Several studies have focused on the efficiency of laser-material interactions compared to other manufacturing processes in the past. This process energy (PE) models the energy inputs that directly contribute to the manufacturing process, e.g. the fusion of material during welding. PE, however, is not a true reflection of the entire manufacturing process's total energy and resultant carbon emissions. There is a need to include all the operating states of the machine and all consumers of auxiliary energy (AE), i.e. the sum of all required energy inputs that do not directly contribute to the process, e.g. the cooling sub-system for the laser. The key observation from this analysis is that there are significantly more variables beyond the laser processing energy that need to be considered to advance energy effectiveness.

The first step adapted from BS ISO 14955-1:2017 identifies the common operating states: off, standby, warm-up, ready, and processing; and the common sub-systems: laser, extraction, cooling, motion, and control. The exact state(s) for each process or auxiliary sub-system and the number of sub-systems will be bespoke to each system. The key observation from this analysis is that there are significantly more variables beyond the laser processing energy. While laser users are aware of these sub-systems, there is little analysis of the contribution of each operating state or sub-system. These are areas where innovations can help advance energy effectiveness.

Complete system measurement

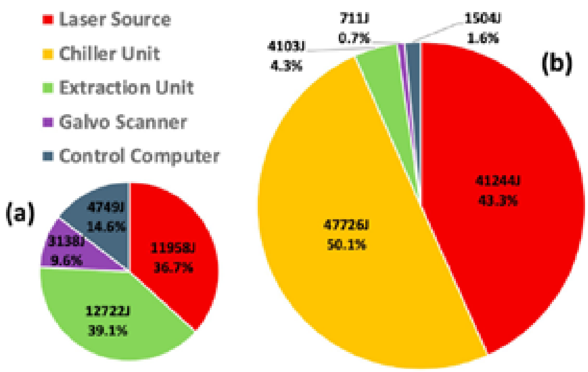
Two case studies have been used to assess the current energy use in different laser manufacturing processes. These are; picosecond laser cleaning/de-coating of TiALN cutting tools, and continuous-wave laser welding of 316L stainless steel. The cases show different uses for lasers in manufacturing. Each case measured the electrical energy consumption for individual sub-systems using a Fluke 343 power quality and energy analyser with current probes and a Cube 350 power meter with a direct connection. The Electrical Supply Waste (ESW) was evaluated as the sum of all electrical losses related to the apparent power and power factor in the system. Specific energy was calculated to compare the efficiency of the systems as energy per unit area or mass. Carbon intensity was calculated using the method of Carbon Emission Signature [2].

Carbon Intensity of Laser Cleaning

There is much to be analysed in the process efficiency and unique processing capabilities of ultrafast laser pulses compared to their energy efficiency. The results of the sub-system measurements in both cases show that the laser processing energy is not the largest contributor to the total system. There are also some significant differences between lasers undertaking similar manufacturing processes. Figure 1 shows a comparison between a 1064 and 355 nm laser cleaning process. Shorter pulse length ultraviolet laser sources are often used for their improved ability for chemical ablation compared to the photothermal processes in the infrared wavelengths [3], which results in improved cleaning performance and processing rates. In this case, the 355 nm system can process at twice the rate of the 1064 nm system. However, the specific energy is nearly four times greater, resulting in approximately three times the carbon intensity. This shows how sensitive the different carbon intensity of laser manufacturing can be and that the process mechanism is not an indicator of system-wide energy requirements and carbon emissions.

Energy Efficiency of Laser Welding

The analysis of laser welding presents similar features. Figure 2 shows a comparison of two identical laser systems, but with each one operating different parameters to achieve a comparable weld, as shown in the weld cross-sections. This energy flow analysis demonstrates that an 80% saving in specific energy requirements can be achieved by selecting operating parameters, a valuable tool in assessing the carbon intensity of specific welding parameters. Breaking down the energy sources into categories for each sub-system



Laser system	1064 nm, 150ps	355 nm, 10 ps
Total energy	32.5 kJ	95.2 kJ
System specific energy	15.4 MJ.cm^{-3}	58.0 MJ.cm^{-3}
Scope 2 carbon emission	2.31×10^{-3} kgCO_2	6.77×10^{-3} kgCO_2

Figure 1: Sub-system energy comparison for laser cleaning of a tool insert using a) IPG 1064 nm, 150 ps, and b) EdgeWave 355nm, 10 ps laser systems [4]

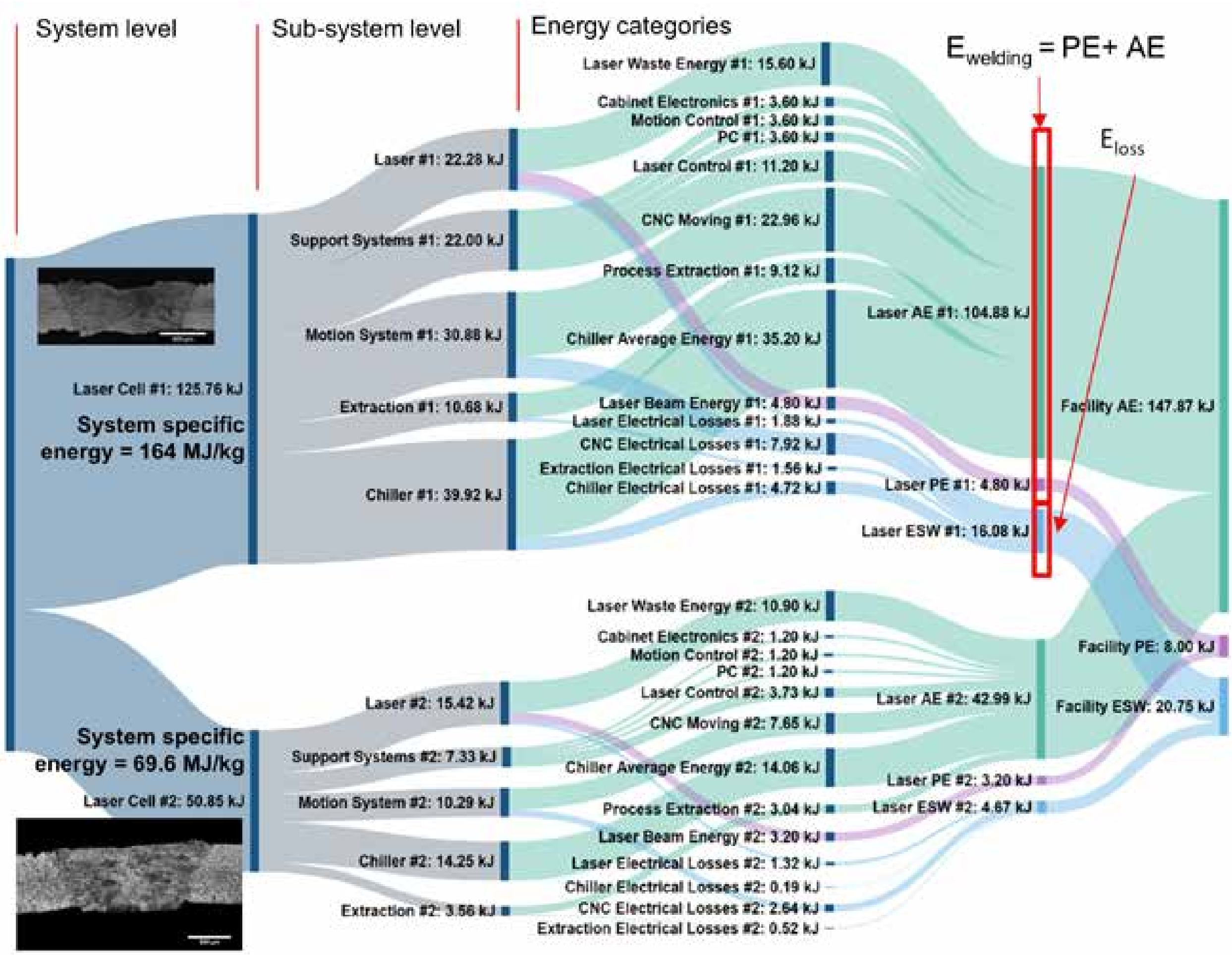


Figure 2: Sankey diagram showing the breakdown of energy categories and the energy use for two welding production cells using a 300 W, 1070 nm fibre laser [5].

reveals that most of the energy used in welding is from the auxiliary energy (AE) sub-systems, not the actual process energy (PE), e.g. in laser #2, the process energy is only 6.5% of the total energy. This is important as it suggests that more significant energy savings can be made with the optimisation of the support systems compared to improving the actual process.

Summary

The key findings are that a whole system analysis of the manufacturing process is required to calculate the total specific energy consumption and Scope 2-related carbon emissions. This requires an understanding of the energy states and energy-consuming devices of the whole laser system or manufacturing cell. The most significant contributor to the total energy consumption of the laser system was the auxiliary or supporting sub-systems.

While meeting the required quality threshold, small changes to welding parameters can significantly change the energy efficiency and carbon intensity. The analysis shows huge unrealised potential for reducing the energy intensity, and Scope 2-derived carbon emissions of laser systems, supporting the net-zero agenda. This will support energy effectiveness and allow manufacturers to pursue process innovations and the net zero agenda simultaneously.

Webinar on Low-Carbon Laser Manufacturing

Following the analysis of representative laboratory equipment, the team has also investigated a more comprehensive range of laser types and processes in real-world conditions. The team and industrial partners plan to share full details on strategies for Low-Carbon Laser Manufacturing at an AILU webinar in February 2022.

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SEE OBSERVATIONS P28

HOW NATURE INSPIRES LASER SURFACE TEXTURING

SABRI ALAMRI

What makes the Morpho butterfly blue and the moth's eyes anti-reflective? Micro- and nano-structures have evolved in nature over millennia to address specific functions that nowadays can be transferred to technical surfaces to enhance everyday products. Laser technology offers a viable tool to create so-called biomimetic surfaces on an industrial scale.

Evolutionary surfaces as a blueprint for technical innovation

Colour plays an important role for different species, ranging from mammals to insects, being one of the most effective means for transmitting a message or hiding from predators. Beside pigmentation, structural colouration has recently attracted the attention of biologists. Structural colouration involves the selective reflectance of incident light by the physical nature of a surface. Moreover, although the colour effects often appear considerably brighter than those of pigments, structural colours often result from completely transparent materials. Structural colours have been found to be formed by one of three mechanisms: multi-layer thin-film reflectors, diffraction gratings or structures causing scattering of light waves.

There are many examples of insects and marine species whose surfaces appear iridescent because they are covered with periodic structures, with a size in the order of 500 nm. These gratings cause iridescence with a higher reflectance than the iridescence of the membranous wings of other insects, which reflect light by interference [1]. The blue Morpho butterfly (Figure 1) is a prominent example of the use of diffractive structural colours in nature. When these insects fly, the upper surface of their wings continually changes from bright blue to dull brown because the angle of the light striking the wing changes, making them difficult for predators to pursue.

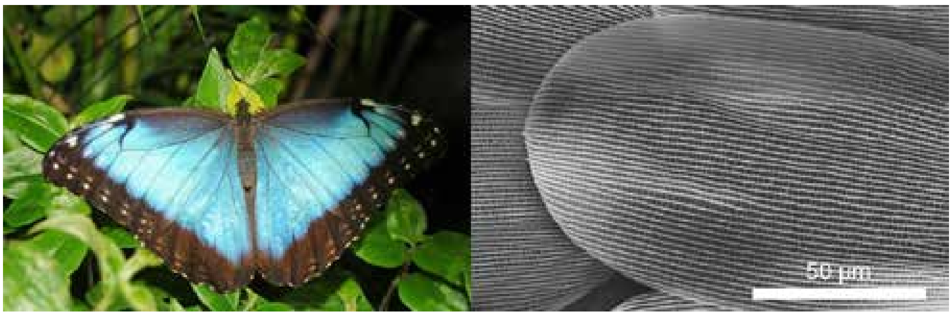

Figure 1: (left) Morpho peleides butterfly showing blue colouration and (right) periodic microstructures present on its scales. © Z. Schnepp

Other types of natural periodic surface structures act to prevent reflection of light: this is the case of the corneal nanostructures present in several moth families, whose periodic distance is typically in the order of 250 nm. Moth-eye nanostructures are pseudo-regular arrays of nanopillars which gradually match the refractive index of air to that of the lens material, minimising light reflectance and maximising perception.

Apart from the well-known moth-eye nanostructures, the cicada wing is also studied as an excellent biological model with highly efficient anti-reflective performance, which also shows a superhydrophobic (water-repellent) function [2]. The cicada wings (Figure 2) are covered on both sides with nano-nipple arrays on two scales, (nanospheres on the top of nanocones) and this multiscale is believed to lead to the double optical and rheological function.

Biomimetics meets laser technology

In recent years, industry has developed the capability to replicate these functional structures on technical materials (biomimetics), nowadays mostly employed for high-end products. To fully exploit the potential of biomimetic effects, high-performance production technologies are required for fabricating bioinspired structures quickly, precisely, with sufficient resolution and at an affordable cost.

Within this framework, laser surface texturing (LST) emerged as a key enabling technology for addressing topics such as structural colours, wettability change, anti-icing properties, anti-microbial surfaces and many more, making them viable for products used on a daily basis. Although focusing a laser beam on a surface produces only super-µm microstructures, smaller periodic surface structures for structural colouring can be fabricated by LST, employing ultra-short pulsed lasers and creating Laser-induced Periodic Surface Structures (LIPSS),

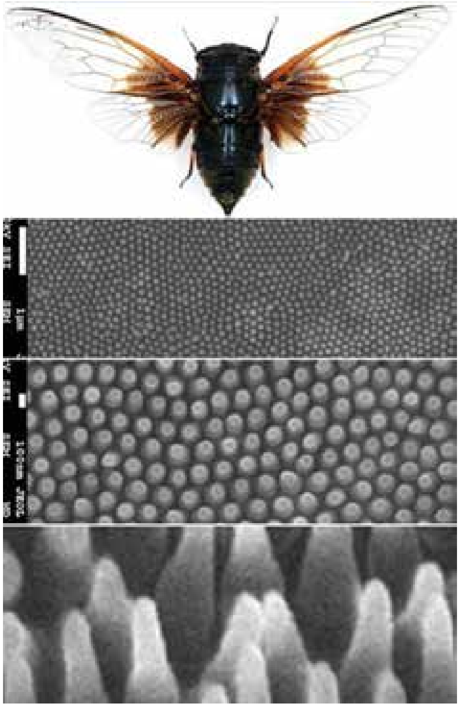

Figure 2: (Top) Photo of a cicada and (below) scanning electron microscope charactersation its wing (Cryptympana atrata Fabricius) © OPTICA

with lateral dimensions comparable with the visible wavelengths (i.e. ~1 µm) [3].

The resolution limits of LIPSS can be overcome when multiple laser beams are combined and induced to interfere with the surface of the workpiece, creating a periodic pattern within the laser spot size, whose dimension can be tuned and can easily reach the sub-µm level: this technique is known as Direct Laser Interference Patterning (DLIP).

Fusion Bionic, a spin-off of the Fraunhofer Institute for Material and Beam Technology (IWS), provides commercial DLIP solutions that enable the efficient fabrication of biomimetic structures on almost any material. Using this technique, surface features with structure sizes between 300 nm and 30 µm can be generated at area rates of currently up to 0.9 m²/min and prospectively up to 2 - 5 m²/min.

The working principle of DLIP is depicted in Figure 3, showing the superposition of four partial beams of the same laser source creating a dot-like interference pattern. The pattern size (spatial period) is mainly defined by the interference angle. A high degree of freedom in producing more complex patterns can be

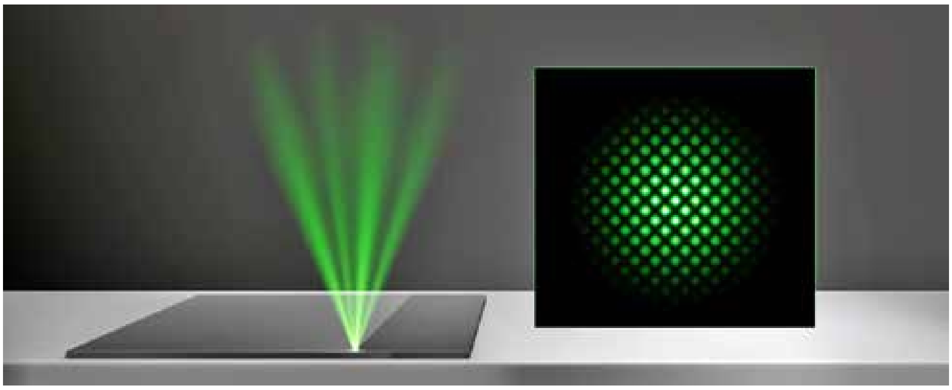

Figure 3: (left) Superposition of four partial beams from the same laser source to form a dot-like interference pattern (right). © Fusion Bionic

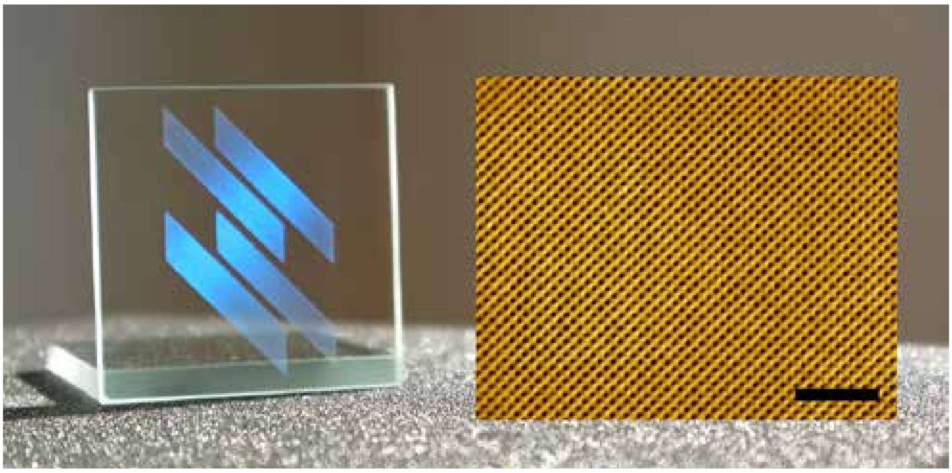

Figure 4: (left) Glass substrate textured with DLIP, showing a blue Fusion Bionic's logo and (right) microscope image of the surface structures inscribed on the glass surface responsible of the structural colours (scalebar: 10 µm). © Fusion Bionic

Figure 5: Glass substrate textured with DLIP for anti-reflection. The periodic structures inscribed on the glass and forming the Fusion Bionic's logo mimic the moth-eye structures and reduce the amount of reflected sunlight. © Fusion Bionic

demonstrated by varying the number of laser beams used, as well as their own polarisation or the intensity [4].

The intrinsic possibility of reaching sub-wavelength and sub-µm structures, and the possibility to fine-tune the interference pattern, make DLIP the most suitable laser technique for mimicking natural surfaces and addressing the fabrication of structural colours, holograms, and anti-reflection on different materials. Figure 4 shows an example of the structural colouration obtained on a glass surface using DLIP. The incident light coming onto the glass surface is reflected (dispersed) in all directions by the presence of a periodic pattern and, by the correct choice of its shape and dimensions, specific wavelengths of the light spectrum can be directed towards the observer. With DLIP, different periodic patterns can be combined on the same textured surface, increasing the degree of complexity of the pattern and, for instance, inducing the creation of structural white light, by manipulating the light diffraction [5].

Biomimetic effects inspired by the moth eye effect can also be realised with DLIP technology. This requires special surface structures that diffract the light in such a way that it can be better coupled into the material. Figure 5 shows a glass substrate in which the reflection has been reduced in selectively chosen areas by laser structuring. Anti-reflection surfaces fabricated by DLIP can be used not only in fields such as solar cells, diodes, optical and optoelectronic devices, screens, sensors, anti-glare glasses and so on, but also offer a viable option to tackle common problems of anti-reflection coatings, such as stability, process time and wide-angle reflection.

Laser biomimetics aims to significantly improve today's materials and, in some cases, replace well-established production steps. This opens new opportunities to solve existing problems and create new products. The enormous potential for bio-inspired surfaces is already emerging in the aerospace, automotive and energy sectors, as well as in medical components such as implants. Ultimately, advanced laser processes like DLIP will allow large areas to be treated at high processing speeds, making surfaces evolved over millennia viable for everyday use.

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SEE OBSERVATIONS P29

AUTOMATED ROBOTIC ASSEMBLY OF LASER SYSTEMS

RICHARD CARTER

Those of you who have lifted the hood on a laser system to look at the inner workings will understand that they are complex beasts. An array of optical and mechanical components work together to produce the high intensity coherent light so valued across a multitude of sectors. However the manufacture of these complex systems does not come without a cost in terms of both design and assembly. Across the laser manufacturing sector there are generally two approaches.

The first is largely used in the more responsive sectors where laser designs are frequently updated or replaced to keep in step with customer demand. This requires a degree of flexibility in manufacturing which is achieved only through high staffing costs and longer manufacture times for systems. Each optic, or assembly, is placed into the system and then adjusted by hand to ensure alignment within desired specifications. This is time-consuming and usually requires a high degree of technical competency from staff, who often have masters or PhD level qualifications.

The alternative, most commonly deployed where identical systems are produced in volume, is to heavily invest in production engineering. Sub-assemblies, careful ordering of steps, jigging and alignment guides are carefully designed to minimise the requirement for manual alignment processes. In addition, considerable time can be devoted to developing assembly instructions. This combination of jigging and clear process steps allows for much less qualified assembly technicians to assemble systems; although there is always a premium placed on experienced personnel who can troubleshoot quickly and efficiently.

So regardless of whether the investment is in people or in process, manufacturing laser systems is an expensive process which can be slow to respond to customer requirements or to adopt the latest technological developments.

Potential for automation

On the face of it this should be an industry which is ripe for automation, but despite the size of the market (UK photonics was valued at $13.5 B total revenue in 2020) there has been very limited uptake. The issue here is the complexity of the assembly, particularly in the alignment processes (Figure 1). While there have been numerous demonstrations of automated alignment for simple operations (free space fibre coupling is a good example here) the solutions are quite specific to the system tested and often rather expensive to implement. What is required therefore is a flexible automation system able to deal with a range of optical alignment processes.

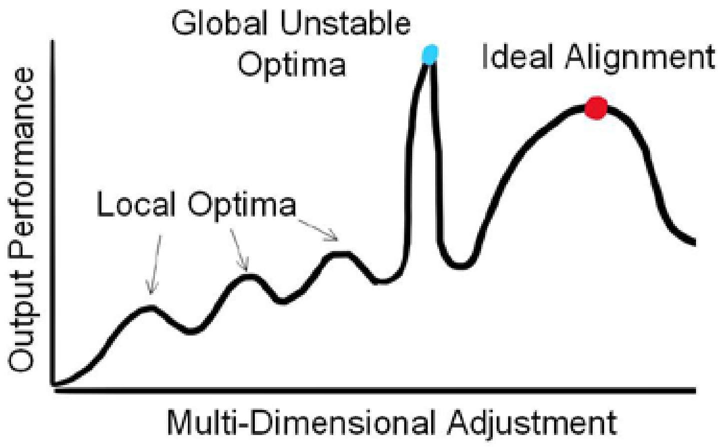

Figure 1: Graphical illustration of a complex alignment space. Complex multi-dimensional spaces of this sort are typical of laser systems. In this case the system exhibits a number of local optima as well as an unstable global maxima which would be avoided in comparison to the more stable ideal position.

The obstacle is the complexity. While a typical industrial laser system does not attempt to align each optic individually on a baseplate, it will nevertheless be comprised of a number of sub assemblies. As each sub assembly is added to the system an alignment process is required to ensure the accuracy of the placement. Typically, this is achieved through opto-mechanical systems which allow for manual adjustment of screws or Allen keys. These require human manipulation to align the optical parts to the required sub µm, sub mrad accuracy in multiple axes. Typically anything from 2-5 axes of alignment are required for any given sub assembly.

This is further complicated by the alignment space. Alignment processes are undertaken not to an absolute position of accuracy but rather with diagnostic feedback. This might be in the form of laser power, mode shape, beam pointing etc. Thus, as a particular actuator is adjusted, the user will compare the current system readout to a desired specification and use their experience to determine where they are in the alignment space and adjust accordingly. But for complex systems the alignment space is similarly complex. With a minefield of localised maxima, unstable alignment positions and misleading local alignment gradients, alignment is often regarded as an intuitive process – and one which cannot be replicated through an automated system.

Robotics for laser assembly

The immediate questions for both academic research and industrial implementation are:

- How can a robotic system, machine intelligence and live diagnostic data, replace a trained, experienced, laser engineer to align multiple parts in a complex industrial laser system?
- How can machine learning be applied to develop autonomous procedures to optimise highly-complex, non-linear laser output performance; a knowledge-driven compromise of multiple laser beam parameters?
- How much can part tolerance specifications in sub-assemblies/alignment jigs be relaxed or removed due to the advanced capabilities of a dynamic, re-trainable autonomous manufacturing system?
- How will it be possible that an autonomous system learns how to align a new product given sufficient "digital twin" data on the design and output requirements from the system designer?

This is exactly the sort of challenge that the new National Robotarium at Heriot-Watt seeks to meet. The National Robotarium is a £25M facility formed through the global reach of Heriot-Watt and Edinburgh Universities with expertise in autonomous systems, human-

Figure 2: The National Robotarium is the first of Heriot-Watt Universities new Global Research Institutes. This £25M state-of-the-art facility will combine a range of robotic activities including autonomous systems, robotic manufacturing and human robotic interactions.

Figure 3: Three lab areas within the National Robotarium will house the High Precision Manufacturing Laboratories including a number of optical and laser based manufacturing capabilities.

robot interactions and robotic manufacturing (Figure 2, Figure 3). As part of this new centre a major new EPSRC-funded project "Developing Machine Learning-empowered Responsive Manufacturing of Industrial Laser Systems", £1.8M, seeks to address the issue of automated laser assembly. This project brings together a diverse range of expertise from four research institutes: Photonics and Quantum Sciences; Sensors, Signals and Systems, Mechanical Process and Energy Engineering; as well as the School of Mathematics and Computer Science. Additionally there is industrial input from four collaborators: Leonardo MW Ltd., Renishaw Plc, Luxinar Ltd. and Gooch and Housego (UK) Ltd.

The project will develop a flexible, responsive system based on a series of robotic manipulators (arms) able to position, adjust and actively align arbitrary optical components and sub-assemblies (Figure 4). This will combine a robot manipulator with millimetre precision with a micron-level end-effector. Such a manipulator will not only be able to replicate the fidelity of a human in alignment but also improve on the accuracy and precision thus reducing the requirements for the many opto- mechanical assembly jigs needed for human alignment processes.

However replicating, and improving on, human dexterity operations is only one part of the challenge – how will this flexibility be directed, how can it be controlled? We propose a control system which will be able to align to a globally-optimised position within the overall alignment space, by employing and developing machine learning search strategies informed by knowledge and insight gained from both modelling and human operator studies. The study of expert (human) alignment strategies is an entirely novel approach to solving the, often intuitive, steps required for complex alignment procedures defy simple optimisation processes.

The potential for such automation in our sector is considerable. Such a system will be capable of not only assembling the current generation of systems engineered for human alignment but also be able to accommodate modifications to designs. These come in the form of changed specifications, tolerances and conditions (e.g. customer requirements, bespoke arrangements, supply chain modifications, etc.). Also, system re-training procedures are required to adapt to entirely different laser products offered by our UK-based industrial partners, increasing productivity and generating a new wave of high-value products produced with high value jobs.

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Figure 4: Example robotic manipulator (arm). This Kuka robot is of the order of 1 m with a reach and load capacity to cover a typical laser build bed. With accuracies in the order of ~1mm it can replicate a human alignment process given the right programming.

Richard Carter is an Associate Professor at Heriot-Watt University, and the Academic Lead for High Precision Manufacturing at the National Robotarium.

SEE OBSERVATIONS P29

OBSERVATIONS

LASER CALORIMETRY AS POROSITY MINIMISATION METHOD IN L-PBF

GIUSEPPE DEL GUERCIO ET AL.

The article presents an interesting approach for the identification of optimal L-PBF processing windows, by measuring absorptivity of metallic powders and coupling with analytical models. Other L-PBF process optimisation methods reported in literature evaluated the effect of laser energy density in the process melt pool dimensions (i.e. width and depth) in order to understand the densification mechanism (i.e. transition between LOF, gas porosity, and keyhole porosity) of various materials. The present research elucidates fundamental aspects which are relevant to such studies, and incorporates key L-PBF laser-material interaction phenomena: varying laser energy absorption of metallic powder beds.

I look forward to seeing more work using the present laser calorimetry method for L-PBF process optimisation, testing different laser wavelengths (e.g. green lasers, etc.) and laser beam shapes (e.g. doughnut beam shape, etc.), which are expected to improve absorptivity of different metallic powders.

Miguel Zavala, TWI

MULTI-BEAM PROCESSING OF ULTRASONIC MEDICAL SENSORS

DANIEL ARNALDO

Parallel processing using lasers has been touted for decades as a really efficient way to scale-up machining capacity but real-world demonstrations are often scarce; what can be done in a research setting does not necessarily transfer to an industrial platform. In this regard this article is refreshing because it highlights an interesting medical area where laser-machined acoustic sensors are needed. As with almost all 'scale-up' discussions there are two aspects: (i) can the required results be achieved and (ii) can something be applied (engineering solution or otherwise) to increase the throughput?

The article shows excellent results (small kerf width, good sample responses) but unfortunately does not share much of the laser-related information which laser users would find most interesting: things like wavelength (UV?), optics (special lens, objective, scanner), method of obtaining three beams, is the sample moved or are the beams deflected, comments on how scale-up with larger number of beams would be implemented, and what issues there might be (e.g. keeping the kerf width constant over larger areas with multiple beams).

There is no doubt that parallel processing is proving to be increasingly useful in many areas and this article nicely shows that the sample performance can be maintained when going from one to three beam processing. It will be very interesting to see the further nine-beam results from the bespoke DOE.

Nadeem Rizvi, Laser Micromachining

This is a good and timely article, taken in the context of an R&D project it makes several interesting points. I assume the alternative process would involve etching the structures using multiple masks. Using laser scribing offers a completely dry process and instant design flexibility.

This is also an example of ultrafast “cold” laser processing that is not so cold, as ultimately the energy must go somewhere. This can be a problem for thermally sensitive materials, so using a fast thermal imaging camera to monitor the temperature of the cut zone in real time, is an innovative solution.

Using diffractive optics or a spatial light modulator to split the beam, in conjunction with a Galvo scanner is an efficient use of laser power. Moreover, the cut result of 8um width over 50 um depth with micron alignment accuracy is not an easy thing to achieve. Using these techniques, I hope they achieve the goal of producing economic single use probes.

Paul Apte, Rideo Systems

IN-PROCESS TEMPERATURE MONITORING FOR WELDING PLASTICS

SATOSHI MATSUMOTO

This is an interesting and informative article by Satoshi Matsumoto. The detailed investigation and analysis of the relationship between the various parameters such as laser power, heat input, temperature and processing speed, and how these influence resultant weld-strength, provides a valuable insight into the world of laser welding plastics. The ability of users to predict the conditions required to produce repeatable results on individual applications will definitely encourage greater uptake of the technology for these types of applications.

One additional factor however, which is also crucial to success in laser plastic welding, is that of clamping pressure. Too little pressure will result in a failure of the two parts to bond, and as one might imagine, too much pressure is likely result in a complete collapse of the weld pool. This scenario could result in the part being scrapped as a result of out of specification dimensional tolerances. If, in future, it is possible to add “Pressure Profiling” alongside the other key parameters, this would further enhance the overall process of laser plastic welding.

Andy Toms, TLM Laser

This article introduces us to a very effective process monitoring and quality control method, using non-contact infrared pyrometers, for laser welding plastics. The study gives good examples of how the monitored weld temperature correlates with processing parameters and weld strength. This type of monitoring is convenient to use, cost effective and can provide feedback quickly enough for real-time process control. As suggested, potentially faulty parts can also be identified and rejected in situations where there are gaps at the joint or variations in the equipment operation. Some situations, such as surface contamination, might not be identified by this technique, but it still remains very useful. Careful calibration and identification of the operating window is needed to set up the system for a given application, but once this is in place, parts can be readily flagged for rejection or further assessment.

Ian Jones, Laserweld Plastics

As the author notes, at these relatively low temperatures two colour pyrometry is required to obtain accurate results especially when the substrate’s emissivity is unknown. However many plastics have absorption peaks in the near infrared where the pyrometer operates so cannot be considered grey body emitters.

Figure 5 shows that weld strength increases with temperature above 220°C which is consistent with a substrate softening point of 200-240°C but the conclusion that it is possible to predict weld strength from the process temperature alone is perhaps not sustainable as it can be seen that the weld strength also has a strong dependence on the process speed.

One of the most important parameters in plastic welding is the consistent contact between the two surfaces and the use of temperature rise to detect gaps is encouraging.

The evidence that temperature monitoring of the weld point may provide some information on the welding process is interesting and further advances to use these methods as a useful process monitoring tool are welcomed.

Neal Croxford

LOW-CARBON LASER MANUFACTURING

LEWIS JONES ET AL.

This is an interesting article that arrives at the time of COP26 and so is fitting too. Analysis of processes in terms of their energy usage is a complicated business and this is highlighted by the authors. There are even more parameters to think about which I am sure that they are aware of; what is the energy budget for making the laser, disposing of it at the end of its life, repairs and servicing? If we compare these to a mechanical drill, then using a laser to make holes looks wasteful. But, we know that the laser has unique abilities: the choice of tool depends on what size hole you want to make and how many. If we are producing a hydrogen fuel cell or solar panel, then the whole process audit would need to include the potential carbon savings of the end product.

The authors make a very interesting observation that for the same outcome substantial savings could be made by using different laser parameters. We are often focused on the result but not the options that we may have in getting there. This work gives much to consider in this regard.

Howard Snelling, University of Hull

LaserMARK Prestige

LaserMARK Primary

SWT - Open frame Welding System

LMD - Desktop Welding System

HOW NATURE INSPIRES LASER SURFACE TEXTURING

SABRI ALAMRI

Necessity is the mother of invention and what better inspiration than mother nature herself? The microscopic control of material enabled by DLIP leading to these useful macroscopic effects is quite extraordinary. These kinds of applications prove to me that lasers are one of the most versatile tools at our disposal and I look forward to seeing the future evolution of biomimetics generated by laser. As processing rates increase this functionality becomes viable for larger surface applications and will no doubt help society through advancing our control over the behaviour of materials at a large scale. Congratulations to Fusion Bionic GmbH for being pioneers in this field!

Simon Hutchinson, AILU

AUTOMATED ROBOTIC ASSEMBLY OF LASER SYSTEMS

RICHARD CARTER

This is a very interesting article and as a major UK automation systems supplier we are of course an advocate for automation at all levels. I think the article touches on some very key points with what current ‘mainstream' robots can do, or not. We have built an number of systems in which we have used robotics with a combination of high accuracy 3D laser/cameras and precision end effector manipulators for some of the very fine final stage movements required. These have been very successfully deployed into industrial manufacturing lines with great success. However, it does rely on the product being worked on to be fairly generic.

As Richard alludes to in his article, building in a level of learning and AI will be required to give a high degree of flexibility to production. We see this coming down the line extremely quickly and we all see it with the likes of Google, V7 Darwin, Open 3D, Framos RealSense and others all pushing the boundaries in their field. These valuable resources are slowly becoming readily available for adaptation to suit the automation game.

One important point that’s worth a mention is that the industrial world lost nearly 2 years of production due to the global pandemic. Robots do not need to socially distance, go into quarantine or work from home. Maybe the mass global shortages of items we now see may not have been as bad if factories had been more fully automated.

Tony Jones, Cyan Tec Systems

FLEXIBLE ENERGY: A LONG TERM SOLUTION TO PRICE VOLATILITY

Energy prices have soared by an alarming amount since June 2021 amid the demand for power in different industries and supplier constraints. As economies around the world recover from the pandemic, energy prices continue to steepen. Despite this, the energy regulator Ofgem says that there will be further "significant rises" next year. Analysts have forecasted that domestic bills in the UK could rise by £400 or more next year if this issue is not solved.

With wholesale energy prices at record highs, energy suppliers that haven't fully hedged requirements to cover their customer portfolio are left exposed to balancing requirements at a significantly higher price that they can sell it, either due to the price cap for domestic customers or existing contractual agreements with their business customers.

Dozens of domestic energy companies in the UK have gone bust. Last month alone, nine domestic energy companies went out of business, leading to over 1 million customers being moved to new suppliers and onto much higher rates.

What is the government doing about it?

Business secretary Kwasi Kwarteng has said "the key way we protect consumers is through the price cap". The most the Government can do is provide support for industries and consumers. With many companies and households keen for an answer, Mr Kwarteng has said he is "looking for a solution".

Energy suppliers have criticised the domestic energy price cap, denying that it will 'protect' households from an expected rise in costs. The chief executive of Together Energy, Paul Richards, told BBC Radio 4: "The price cap as a mechanism is not fit for industry, nor is it fit for customers." Richards has stated although some customers were protected by the price cap, there was between £1bn and £3bn in costs due to failed suppliers that would be placed upon businesses and households.

So, no sign of the government intervening or offering much support for business in the current energy crisis.

Rise in wholesale gas prices

Wholesale gas prices have risen 250% since January. Businesses unable to afford soaring energy prices are worried about potentially having to close. Closure of business will leave thousands of people unemployed. The Director General of UK Steel, Gareth Stace, describes the lack of support for businesses as "frustrating".

Companies all over the UK want a business price cap implemented, similar to the one in place for domestic consumers, on the amount that suppliers can charge them. This is crucial for businesses within energy intensive industries like steelwork, chemical plants and paper production.

The British Chambers of Commerce has called on an energy price cap to be introduced for small to medium sized companies struggling with rising gas prices.

A multitude of factors have impacted on wholesale gas prices. The UK has comparably fewer gas storage facilities than other countries and being a net importer of gas, far more exposed to sharp price rises.

Lower than anticipated wind generation in 2021 has forced Britain to rely more on gas to produce power at a time when the UK is already facing supply issues. On top of that, there is a huge pressure on generators to not use fossil fuels and where they do, they have to buy carbon credits which have also gone up a huge amount.

How can we manage our energy prices?

Energy contracts have a larger impact on business costs than ever before and traditional fixed price contract management is becoming less effective at managing costs.

The key is to have a long-term energy management strategy designed to take advantage of forward pricing curves and reduce risk exposure. Buying all your energy at one time for a fixed period can leave you exposed to short term market conditions that affect the overall price of your contract.

Flexible energy contracts provide a long-term solution that gives you the ability to reduce the effect volatile conditions have on your overall costs by looking at the market 3 or 4 years ahead. Businesses can capitalise on market fluctuations and get the best price for energy by purchasing in blocks when the market is favourable.

With energy prices showing no sign of easing, find yourself an energy partner and work with them to find a product that gives you the opportunity to manage any increases and make better purchasing decisions.

Contact: Liam Conway
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www.cec.uk.com

SYSTEMS & SOURCES

SMALL CHARACTER CODING LASER

Macsa id has been developing lasers for coding and marking for over 30 years. The company has launched the iCON 3 with improvements to previous models making its installation, utilisation and service even more simple and user-friendly, while ensuring that the laser itself is even more reliable and durable than before.

Contact: Neil Greatorex
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www.iconbymacsa.com

THE 'SWISS KNIFE' OF LASER CLEANING

The JETLASER M100 system uses maintenance-free fibre laser technology and is compact in design. Powered by a single 220 volt connection the system does not require other services such as compressed air, water or other cleaning media. Extraction is required for removal of fumes and particulates, and as a class 4 system, the operation needs to be carried out within a laser-safe environment.

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PLASTIC WELDING PROCESS INCREASES EFFICIENCY

Evosys Laser GmbH develops and manufactures tailor-made systems for laser welding of plastics, and is distributed in the UK by TLM Laser. Evosys recently started offering a new, patented welding process that leads to a significant increase in efficiency. With so-called Advanced Quasi-Simultaneous Welding (AQW), selected plastics can be processed even more economically. Automotive components such as the rear lamp shown in the image are suitable for the new AQW welding process.

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HIGH-SPEED CUTTING OF SMALL & MEDIUM TUBES

The FT-150 FIBER from Mazak is its latest laser tube processing machine specifically designed for the high-speed cutting of small and medium tubes up to 152.4mm diameter in large-lot and for high productivity.

Contact: Ian White
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www.mazakeu.com

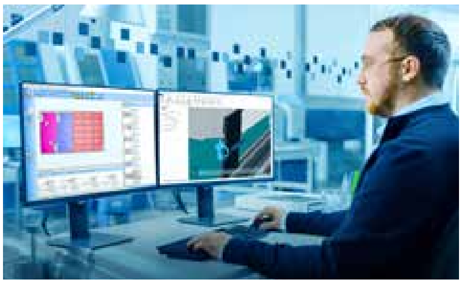
PRODUCT NEWS

ANCILLARIES

NEW MODELLING TECH FOR METAL FABRICATORS

New modelling technology for sheet-metal applications announced by Hexagon's Manufacturing Intelligence division enables the 'flattening' of 3D models in preparation for manufacturing, making it easier to prepare 3D computer-aided design (CAD) data for production.

These new modelling tools also provide fabricators with a competitive advantage by predicting material behaviour and helping to create designs for parts and assemblies that perform as required with less material.



Contact: Laura Mohan
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www.radan.com

NEW FILTRATION TECHNOLOGY FOR AM

BOFA International has unveiled an innovative filtration technology to boost metal additive manufacturing productivity. The new stand-alone AM 400 system uses patented technology that enables the filters that remove potentially harmful fume, gases and particulate from metal additive manufacturing to be exchanged on-site without risking a thermal event. The manufacturing process is safer, faster and more productive.

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www.bofainternational.com

LASER-CLAD PARTS LAST 3 TIMES LONGER

Customers report that transfer rolls laser-clad with Colmonoy® alloys last at least 3 times longer than uncoated parts. The increased life results from the special properties of the Colmonoy® 7331-60 alloy. Laser cladding with this alloy has improved thermo-mechanical fatigue properties, meaning it is better at coping with cyclical heating up and cooling down, which can cause fatigue and failure in other metals. The perfect balance of hardness and ductility, this alloy will soak up stress and reduce the potential for cracking. Packed with the maximum fraction of tungsten carbide, it gives tough support to hard metallics.

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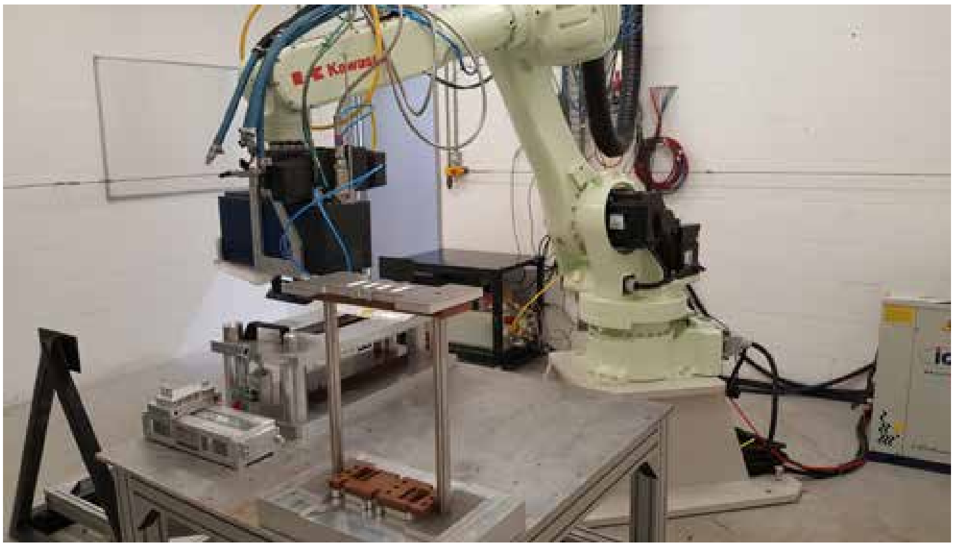
TWI'S EXPERTISE HELPS BMW SOLVE ELECTRIC VEHICLE BATTERY CHALLENGES

TWI's expertise in welding and joining has helped BMW solve a series of challenges related to the production of battery modules for their future electric vehicle (EV) needs.

TWI's experience meant that they were well placed to help overcome the challenges associated with the fixturing and manufacture of high voltage modules. These include structural welds in the module's frame containing the cells and welding of the cell control system (CCS) to the individual cell terminals.

The work - to support BMW entering into module prototype production in the UK - has been supported with funding from the Advanced Propulsion Centre (APC). It includes tooling design and manufacture, the development of laser welding procedure specifications for CCS to terminal and module frame joints, validation on live assemblies, series prototype production (involving both assembly and welding) and logistics (component receipt, storage, packaging and dispatch).

Additional work was carried out in confirming incoming cell status and a number of in-line process checks and procedures to ensure finished quality.



Paola De Bono, TWI's lasers section manager, said, "Our technical team of design, fabrication and welding experts has worked closely with BMW to find innovative solutions to the unique challenges associated with electric vehicle battery production."

TWI is looking forward to continuing the relationship with BMW as it develops its EV component technology capabilities. This includes the upcoming creation of a dedicated EV centre to assist with the growth of this important area of the automotive industry.

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CLASSIC CAR TROUBLE

Owners of classic 2-seater British cars will know that there are precious few days when the car is fully functioning, the weather is sunny and you have the time to enjoy a trip out in the country. In my younger years I bought an MGB Roadster (a car born in 1967) which probably had more call-outs for roadside recovery than any other vehicle I have owned. Even on the evening I collected it, I had a breakdown due to running out of fuel. The journey was less than 40 miles along country roads and about 5 miles from home, it spluttered to a halt. I have to add it was dark and foggy, but the reason for the breakdown was that the previous owner had only put a small amount of petrol in and it wasn't quite enough to get me home. A purchase of a plastic petrol can and a gallon of petrol meant that in half an hour I was home, and wary of the fuel gauge accuracy ever after.

Spending a lot of time in my garage and needing quite a bit of work on the engine and bodywork, the car spent most of its years motionless and under cover. For one brief season (of about 2 months I guess) it was my only car and so had to cope with the daily commute to work – a 30 mile round trip. During this time, it actually didn't break down as far as I remember, but it rained a lot and there was a certain amount of spray that used to get thrown up through some rust-related holes in the subframe that often meant I would arrive at work with steamed up windows and wet trousers. I also became used to avoiding pot holes or bumps in the road surface as the resulting jolt was enough to make one of the 2 latches that fixed the hood to the windscreen spring open. As long as it didn't coincide with a gear change, I could one-handedly refasten the latch in a few seconds whilst keeping a hand on the steering wheel.

In this year, the company I was working at was booming and the car park tended to fill up before the official start time in the morning– meaning a late arrival at work meant parking on the road outside. Around this time, I formed an opinion about industrial boom and bust of the late 1980s, that when the car park got full a round of redundancies was likely to happen. The reason perhaps being that excess growth in employees rarely results in additional car park capacity and that the mean level of employees was probably only slightly less than the number of spaces available. As an aside, I have also observed that a new multi-million building is often vacated a few years after construction due to unpredicted change in business circumstances.

Whilst the above car was my main transport, I had to attend a residential course for a week in Derbyshire over 90 miles away from home. My journey there was again nearly complete when the car broke down and my arrival was later than planned on Sunday evening after arranging for the car to be delivered to a local garage to be fixed. All this before the days of mobile phones, a walk to the nearest red phone box or friendly pub to use the phone adding interest to the drama.

I think I must have sold the car just before moving house (needing to empty the garage) so I probably only owned it for about 4 or 5 years, but I don't remember more than one or two of the lovely drives in the sun that would have been a motivation for buying it in the first place.

What is the moral of the tale? Sometimes the dream and reality can be very different experiences – and maintaining the appearance and condition of elderly bodywork can be more expensive than you think!

Dave MacLellan
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FORTHCOMING AILU EVENTS

2 DECEMBER 2021
AILU ANNUAL JOBSHOP BUSINESS MEETING
RUNNING A LASER JOBSHOP IN DIFFICULT TIMES
MAZAK UK - 09:30 - 16:20

PROGRAMME

09:30 - 10:00	*Registration & Refreshments*
10:00 - 10:10	Welcome & Introduction to the day - Mark Millar (Essex Laser)
10:10 - 10:20	Welcome to Mazak - Alan Mucklow (Mazak)
10:20 - 10:40	Supply chain outlook for sheet steel and aluminium - Michael Horan (NASS)
10:40 - 11:00	Reducing energy costs - Liam Conway (CEC)
11:00 - 11:30	*Refreshments (in European Technology Centre Showroom)*
11:30 - 11:50	ABGI: R&D Tax Relief - an update for AILU Members - Antony Beak (ABGI)
11:50 - 12:10	Make or buy - using Nitrogen Generators for laser cutting gas - Carlos Gonzalez-Lee (MSS Lasers)
12:10 - 12:20	How AILU can help the Job Shop community - Dave MacLellan (AILU)
12:20 - 13:20	*Lunch*
13:20 - 14:20	What's new – short commercial presentations
14:20 - 14:35	Electrical survey results feedback - Dave MacLellan (AILU)
14:35 - 15:20	Open Discussion Forum
15:20 - 16:20	Optional Tour of Mazak Factory

VENUE:
Mazak UK Ltd,
Badgeworth Drive,
Worcester,
WR4 9NF

2 FEBRUARY 2021 - WEBINAR
LOW-CARBON LASER MANUFACTURING

Laser manufacturing in industry has a challenging future ahead as we see the need to implement strategies to reach net zero by 2050.

Research undertaken by the University of Manchester together with Loughborough University and other partners will be presented in this sponsored webinar.

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DATE	EVENT	LOCATION
22 November 2021 2-4 pm (UK time)	Advanced Laser Manufacturing for Automotive	Online
2 December 2021 9:30 am - 4:20 pm	AILU Job Shop Annual Business Meeting	Mazak UK
25-27 January 2022	SPIE Photonics West	San Francisco, USA
2 February 2022	Low-Carbon Laser Manufacturing AILU Webinar	Online
March 2022 TBC	Laser Surface Texturing	TBC
4-8 April 2022	MACH	NEC Birmingham
19-21 April 2022	4th Smart Laser Processing Conference	Yokohama, Japan
26–29 April 2022	Laser World of Photonics	Munich, Germany