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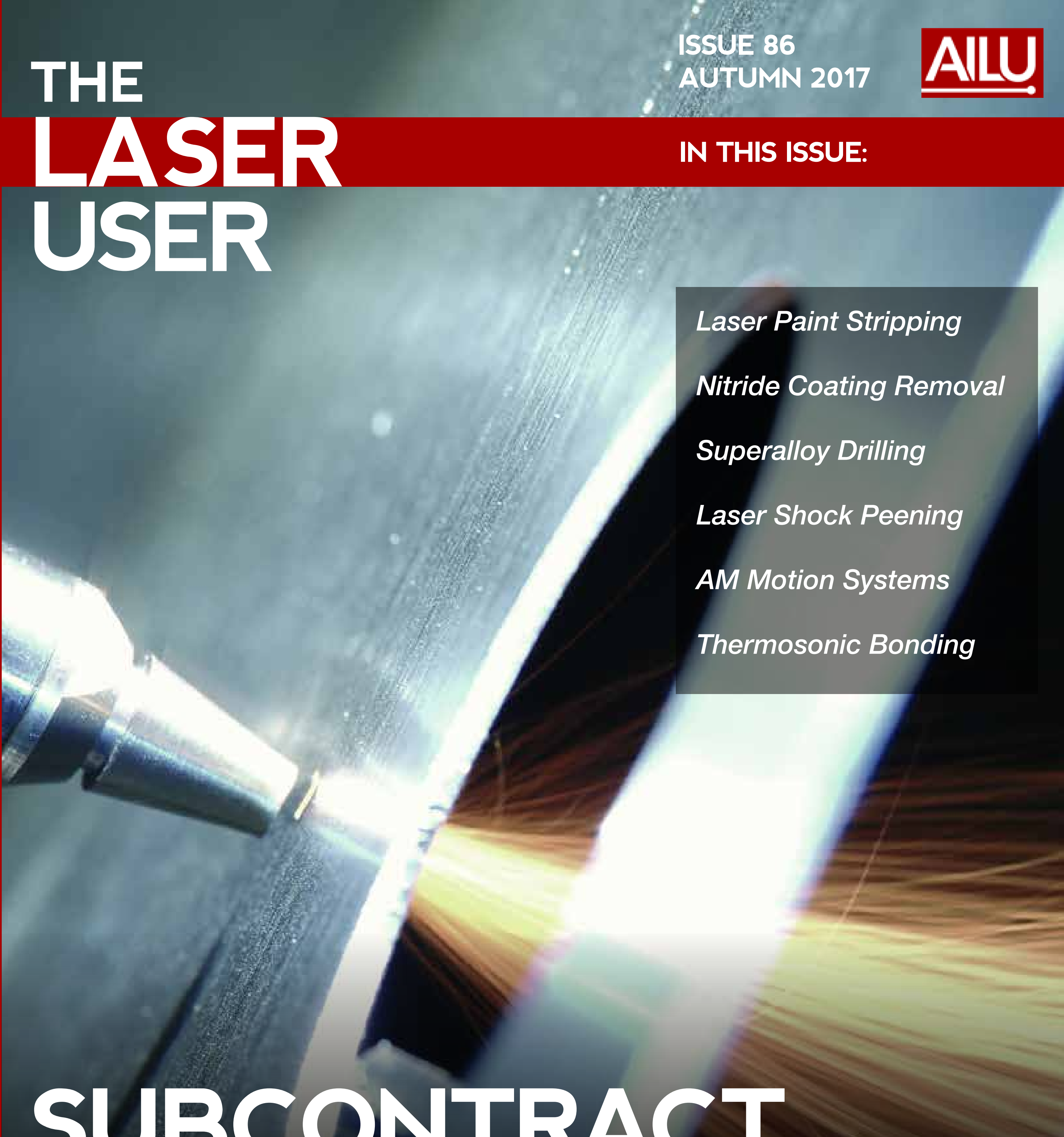
AILU

THE LASER USER



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SUBCONTRACT LASER PROCESSING: MAXIMISING POTENTIAL FOR PROFIT IN BUSINESS

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

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WELCOME TO NEW AILU MEMBERS

Laser 2000
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Laser Age
Leo Sexton
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AILU STEERING COMMITTEE 2017-18

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

Elected until 2020

Shireen Khanum	(GF Machining)
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Vojtech Olle	(OSI Optoelectronics)
Mike Poulter	(SPI Lasers)

Elected until 2019

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

Elected until 2018

Paul Goodwin	(TWI)
Roger Hardacre	(ALT)
Tony Jones	(Cyan Tec Systems)
Adrian Norton	(thinklaser)

Co-opted

Adam Clare	(University of Nottingham)
Mark Millar	(Essex Laser)
Stan Wilford	(IPG Photonics)

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

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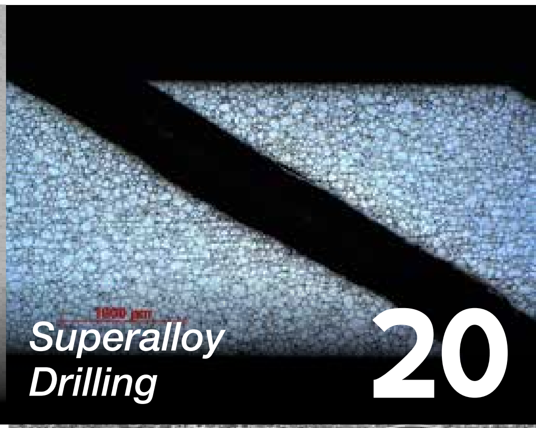

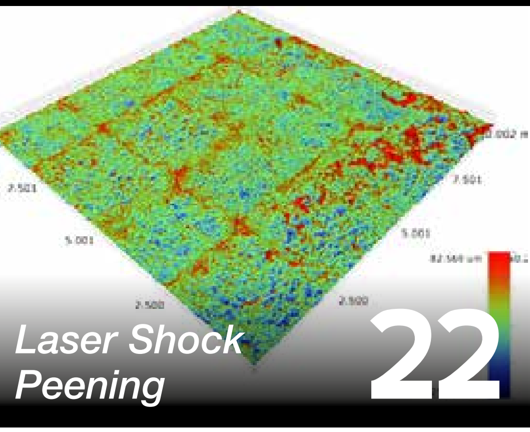

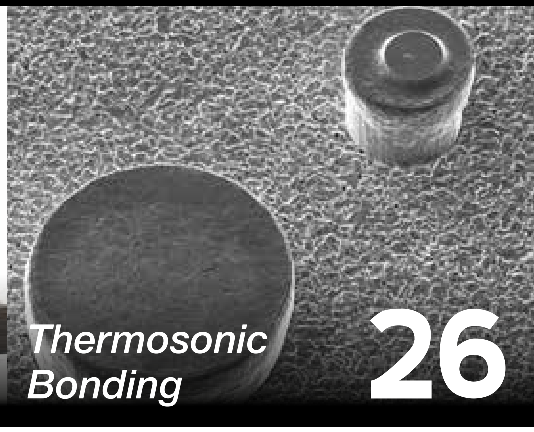

ASSOCIATION NEWS

FIRST WORD

As a parent of 4 children who have attended 6 UK universities (my youngest started his BA course this year), I struggle with the difference between the undergraduate timetable which is typically 30 weeks per year and the typical industrial employee who works 47 or more. The possibility of many "fast track" degree courses being delivered in 2 years, to me seems logical and inevitable – with potential career and cost advantages. Of course, also up for debate is the future of employment itself. Recent news has suggested GPs, lawyers and university lecturers might soon be under threat from AI (artificial intelligence) – with the future of commercial drivers, assembly workers and many other careers due for radical change.

Looking for books for your Christmas list? I can recommend a couple from my year. Firstly, related to the above, the book *Utopia for Realists* by Rutger Bregman was the most engaging book on political economics I have ever read and has seriously challenged my thinking. If you are not sure whether to buy it, you can see if you are interested by watching one of his TED talks on YouTube. If you haven't watched any TED talks, I can recommend at least 5 excellent ones which will challenge, entertain and possibly even change your thinking about many aspects of life. Start, like I did, with Ken Robinson on education, and don't miss Hans Rosling (who sadly died earlier this year) to understand how visual data is both beautiful and essential for communication of statistics. For something light watch James Veitch on replying to spam.

Another book that might change your approach to time management (very topical) is by Kevin Kruse: *15 Secrets Successful People Know About Time Management* although you might want to save the time it takes to read the book by studying the infographic (look for it using the book title in an image search) – you will find that a focus on how the 1,440 minutes of each day are allocated makes you rethink the question "have you got a minute?". Last week, a request for 5 minutes of my time on the phone turned into 26, but you can't win them all.

Dave MacLellan
AILU Executive Director

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PRESIDENT'S MESSAGE

In October this year, AILU held the first Early Career Researchers (ECRs) committee meeting in Birmingham, attended by 12 representatives from 9 universities in the UK. The main purpose of setting up this committee or forum is to promote ECRs' participation in AILU activities, hearing their voices, and promoting their communications and better engagements with other laser users. The ECRs are introduced on p 6. This is a very good start and I encourage AILU members to give strong support to this forum. After all, the ECRs are the future of our research and industrial laser user community.

Recently I attended the AILU Workshop on Laser Cleaning, chaired by Tony Jones of Cyan Tech Systems, and delivered my presentation on The University of Manchester's work on laser cleaning of Al alloys for automotive component manufacture, in collaboration with Jaguar Land Rover. The workshop was well attended and is reviewed on p 29.

In October I attended the 36th ICALEO (International Congress on Applications of Lasers & Electro-Optics) conference in Atlanta, organised by Laser Institute of America (LIA). Over 340 attendees were present. ICALEO is the longest running laser materials processing conference in the world and probably the best known. As the past President of the Laser Institute of America, I presented the LIA awards and extend congratulations to Jack Gabzdyl from SPI Lasers who was elected as an LIA Fellow. Next year's ICALEO in Orlando will celebrate the 50th year anniversary of LIA.

AILU is to co-hosting the 19th LPM (Laser Precision Microfabrication) Symposium with the Japan Laser Processing Society at Heriot-Watt University, Edinburgh, 25-28 June 2018. This is a well-established international conference with typically 200-300 attendees. This conference will bring many researchers and companies from all over the world to the UK to present their latest findings in laser micro/nano fabrication. I hope AILU members and the UK industrial laser community will use this opportunity to showcase our research, innovation, and applications to the world and learn the latest developments from other countries.

Lin Li
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RIC'S RAMBLINGS

Dear Readers, adhering to my adopted theme of random walks and the countryside, I will start my tale on a farm in the middle of the Oxfordshire countryside and end it at St James Palace in central London. Why? Well recently I had one of the most bizarre and interesting days of my career so far, and it all comes down to the power of networking. A couple of weeks ago I was invited by a chap whom I had met during a networking breakfast to look over some highly impressive laser kit belonging to a company who are looking to find the kit a new home. Cutting a long story short, the kit was stored in containers on said farm and our journey to it was not for the faint hearted. I have to say that I have never looked at an Excimer laser whilst the sweet and pungent smell of pigs and their "output" filled my nostrils (needless to say I have been in various meetings about lasers where the faint smell of bulls and their "output" has been present). Having inspected said lasers and associated kit I then returned to work, changed out of my welly boots, put on a suit and proceeded to London to attend a networking evening reception at St James Palace, organised by the Harwell Campus and hosted by non-other than Prince Andrew. The surroundings were beautiful and historic, the wine good and the canapes spot on. The event was excellent and I made a large number of great new contacts whilst cementing existing relationships.

The common thread running through this most bizarre of days being the contacts made, the opportunities afforded through talking to people and the potential for new and exciting future projects. Networking, as they say, is a contact sport and it doesn't matter in which environment that contact is made. AILU enables networking, I encourage you all to embrace the opportunities afforded to you by AILU events and get out and meet people, whether that's in your welly boots or your poshest suit!

Ric Allott
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SAD ANNOUNCEMENT FROM LASERMET

Lasermet is sad to announce the passing of Bryan Tozer, the Chairman of Lasermet, on 1st September 2017. Bryan Tozer was a family man, physicist, electrical engineer, company founder and director, research scientist, pioneer in laser science, expert in laser safety and yachtsman, among many other things.

Bryan attended Liverpool University where his studied Physics. After graduating he completed his Doctorate with a thesis in Plasma Physics, then taking up a place as a Research Fellow at Queen Mary University London. In 1961 he started work with the Central Electricity Generating Board at their Research Laboratories in Leatherhead. He was to spend the majority of his career working for the CEGB.

During his professional career he had more than 100 scientific papers published and was invited to give scientific lectures all over the world. In 1987 he took the opportunity for early retirement from the CEGB, but instead of choosing a life of leisure he embarked on a new project, founding his company Lasermet.

Bryan will be remembered as a kind, gentle and highly intelligent man who was well versed in business, politics, sport and world affairs. He will be sadly missed by family, friends and colleagues, particularly in the laser industry.

Phil Jones, Lasemet

AEROTECH EXPANDS CAPABILITIES IN GERMANY

Aerotech has announced the official opening of it's new office in Fürth, Germany. The company looks forward to the additional sales, service, and support that the new office will allow it to extend to customers in Germany, as well as throughout Europe. The German building now joins the dedicated UK building, as well as a network of offices and representatives, in support of European customers.

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ULO OPTICS EXPANDS

ULO Optics Ltd has recently purchased Laser Beam Products Ltd. Continuing its plans of growth through diversification, the acquisition now gives ULO two manufacturing sites within the UK. The LBP site in Bedfordshire will now operate as LBP Optics Ltd.

Paul Maclennan, Director, says 'Combining the expertise and manufacturing capabilities of the two businesses was an easy decision. We've worked closely together for many years and could clearly see the benefits for us and our customers. We will now be able to offer increased production capacity, extended metrology capability, additional technical expertise and resources. With a focus on quality we'll also be implementing ULO's ISO9001:2015 accreditation across all LBP Optics operations.'

As part of their on-going strategy for growth, Simon Lem has recently joined the Business Development team as Sales Manager.

Mark Wilkinson, LBP Optics (left) with Paul Maclennan, ULO Optics.

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EOS' ACADEMIA PROGRAMME GROWS

EOS is expanding its Academia programme to promote powder-based 3D printing at universities and research institutions, including the University of Wolverhampton. After registering, participating institutions can benefit from exclusive access to regular updates from the Additive Manufacturing world, such as sample applications, white papers, and various activities specially designed for the academic field.

The combination of specialised training with the practical use of their own 3D printing systems will enable both researchers and lecturers to experience first-hand the host of possibilities this technology offers. As such they can actively teach their knowledge to others.

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A NEW DIRECTION FOR ROFIN-SINAR UK

Rofin-Sinar UK (RSUK) recently announced the completion of its acquisition by the European private investment company CMR GmbH (CMR) from Coherent Inc. In parallel, CMR announced a joint worldwide sales, service and production agreement between Rofin-Sinar UK and Iradion Lasers Inc. to combine the two companies' complimentary product lines and to market them globally. Both companies are specialists in CO_2 laser sources. The combined product portfolios cover a wide range of laser power levels up to 1 kW, using different technologies, enabling most industrial CO_2 laser applications to be addressed and for the companies to realise global synergies and strengthen their joint competitiveness.

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PAUL HILTON'S SURPRISE RETIREMENT GIFT

In June, Paul Hilton gave a keynote presentation at LiM in Munich. After the presentation, and much to his surprise, Stefan Kaierle (LZH) told the audience about Paul's recent retirement from TWI and thanked him for his contribution to lasers in manufacturing over many years.

"That was not the only surprise!" commented Paul, "I am a keen closet guitar player and a great fan of Dire Straits. On behalf of my German colleagues, Markus Kogel-Hollacher (Precitec) presented me with a vinyl copy of the Brothers In Arms LP, signed 'To Paul from Mark Knopfler'!"

Paul Hilton (left) receives his retirement gift from Markus Kogel-Hollacher.

JENOPTIK SUPPLIES CAR MANUFACTURERS

Leading German car manufacturers and automotive suppliers have recently ordered several laser systems from Jenoptik with a combined value of approximately €10 m. The lasers are used for features such as the contour trimming of structural components, especially for next-generation electric cars.

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INTRODUCING AILU'S NEWEST COMMITTEE: EARLY CAREER RESEARCHERS

The Early Career Researchers Committee.

Back row (l-r) Ioannis Bitharas, Heriot-Watt University; Armando Caballero, Cranfield University; Prveen Bidare, Heriot-Watt University; Michael Reilly, Heriot-Watt University; Xiaojun Shen, Coventry University; Yang Jiao, University of Cardiff; David Rico Sierra, University of Liverpool.

Front row (l-r) Nesma Aboulkhair, University of Nottingham; Goncalo Pardal, Cranfield University; Anton Serkov, University of Hull; Jean-Michel Romano, University of Birmingham; Chao Wei, University of Manchester. Members not present: Rosie Horner (Liverpool John Moores University); Krste Pangovski (University of Cambridge); Arina Mohammed (University of Hull).

Why has this committee been formed?

We are delighted to present AILU's new Early Career Researchers Committee (see above). The committee was set up to develop ideas put forward by AILU President, Lin Li (University of Manchester) and Adam Clare (University of Nottingham) to increse the visibilty and engagement of younger members within the AILU community.

We hope that, as the careers of Early Career researchers (ECRs) develop through industry and academia, they will maintain contact with AILU members and encourage the next generation of industrial laser users.

There are also benefits for the young researchers such as increased networking with other academic institutions, profile-raising and the addition of new skills to enhance their CVs.

How was it set up?

The initial thrust of the ECR initiative is to produce a column of articles and features for this magazine. University supervisers were contacted initially, and were wholly supportive of giving their researchers a voice in the magazine. They nominated one or more ECRs from their institutions to join the committee.

A start-up meeting was held in early October giving researchers the chance to get to know each other and share their research interests. After familiarising themselves with AILU and the content of the magazine, a break-out session allowed the ECRs to discuss and develop ideas for forthcoming issues of The Laser User.

The meeting concluded with a summary of the discussions and it was heartening to see how the enthusiasm and intellegent thinking of the committee produced new and interesting ideas for their magazine column. Prveen Bidare of Heriot-Watt University was voted as the committee Chair and is now organising the next committee meeting in early December.

Interested in joining?

The committee is open to any ECR - if you are interested in joining, especially if your university is not represented, please contact Prveen (pb3@hw.ac.uk) or Cath Rose (cath@ailu.org.uk).

The introduction of fresh blood and insightful ideas can only be of benefit to AILU so please look out for the first ECR column in the next magazine issue.

UNIVERSITY OF HULL

The laser group at the University of Hull has a long history dating back to the earliest days of gas lasers in the UK. During the 1970s, research concentrated on pulsed gas lasers, particularly CO_2 based devices. The 1980s saw a move into the development of excimer lasers and, in turn, the study of laser-material interactions. Our light-matter interaction research now ranges from the millimetre length scale to the nanometre regime.

We are organised into two groupings: the Lasers and Light-Matter Interactions group is primarily concerned with understanding the physics of light interaction with matter and how this knowledge can be applied to real-world applications; these are often micromachining based. The Nano-Photonics group has particular interest in how small scale structures affect light.

We are based within the Physics subject area of the School of Mathematical and Physical Sciences. Our facilities include a suite of eleven laser laboratories that house systems with wavelengths in the range of vacuum ultraviolet (157 nm) to 11 micron and pulse durations from continuous wave to 120 fs. These are augmented by an optical parametric oscillator and white light picosecond source.

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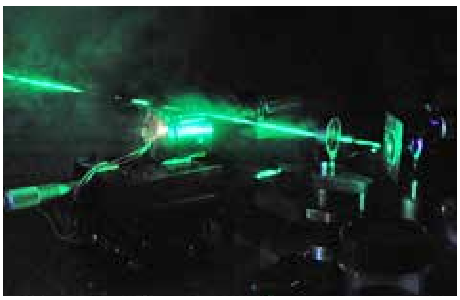
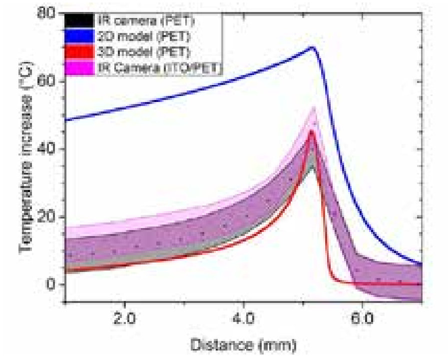
NANO PHOTONICS

The nanophotonics group in Hull (Drs. Adawi and Bouillard) uses a wide range of CW and pulsed lasers to explore light-matter interactions at the nanoscale using far field nano-spectroscopy techniques such as fluorescence-lifetime imaging microscopy (FLIM) and Fourier plane imaging as well as surface enhanced Raman scattering (SERS). Our research aims to develop novel nanophotonic systems for single molecule sensing, nanolight sources, energy transfer and novel biosensing nanoprobes.



FLEXIBLE ELECTRONICS

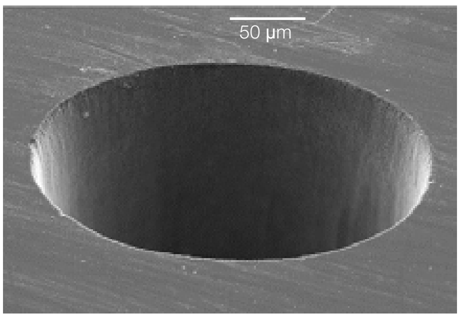
Drs. Snelling and Walton have been funded by the EU through the H2020 scheme to explore laser sintering of indium-free inks to produce transparent conducting tracks for displays and photovoltaics. Here, we are collaborating with TWI, who are the coordinators, as well as partners in Germany, the UK and Spain (https://infinity-h2020.eu/). The need for low temperature processing has led us to model the interactions and verify these calculations with thermal imaging. To-date, we have achieved a dramatic reduction in resistivity of the laser irradiated inks relative to their as-deposited characteristics.



Calculations of laser-induced temperature rise.

GLASS PROCESSING AND FREE-FORM OPTICS

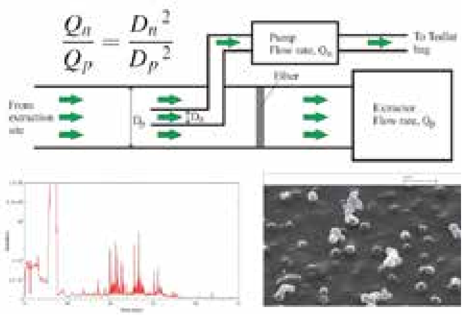
Glasses are difficult to laser process due to their low absorption in the visible wavelength range and their brittle behaviour. Intrinsic absorption can be utilised if the wavelength is short enough and we have demonstrated high quality etching using the 157 nm molecular fluorine laser. Absorption can also be induced through non-linear processes with ultrashort laser pulses in the femtosecond to picosecond regime. Our goals are to produce optical quality surfaces that have a high degree of height fidelity. Current modelling predicts the final stress-strain state of glasses irradiated with long pulses (up to millisecond) and we plan to extend these studies into the short and ultrashort pulse regimes. A new project is just beginning funded by The Leverhulme Trust to explore the fabrication of free-form optics. This is a collaboration between Dr Howard Snelling (Hull), Prof Sir Michael Berry (Bristol) and Prof David Jesson (Cardiff).



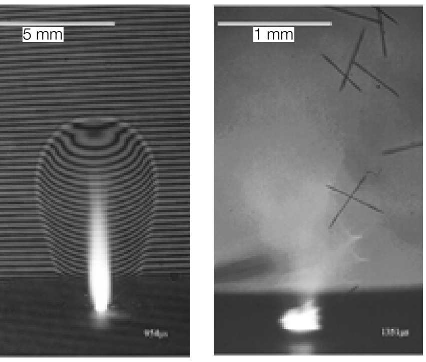
Crack-free femtosecond laser trepanning of a hole in glass

LASER INTERACTIONS WITH COMPOSITE MATERIALS

Composite materials are ever more prevalent and I am sure that the readers of the AILU magazine would agree that the integration of laser technology into the manufacturing process is something to be encouraged. We have two main goals in our laser-interaction studies. These are the application of short laser pulses to minimise the heat affected zone, and exploration of fume produced during processing. Laser generated fume is not often studied and we have developed techniques for characterising both particle and gas phase products. Fast (nanosecond) photography can track the movement of debris and isokinetic gas sampling combined with mass spectroscopy is used to identify vapour.



Isokinetic gas sampling of laser-produced fume with the corresponding mass spectrum and captured particles.



High-speed interferometry (left) of the evolution of gas from a laser irradiated composite and nanosecond shadowgraphy (right) of ejected carbon fibres.

OPTICAL SENSOR NETWORKS

Composite materials have a major application in the off-shore wind industry. We are part of an EPSRC funded Prosperity Partnership that is exploring various aspects of the turbine construction (University of Sheffield, Durham University, University of Hull). At Hull, we are incorporating fibre optic sensors into these large composite structures to enable a "digital twin" to be recorded during manufacture and service.

FIBRE LASER WELDING CUTS COSTS AND IMPROVES RESULTS

As fibre laser welding applications become more diverse and sophisticated, customers increasingly demand a more complete welding solution, rather than simply a laser source. This may mean the purchase of a laser along with support from the vendor in process development, or a subsystem that delivers a laser spot having specific characteristics at the work surface, or even a complete workstation supplied together with applications know-how. Specifically, the latter may mean the process knowledge and recipe necessary to achieve a particular result (e.g. a weld with certain dimensional, mechanical or cosmetic characteristics, produced at a given feed rate).

This evolving market demand has driven a wave of mergers and acquisitions as suppliers endeavor to vertically integrate laser sources with beam delivery, part handling, and process expertise. For example, in the past few years, laser builder Rofin acquired beam delivery expert Lasag. Then Coherent acquired Rofin in a move that now gives the company an enhanced ability to lead and innovate.

This article examines some of the technology and process improvements recently developed to deliver the higher level of functionality often required in the welding market, and then reviews an application that has benefited from them.

Fibre lasers for welding

There are currently several manufacturers of high power fibre lasers for welding and other materials processing applications. The modular construction approach employed by Coherent | Rofin allows several options to be offered in terms of output power, delivery fibre diameter, and beam parameter product. The benefit is the ability to readily adapt the laser beam characteristics to precisely match the requirements of a specific process.

Some users have experienced fibre laser damage or process inconsistencies caused by back reflections when processing highly reflective metals such as copper and brass. Coherent | Rofin lasers utilise an optimised power generation and delivery technology, as well as sensors at different positions within the system, in order to protect laser components from such damage. These safeguards eliminate the problem of back reflections, and allow reliable welding of brass, aluminum and copper without any concern for damaging the laser.

Of course, the fibre laser is just one part of the entire welding system, which also includes a beam focusing welding head, as well as control electronics. These integrated solutions often feature fast and flexible beam scanning technology which allows rapid beam movement from one welding contour to the next. This increases the productivity of a laser processing system enormously.

Case Study: Laser Welded Towel Radiator

Steam radiators for heating towels have become popular at gyms and spas worldwide. A Russian manufacturer of these towel heaters now employs an automated welding system, developed by the Dutch special purpose machine manufacturer Rodomach, which is based on a Coherent | Rofin fibre laser.

Previously, the radiator manufacturer had utilised the traditional TIG (tungsten inert gas) arc welding method by hand in their production. The goal of the radiator manufacturer was to transition all their manufacturing to an automated system. This meant that the process would have to be able to accommodate a variety of different product configurations, including models with round pipes, as well as those having pipes with various other shapes. For all these products, the desired welding depth is 100% of the pipe thickness, and the final assembly must withstand air pressures of 25 bars.

Product appearance is also critical in this application, and the manufacturer wanted to achieve a uniform, smooth seam weld, which is attractive and requires no post processing. This is necessary because the final step in their production is electro-polishing, which brings the stainless steel radiators to a mirror finish.

In order to develop a laser-based solution for this process, Coherent | Rofin ran trials for Rodomach at our Hamburg Applications Laboratory. These proved that the austenitic Cr-Ni-Steel AISI 304 used by the radiator manufacturer was easy to laser weld. However, standard tooling could not ensure an optimum fit between parts for the entire operation, and a consistent, high quality seam could therefore not be guaranteed.

Coherent | Rofin and Rodomach therefore undertook to design an approach which would clamp the part in a way which enables consistent welding, and also prevents part warping during the process. The particular solution was to replace the traditional, static clamp tooling used for welding with a servo-controlled clamping mechanism having integrated cooling. This method evenly clamps the part at all welding points, while the cooling prevents the joints from warping.

The testing also allowed Coherent | Rofin personnel to recommend a 2 kW fibre laser with a 300 μm delivery fibre, and focusing optics having a focal length of 300 mm, as being optimum for this application. This optical configuration provides a long depth of field, allowing the customer a high degree of process tolerance. The result is reduced scrap and improved productivity.

Rodomach configured the system so that, through the use of a beam switch, a single fibre laser can feed two robotic welding stations which alternately process the two sides of the radiator. "We pooled the control of the system, the two robots, and the laser on to one terminal," notes Roel Doornebosch, Manager at Rodomach. "This simplified operation for the customer, who had expressed some concern at the outset that the system would be complex to operate due to their stringent quality requirements. The final system we delivered operates at a welding speed of 2 m/min, and provides welds which can withstand 250 bars of steam pressure, ten times their original specification. Plus, the weld quality and cosmetics are consistently high. Since they ordered two additional systems after using the first one, I think we can conclude that we successfully met, and even exceeded, their expectations."

Two models of towel heater, produced by a Russian manufacturer using an automated welding system.

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BYSTRONIC LASER UPS PRODUCTIVITY

At the Bolton factory of trailer manufacturer, Indespension, sheet metal cutting productivity has doubled following the replacement of a CO_2 laser-powered machine with a fibre laser profiling centre. The ByStar Fiber 6520 has a 4 kW fibre laser and a 6.5 metre x 2 metre capacity bed, making it the largest fibre machine to date delivered by this supplier into the UK market. At the outset, the main reason for investing in laser cutting was to achieve a greater degree of in-house control over trailer production and save the expense of putting work out to sheet metal subcontractors. Another important consideration was to streamline the prototyping and design process and bring new products to market faster.

A decade ago few trailers incorporated laser-cut features whereas today they are used extensively. Indeed, products are designed around the considerable capabilities of modern laser cutting machines. One advantage is that machining is so accurate that components fit together precisely and quickly during assembly. The other benefit is that machining is so fast, especially with the fibre laser, that it is a cost-effective way of taking weight out of components by incorporating numerous holes and slots. It would be too labour-intensive and therefore uneconomical to do manually.

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CYCLE TIMES CUT WITH TRUMPF

The UK's first TRUMPF TruMatic 1000 fibre laser-punch combination machine is helping Luton-based Islebest Ltd achieve cycle-time reductions of 35% against stand-alone laser and punching machines. The investment, which has also saved on floor space, is now helping to attract new prospects for this progressive manufacturing business.

For 26 years Islebest has been generating a reputation as a leading supplier of bespoke metalwork solutions. The company prides itself on the timely delivery of high-quality, cost-competitive parts. From straightforward laser-cut components, through to folded, welded and assembled parts, Islebest supplies to sectors that include ventilation, lighting, drainage, shop-fitting, office furniture and agriculture.

Installed at the end of April 2017, the machine has been set to work producing parts at the thinner end of Islebest's range, typically around 1.5mm. The company can now add reflective materials such as copper and brass to its portfolio, complementing the existing mild steel, stainless steel, galvanised steel and aluminium.

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PLANNING AHEAD: WHY YOUR BUSINESS' ENERGY STRATEGY SHOULD REFLECT MORE THAN JUST MARKET ACTIVITY

In the last issue of the Laser User, I talked about the factors that impact the gas and electricity market and provided tips on how to negotiate the right contract for your business. This is not always an easy task as the energy market is highly volatile and susceptible to a number of uncontrollable variables. Economic and political uncertainty coupled with taxes and levies incurred through legislative changes, means that forecasting the total cost of your energy bills can be a challenge. With the wholesale cost of energy rising, businesses need to be more strategic when purchasing energy and introduce measures to keep costs low.

When planning your business' energy procurement strategy there are a number of aspects to consider:

1. Don't just focus on the global energy markets

Unfortunately securing the most competitive energy pricing alone is not enough to protect your business' bottom line; steps will need to be taken to manage and reduce energy usage, improve efficiency, understand non-commodity costs and comply with the necessary energy legislation.

2. Track your business' energy usage

Technological developments in the energy sector means that it is now possible to remotely monitor your business' energy consumption. Whilst not all businesses meet the requirements for half hourly energy meters there are a number of benefits as the information to be obtained from these devices is invaluable. Data from meter readings can be fed through to reporting systems which in turn provides valuable insights in to your energy usage. With access to so much live data together with online analytical tools it's easy to generate definitive reports and enable a better understanding of your business' energy consumption.

By measuring and monitoring consumption, not only will you understand exactly how much energy your business requires and when you use it, this will allow you to ensure that you are not paying more than necessary and identify where savings can be made.

3. Know which energy regulations will impact your business

As the UK moves towards a low carbon future, industry specialists are seeing more and more regulation in the energy market. With the sheer number of different regulations applicable it's vital that businesses are aware of the pitfalls and penalties surrounding energy legislations. Recent legislations include: ESOS Phase 2, P272, DCP 228 and DCP 161. All have been executed to encourage businesses to manage their consumption and to know what capacity they require.

The cost of non-compliance can be significant, having a strategy in place to ensure you are up to date with current regulation and complying to the relevant legislations will prevent any unwanted penalties and ensure that you are not at risk of reputational damage if found to be in breach of UK energy legislation.

4. Consider energy efficiency measures

As you may be aware, the UK's electricity infrastructure is strained and the network (National Grid) is being pushed to absolute capacity. This, combined with a global push to reduce emissions and energy consumption in general, means that you will see an increase in taxes and charges relating to environmental issues. For this reason, you would be wise to consider energy efficiency as part of your business procurement strategy. There is increasing pressure on businesses to take active steps to reduce their energy use and find renewable, sustainable solutions that are more energy efficient than your typical sources of energy. The key is to find the right solution for your business. Some energy efficient solutions incur high upfront costs but will reduce the cost of your energy bill in the long run. It's important that you consider installation of any new technology in line with your overall business plan to make sure that your chosen efficiency solution is affordable.

5. Know your business' energy capacity

Capacity is the amount of electricity that is available to your business at any one time. Each electricity meter that is linked to your business premises has an agreed capacity which is set by your local distributor. Knowing your capacity and monitoring it against usage, did not used to be an issue as any excess capacity used was simply charged at a standard rate. However, when DCP 161 legislation comes in to force from April 2018, if you exceed your agreed capacity limits, your business will be charged at a premium rate.

6. Understand non-commodity costs

The unit rate on your electricity bill is divided into two main elements; the wholesale costs of electricity (the commodity) and non-commodity costs. The wholesale element makes up approximately 48% of your electricity unit rate while the remaining 52% consists of a number of different government levies, tariffs and third-party charges which make up non-commodity costs. Our research shows that non-commodity costs are set to increase over the next five years. Unfortunately, there is little that we can do about these charges and the only way to mitigate against the increase is to keep the wholesale cost of energy as low as possible.

In essence, the cheapest unit of energy is the one that you don't use. If your business is proactive and takes ownership of energy management, consumption levels and efficiency measures you will be able to future proof your business and make sure that the cost of your energy bills are sufficiently budgeted for.

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COOPERATION BETWEEN ACADEMIA AND INDUSTRY BENEFITS ALL

As part of their degree, students from Chemical Engineering and the other engineering disciplines at the University of Chester carry out industrial work placements. These enable students to experience engineering - and potential future roles - in a work setting.

One of the companies supporting this initiative by offering student placements is Croft Additive Manufacturing Ltd, who are based in Warrington. Neil Burns, Director of Croft AM, said: "We've hosted four University of Chester student placement projects over the last two years and we really value this input for our business as a high technology, manufacturing company. The students help us to challenge the existing status quo and provide opportunities for change."

The project: reducing distortion in metal additive manufacturing

Placement student Christian Mamwell investigated an ongoing issue in the AM process: deformation of the component during the printing process. Addressing this issue would mean that scrappage rates would drop, driving down the cost and lead time of producing these components. Product quality would improve and the field as a whole would benefit.

The project focused on optimising one particular component, the AM Diamond filter, additively manufactured at Croft AM (Figure 1). A promising solution to predicting deformation during this AM process was through modelling residual stresses. Christian used cloud based software that takes a 3D model of a component, simulate the build, and in turn simulate the stresses and deformations that occur. The company 3DSIM owns this software and works closely with Croft to assist its development and address this industry-wide issue.

Figure 1: The distorted AM Diamond filter (centre) vs its CAD (right) and distortion models (left)

A rigorous testing methodolgy was applied which resulted in a reduced bulge distortion, and indicated that future work on further simulations would remove the distortion, further improving the optimised design. Figure 2 shows the reworked filter with added support to resist distortion.

Figure 2: Reworked Filter, CAD vs print

Commenting on his time at Croft AM, Christian said: "This has been an excellent first insight into the world of engineering and manufacture. To be able to work on real products alongside professional engineers in a new and exciting field of manufacture has been wonderful, equipping me with skills and experiences I can take with me as I advance my engineering career. I find additive manufacture to be deeply interesting, and hope to eventually find myself doing more work within this field."

University of Chester student, Christian Mamwell, left, with Rob Watkins from Croft Additive Manufacturing.

Acknowledgement
Excerpts were taken from Industrial Placement poster "Reducing distortion in metal additive manufacturing" by Christian Mamwell, Louise Geekie & Neil Burns.

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FAMILY OWNERSHIP: FASTER & MORE FLEXIBLE

AN INTERVIEW WITH JAMES MCDOWELL

BUSINESS DEVELOPMENT MANAGER, LITRON LASERS

Q. Can you tell us about the history of Litron and the company today?

Litron Lasers is a family-owned business, founded in Rugby 20 years ago (1997) by MD Julian Sarkies. Julian is the eldest of three sons of Paul Sarkies, who is well-known in the laser industry, having worked at JK Lasers before founding Spectron Laser in 1982.

Originally the business focused on photodiode energy monitors, launching the first laser products in 2002.

Litron builds between 350 and 400 sources per year, mainly pulsed Q-switched lasers which are either lamp pumped or diode pumped as appropriate. Around 75% of the products are sold into scientific markets with the remainder into industrial applications, largely in the electronics and semiconductor market.

A strong period of growth has led to the company today employing over 50 staff and with open vacancies for a further 4 or 5 staff. Turnover is heading towards £10 million and the company sells worldwide through a comprehensive distributor network and a direct office in Montana, USA. Around 85% of the lasers are exported, with strong sales in the EU.

Q. Which markets are most significant for your products?

The largest market for our products is for the application of PIV (Particle Image Velocimetry), an application for which we are the global market leaders. PIV allows the measurement of fluid flows in gases and liquids, the applications ranging from aerodynamics to combustion analysis and many other fields of study. LIDAR (light detection and ranging) is also an interesting area where our lasers are used for airborne particle mapping of the atmosphere for monitoring pollution and climate change. We also supply laser sources for LIBS (laser induced breakdown spectroscopy) and for pumping Ti:Sapphire and dye lasers. We are also seeing significant interest in industrial applications like silicon annealing, LSP (laser shock peening) and LLO (laser lift off), the latter being used in the manufacture of LEDs.

> *“Most companies want to supply a standard product, but most clients want a customised solution.”*

Q. Fibre lasers are a hot topic currently, do they pose a threat to your business model?

Our products are all in the field of nanosecond pulse widths and high pulse energies, and currently there is no alternative to rod lasers with lamp or diode pumping in this arena. Many of our lamp-pumped lasers are used infrequently for short periods (for example research or discrete experiments), where the advantages of diode pumping are out-weighed by the cost advantage of lamps. Most of our systems are also operating in green or UV and we have a wide range of tunable outputs, so again we are confident of a strong market for these products in the mid to long term. There is also a lot of activity in pico and femtosecond lasers, but we don’t feel the need to compete there as that market is already crowded and competitive.

Q. What makes Litron unique as a supplier?

I think the fact that we are a family owned business, and still relatively small, allows us to be more responsive and agile in taking decisions and implementing new ideas, we really don’t get bogged down in unproductive meetings. We have a good knowledge of the global marketplace and our competitors and have carved out a niche which suits our background. Frankly, we are not interested in a culture of rapid and uncontrolled growth which can easily disrupt the level of support and service that we are able to give our customers. Most companies want to supply a standard product, but most clients want a customised solution – I believe our structure and size allows us to manage this better than very large or very small companies who struggle to meet these demands.

We are also very well vertically integrated – when we analysed the weak link in our overall offering, we found that the bought-in

chillers were not performing with the reliability we demanded. Our solution was to develop our own range of chillers, both to satisfy our own requirements and then as an additional product line to offer to other laser source manufacturers. We now have a new chiller brand Zeropoint as a result.

Q. How do you find the current UK business climate, have you seen any Brexit issues?

Other than the devaluation of the Pound against the Euro, which followed the Referendum, we haven’t seen any delayed purchase decisions or uncertainty – generally, it is business as usual.
Most of our manufactured parts are from UK suppliers, and the exchange rate shift has boosted our competitiveness and margins when exporting. We have also had a flurry of applications from EU citizens to work at Litron in the UK, perhaps due to a desire to get a “foot in the door” ahead of any changes in migration laws.

> *“AILU events are a great opportunity to network with both laser manufacturers and academics.”*

Q. What does AILU membership mean to you?

AILU events are a great opportunity to network with both laser manufacturers and academics. Since we are selling a significant amount to UK universities, and we don’t have any competitors offering UK-built products, there is a strong motivation to attend and exhibit at AILU workshops. Having worked in the laser industry since graduating, I know a lot of the people in the industry – many I have met or will keep in touch with at AILU events.

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ANNUAL JOB SHOP BUSINESS MEETING 2017

On 18 October BOC welcomed the AILU Job Shop Group to their Gas & Gear centre in Wolverhampton.

The day started with a welcome from the Chair, Mark Millar of Essex Laser, and a brief overview of BOC from Stuart Wilders and Jim Fieret, including an up-tempo video introduction to BOC and the event.

Phil Carr, owner of Carrs Welding, gave an overview of how the quality standard AS9100 for the aerospace industry has impacted his subcontract laser welding business, then John Powell led a short discussion about the way in which solid state laser (fibre and disk) cutting systems have completely overtaken CO_2 – although CO_2 still has a place in other applications and non-metal cutting. Dave MacLellan then gave a brief overview of good and bad practice for digital marketing.

After a short break there was an opportunity to catch up with the latest new developments from Bystronic, TRUMPF, Mazak, IPG and Lasermet which included some lively discussion on the differences between fibre and disk lasers. Mark Millar then presented the annual breakdown response survey results before an excellent hot and cold lunch and opportunity for networking.

After lunch there were presentations on R&D Tax Credits and the ever-shifting environment of energy procurement. A panel discussion followed where Brexit was discussed among other topics and then there was the opportunity for a choice of one of two tours of BOC, including some interactive demonstrations about gases which was most enjoyable (see below).

Main image: JS 2017 Panel (l-r) John Powell (Laser Expertise), David Larcombe (Bystronic), Charles Dean (Fimark), Mark Millar (Essex Laser)

Images courtesy of You Agency

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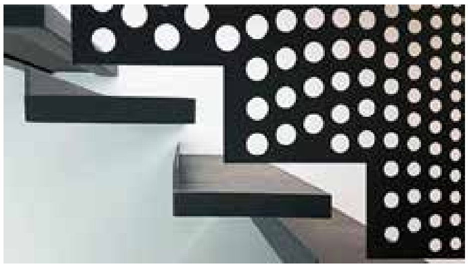
CUT-TEC PROVIDES NEW LOOK FOR OLD FACTORY

The renovation of an old piano factory in London has been given a new look with the help from Cutting Technologies. The factory in Camden has been converted into 15 residential apartments with the whole interior of the building being remodelled and the exterior repaired. Having been commissioned by London based Ambigram Architects, Cut Tec laser cut several panels for balustrades which transformed the building's main communal staircase.



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HUTCHINSON'S QUALITY ASSURED WITH PPAP

Hutchinson Engineering realises that the ability to provide quality components for their customers is a priority, and PPAP is helping them achieve this. The Production Part Approval Process (PPAP) traces back to the NASA Apollo space programme of the 1960s, where elements of the PPAP process were implemented to ensure product quality on the Apollo rockets. A variety of sectors now adopt PPAP as a method of certifying a mutual understanding for the performance of parts between component suppliers and purchasers.

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CHAIR'S REPORT

MY TAKE ON THE JOB SHOP MEETING...

October saw the ever-popular AILU Laser Jobshop meeting, this time hosted at BOC in the Midlands. It was wonderful to see many of you there, to meet some of our newest members and touch base with some of the more regular faces. For those that didn't make it, you missed out! There were several very interesting talks which included how to save money, not waste money and even get free money! On top of the business advice there were laser-specific talks detailing what new kit is out or coming soon.

As is often the case with this event it is not just the talks that were of interest. It is a great opportunity to ask questions of other job shop owners as we all face similar day-to-day issues and between us there are often some creative and unusual solutions. Also it is a great opportunity to network. I found companies which you would have thought were our competitors but who actually specialise in niche parts of the market. The overlap means we often get enquiries better suited to them and by the same token, they are getting enquires better suited to us.

We managed to make it all the way to 2pm before anyone even mentioned Brexit which I think must be some sort of record for a business networking event in 2017. The general consensus, like everything surrounding Brexit, was that opinion was divided upon whether the future was looking better or worse. At the moment though most companies said they were not being noticeably affected.

Overall I would strongly encourage those who didn't make it this year to try and get to next year's meeting. It is only one day out of the office and always pays for itself in either money saving tips or increased business. At the very least we all had an informative and entertaining day. Look forward to seeing more of you there next time!

Mark Millar

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HIGH SPEED NANOSECOND LASER PAINT STRIPPING

ZHENG KUANG ET AL.*

During laser paint stripping of certain materials, flames could be generated that might block the laser beam and contaminate the optics, in addition to creating a fire hazard. Researchers from Advanced Laser Technology Ltd (ALT) have demonstrated a laser paint stripping technique that effectively suppresses combustion flames, plasma and sparks during processing.

Laser paint stripping (LPS) technology is a non-contact technique to remove paint and coatings from different substrates. The main benefits of LPS include high processing efficiency, little substrate damage, ease of automation control and less environmental pollution. Thus, more and more industries have chosen LPS technology as a replacement for conventional paint removal methods, such as sand blasting and the use of chemical strippers.

Many different types of high power laser sources, ranging from continuous wave (CW) diode lasers [1,2] and CO_2 lasers [3,4] to pulsed Nd:YAG lasers and fibre lasers [5], have been used to perform paint stripping. Thanks to the high peak power and relatively low costs (compared to ultra-short pulse lasers), nanosecond pulsed laser systems have arguably become the most popular source employed by industry for paint stripping applications. Nowadays, nanosecond pulsed laser cleaning systems with kilowatt-level average power output are commercially available. However, due to the high laser fluence, combustion flames and plasma formed sparks always accompany the LPS process, resulting in concerns of fire hazards and contamination of the laser optics.

Figure 1: Laser head designed by ALT.

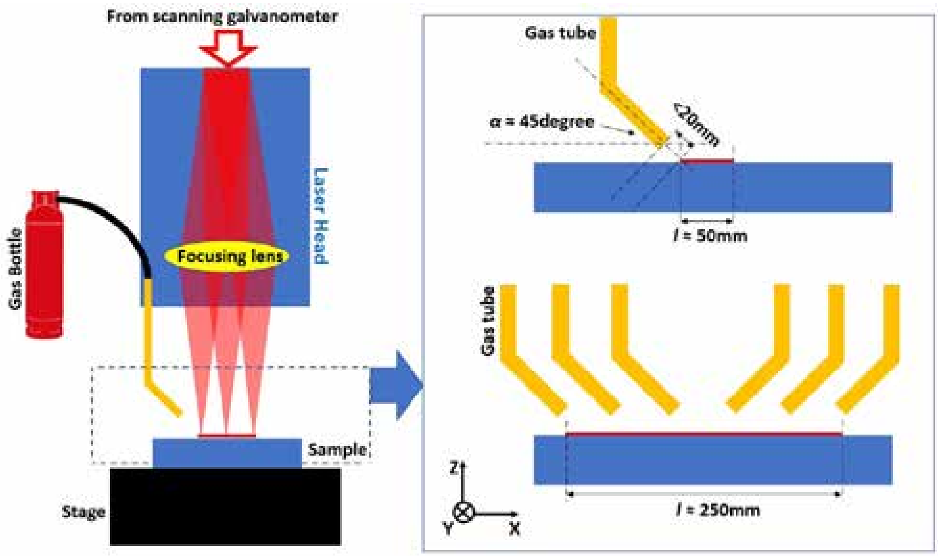

Figure 2: Design of gas blowing.

With this limitation in mind, researchers from ALT have demonstrated a LPS technique that effectively suppresses combustion flames and sparks during processing whilst keeping the high processing efficiency.

Methodology and experiment parameters

Due to the high peak power density, pulsed laser ablation of materials often leads to ionisation of the target material and the surrounding gas during the light-matter interaction. A focused nanosecond laser beam can easily ablate paints with a formation of strong plasmas. The plasma sparks could ignite surounding combustibles (e.g. flammeable solvents in high speed train painting factories) and cause explosions. Plasma formation can be significantly suppressed by decreasing the laser fluence below the ionisation threshold of the processed surface material. With the input laser fluence below this threshold, paint can still be removed with no, or much less, plasma formation by increasing the pulse overlap. This enables the material to absorb sufficient energy and be heated up to boiling point.

The sparks caused by plasma formation can be largely reduced by decreasing the input laser fluence; however, combustion flames may still be generated when the local temperature reaches the ignition point. This can be avoided by blowing an inert gas (e.g. argon) against the processed area to reduce local heat and oxygen. Thus, theorically, both sparks and flames can be prevented during LPS.

The laser source used was a nanosecond fibre laser system (IPG YLPH-100-100-1000-R) with a wavelength of 1064 nm, a maximum average power of 1 kW, pulse energy of 20 mJ at a 50 kHz repetition rate, and a pulse duration of 50 ns. The fibre laser was delivered to a laser head designed by ALT, as shown in Figure 1. The laser head contains a collimation lens ($f_c \approx$ 150 mm), a mirror, a mirror mounted on a scanning galvanometer and a focusing lens ($f_f \approx$ 300 mm). The collimation lens converted the diverging beam from the fibre to a collimated beam with a diameter $\Phi \approx$ 30 mm. After reflection from two mirrors, the laser beam was focused with a lens and was then defocused with a laser diameter of $\Phi \approx$ 2.7 mm at the target surface. The laser fluence was varied from ~88.4 mJ/cm^2 to ~1770 mJ/cm^2. The scanning galvanometer (prototype model ALT-EW-200, from ALT Ltd.) scanned the laser beam along a straight line on sample surface. The linear velocity and scanning length were controlled by adjusting the frequency and the voltage of the signal driving the scanning galvanometer respectively using a functional generator. The maximum linear velocity and the scanning length were approximately $V_h \approx$ 20 m/s and $l \approx$ 250 mm at the focal plane, respectively.

During processing, argon was blown against the processed area through a gas tube with an adjustable flowing speed to reduce the local heat and oxygen. The gas tube had an inner diameter of ≈ 4mm and was placed close to the processed area with a distance <20 mm and an angle ≈ 45 degree. A single gas tube covered a

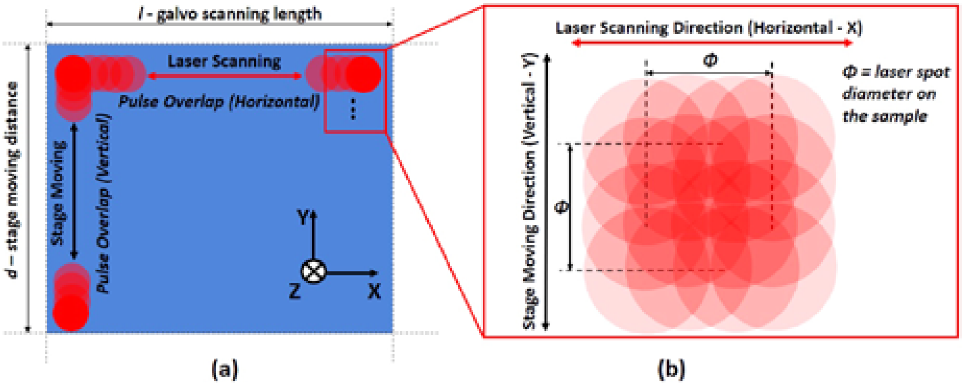

Figure 3: Laser paint stripping method.

scanning length $l \approx 50$ mm. Thus, five gas tubes would be needed when $l \approx 250$ mm, as shown in Figure 2.

The laser beam was scanned back and forth along a straight line on the sample while the stage moved was moved at a perpendicular direction. The combination of the two movements makes the laser beam sweep a rectangular area. The pulse overlaps on the sample can be adjusted by varying the laser scanning velocity and the stage moving velocity. A parameter, Number of Pulse Overlap (NPO), is defined as number of laser pulses fired during a period when laser beam is scanned or moved with a distance of laser spot diameter (Φ), as shown in Figure 3.

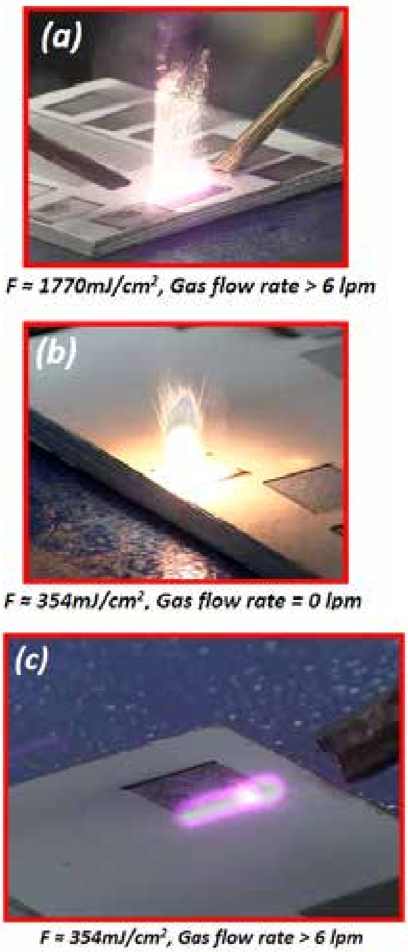

Figure 4: Comparison of sparks and flames flames intensity at different LPS parameters.

The samples used were aluminium alloy sheets with 5 layers of paint, provided by a high-speed train manufacturing company, CRRC Changchun Railway Vehicles Co. Ltd. The thickness of each paint layer was slightly different and ranged between about 30 µm to 70 µm. The total thickness was about 240±10 µm.

Laser paint stripping with surpression of sparks and flames

To effectively suppress sparks and flames during the LPS processing, the laser fluence should be $F \approx 354$ mJ/cm^2, while gas flow rate should be > 6 lpm. The images in Figure 4 show a comparison of sparks and flames intensity at different LPS parameters. Strong plasma sparks were observed in picture (a) due to the high laser fluence, while flames were captured in picture (b) due to combustion. Picture (c) shows that both sparks and flames were significantly suppressed when $F = 354$mJ/cm^2 and gas flow rate > 6 lpm.

The LPS processing results are shown in Figure 5. The paint layers were removed layer by layer when increasing NPO from 6 to 20 and they were removed entirely when NPO = 20. The flames and sparks were significantly reduced due to the low input laser fluence and local oxygen removal. The maximum paint stripping rate (remove all the paint layers) was ~ 1000 mm^2/s, or 0.06 m^2/min.

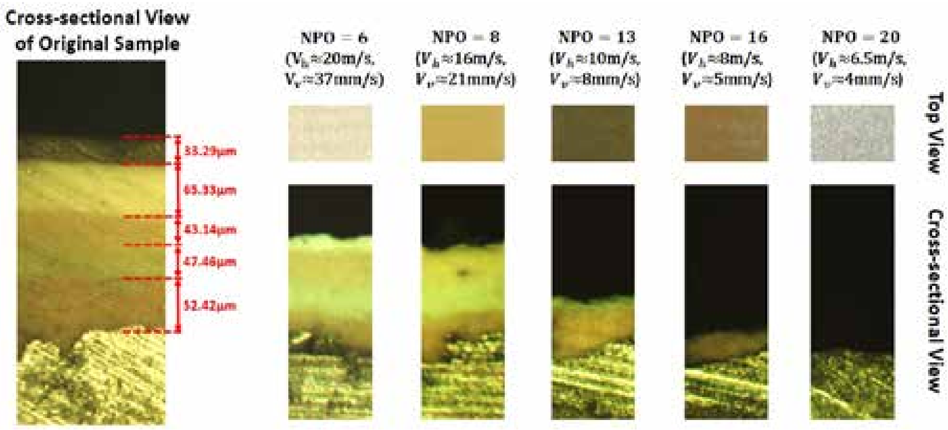

Figure 5: Paintings accurately removed layer by layer by increasing NPO (Vh is the laser beam scanning velocity and Vv is the stage moving velocity).

Conclusions

Researchers from ALT have demonstrated a LPS technique with effective suppression of combustion flames and sparks during processing. The scanning speed of the laser beam was carefully controlled to ensure an appropriate pulse overlap and prevent the aluminium substrate from being overheated. The paint was accurately removed layer by layer by increasing NPO with suppression of flames and sparks. The maximum paint stripping rate (remove all the paint layers) was ~ 0.06 m^2/min.

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CLEANING WITH LASER ADAPTIVELY BY NOVEL USE OF SENSORS

TIAN LONG SEE

Surface cleaning of engineering parts is an essential process within manufacturing production to ensure and enhance the integrity of the components produced. Conventional surface cleaning methods such as grit blasting and chemical etching have various shortfalls leading to the need for a more controllable surface cleaning methods, such as laser cleaning. In order to realise a fully controllable surface cleaning process, a closed-loop control system with the aid of an in-process monitoring unit is required so that the cleaning process can be tracked in real time. The MTC, Andritz Powerlase Ltd. (Powerlase) and Advanced Laser Technology Ltd. (ALT) have designed and developed a closed-loop laser cleaning system with an online monitoring unit to perform coating removal from tungsten carbide substrates. Cutting test were performed on the laser cleaned inserts showing a similar performance compared with the as received inserts.

Traditional cleaning and material removal method such as chemical and abrasive processing are reaching the end of their capability limit as they are either technically or environmentally unviable for next-generation materials (e.g. high value tungsten carbide tools, bismuth alloys, polymer/metal composites). In addition, stringent cleaning requirements are becoming standardised across the aerospace and space sectors and these cannot be met using traditional methods. With the introduction of REACH legislation, chemical cleaning will be restricted to a large extent and will become increasingly expensive.

A study by the European Commission on environmental impact has recommended laser cleaning technology as an alternative to the current chemical cleaning/etching process [1]. Traditional laser cleaning shows huge potential as an alternative process to conventional cleaning methods, but can result in damage to areas of the material surface if over-exposed to the laser beam. The lack of uptake for laser cleaning technology in many industries is mainly caused by the lack of knowledge on material sub-surface damage after laser cleaning. In addition, the optimisation process for any kind of laser processing is laborious and can involve large factorial design of experiments due to the large amount of laser parameters available. The complexity increases when dealing with coating/contamination of variable thickness.

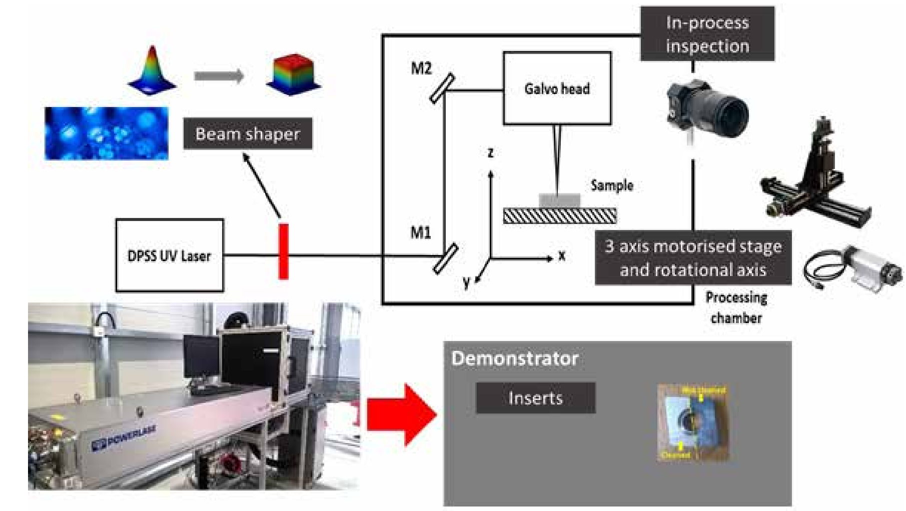

Figure 1: Schematic illustration of the CLEANSE laser cleaning system and its components.

These limitations have created a gap in the market for a selective surface cleaning and material removal process which can achieve high clean quality. The MTC, Powerlase and ALT have designed and developed an innovative, adaptable laser material removal system, combined with a removal detection system which helps ensure complete removal of contamination or debris on components. This was carried out through an InnovateUK-funded project called CLEANSE. The design system was tested on tungsten carbide (WC) inserts coated with titanium aluminium nitride (TiAlN) where the coating was removed by laser and a cutting test was performed to evaluate the performance of the laser cleaned inserts.

The laser cleaning system (Figure 1) consists of a high power diode pump solid state UV laser manufactured by Powerlase, a beam shaper from Powerphotonics, a Digicube galvo scanner by Laser Control Systems, a 3-axes motorised translation stage with a rotational axis and a novel in-process monitoring unit developed by ALT.

The laser used was a Rigel u90 with a wavelength of 355 nm, average power of 90 W, frequency of 10 kHz, pulse duration of 75 ns and a maximum pulse energy of 9 mJ. The in-process monitoring unit was developed based on a laser induced breakdown spectroscopy (LIBS) system, whereby the plasma generated through laser ablation of the material is used to identify elemental composition of the ablated surface. As each element has a unique spectrograph of emited light, a viable, low cost solution can be achieved by using a band pass filter on a CCD camera to detect a single element of choice. In the case of the removal of TiAlN coating on a WC substrate, the intensity of the Ti emission peak at a wavelength of 500 nm is being monitored, as shown in Figure 2.

The CLEANSE system used the motion control software Mach 4 as the master which triggered the start signal for the laser, the galvo scanner and the monitoring system. Once triggered, the monitoring unit measured the intensity of the Ti signal and calculated the cumulative signal magnitude over one rotation. After each rotation, the monitoring unit algorithm indicated whether the cleaning has been completed.

A laser ablation characteristic experiment was conducted on the WC substrate to identify the threshold value for the WC material so that a laser fluence much lower than the WC ablation threshold value was used for the cleaning

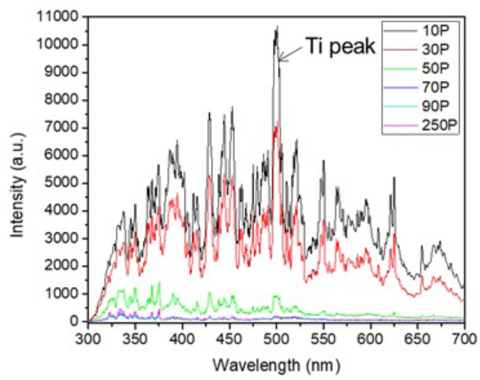

Figure 2: Spectrograph of the TiAlN coating after different number of UV laser irradiation passes, ranging from 10 to 250 passes.

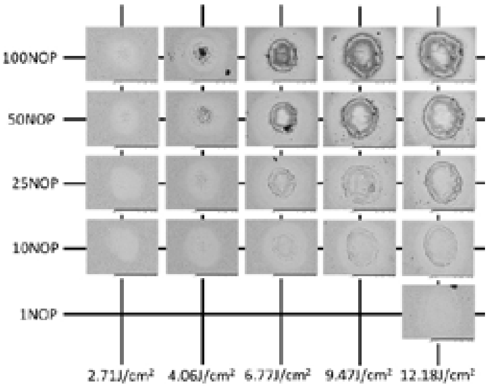

Figure 3: SEM images of the ablated craters on WC substrate with different laser fluence and NOP.

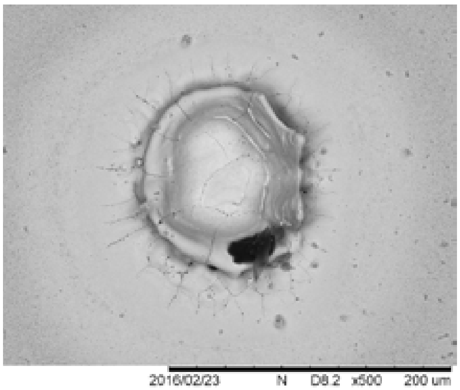

Figure 4: SEM images of crater produced with 6.77 J/cm² laser fluence with 50 NOP on WC substrate.

process. The experiment was carried out by ablating the WC substrate with different laser fluences and number of pulses (NOP) which is summarised in Figure 3. At low laser fluence and NOP, only one ablation region is observed with no sign of melts, re-solidification and periodic ripple structures - Laser Induced Periodic Surface Structure (LIPSS) - which is commonly observed in ultrashort pulse laser ablation of metals [2, 3]. As the laser fluence and NOP increases, a second ablation region is observed, accompanied by melts, re-solidification and cracks as shown in Figure 4.

The observation of the two ablation regions corresponds to the Gaussian nature of the laser beam used in the experiment. The Gaussian spatial distribution of the laser beam follows a normal distribution curve with a peak intensity in the middle that decreases radially outwards. At higher laser fluence or NOP, the area with higher energy intensity distribution has sufficient photon energy absorbed which is then converted into heat energy, reaching the melting point of the material creating a molten ablated region [4]. Conversely, the area with lower energy intensity distribution does not have sufficient photon energy absorbed to create melt but results in optically induced phase transformation on the material [5].

The geometry of the ablated craters (i.e. diameter and depth) was measured with an optical microscope and focus variation microscopy. The ablation threshold value can be determined using either a diameter measurement or a depth measurement technique on the ablated region. In this experiment, the diameter measurement technique was chosen because the latter technique is deemed to be less accurate and more prone to measurement error [5].

A second experiment was conducted to investigate the ablation threshold and removal rate of the coating from the WC substrate by ablating the coated WC substrate with varying laser fluence at a fixed NOP of 286. The material removal rate was measured and is summarised in Figure 5. As can be seen from Figure 5(b), the removal depth of the TiAlN coating increased with increasing laser fluence up to 2.71 J/cm² laser fluence. Then, the removal depth remain roughly constant and increase further with 6.09 J/cm² laser fluence at 285.6 NOP. This is mainly due to the difference in ablation threshold between the TiAlN coating and WC substrate and it agrees with the ablation threshold value obtained from the ablation characterisation experiment.

Based on the ablation characteristic for both TiAlN coating and WC substrate, the laser fluence of 1.6 J/cm² was selected by taking into consideration of the threshold value of the two substrate as well as the incubation effect of the WC material. All re-coated laser cleaned inserts with the close-loop CLENASE cleaning system showed similar cutting performance as compared to the as received insert indicating that the closed-loop laser cleaning process is capable of removing the coating without damaging the substrate material.

Conclusion

The CLEANSE cell demonstrated a closed-loop laser cleaning solution with an in-process monitoring unit for TiAlN coating removal from WC substrate. The solution developed has the potential to revolutionise the cleaning technology where such a system is capable of tackling cleaning of variable contaminant/ coating thickness, easily, without re-optimising the laser parameters. The reliability and performance of the monitoring unit has been proven to be high and repeatable during performance testing of the reconditioned drills.

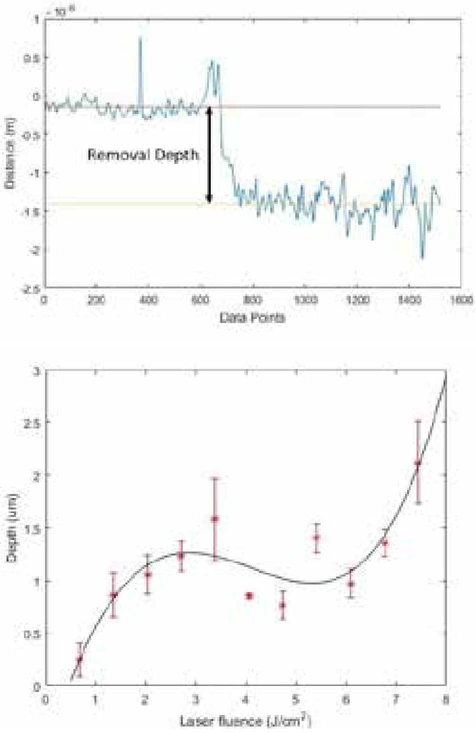

Figure 5: (a) Surface profile scan across non-treated and laser treated surface interface (b) Depth removal rate of TiAlN coating with varying laser fluence at fixed 286 NOP.

Acknowledgements

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LASER DRILLING OF CRACK-SENSITIVE SUPERALLOY

MOHAMMED NAEEM & CHRIS RASMUSSEN

Hastelloy-X is a solid-solution strengthened nickel based superalloy with excellent high temperature strength and oxidation resistance. This alloy is one of the most widely used nickel base superalloys for gas turbine engine and combustion zone components such as transition ducts, combustor cans, spray bars and flame holders as well as in afterburners. Laser drilling of cooling holes in this alloy is well established, however, this alloy exhibits a relatively high susceptibility to microcracking in the recast layer with cracks often extending into the parent material (also referred to as base metal). This article highlights the drilling results achieved with a range of laser and processing parameters in 2.25 mm thick Hastelloy-X nickel based superalloy.

Introduction

Modern gas turbine designs in aerospace and land based engines increasingly require large numbers of small diameter holes (<1 mm) to provide cooling in the turbine blades, nozzle guide vanes, combustion chamber and afterburner. In the modern jet engine the temperature of the gases can be as high as 2000^0 C [1]. This temperature is higher than the melting point of the nickel based alloy used in the combustion chamber and turbine blades. Jet engine components are protected against these extreme temperatures by the use of boundary layer cooling. The number of holes per component may vary from 25 to 40,000. As the cooling air passes over the surface it forms a cooling film, which protects the surface of the component from the high temperature combustion gases.

These cooling holes are currently drilled either by EDM (electrical discharge machining) or by lasers. Laser drilling is a long-established technique and the most widely used among laser-based manufacturing processes. The high processing speed of laser drilling has relegated EDM to secondary roles.

Laser drilling techniques - trepanning and percussion drilling

With laser drilling there are two basic techniques for producing holes within an aerospace component, trepanning and percussion drilling. Trepanning is where the laser beam pierces the centre of the hole and then, moving to the holes circumference, the laser beam or the component interpolates producing a hole. With the second technique, percussion drilling, neither laser beam nor component is moved but by firing a continual series of laser pulses, a hole is produced. The hole diameter is controlled by the focal spot size and the amount of energy used in the drilling pulse. Percussion drilling is a very important enabling technology within the aerospace industry as it allows for the cycle times on a component to be reduced. Referred to as “drilling on the fly” this technique reduces the time to drill a component but the quality of the holes produced are usually of poor quality.

A major difference in material removal mechanisms between percussion drilling and trepanning is the direction of melt ejection; during percussion drilling, the melt is mostly ejected upwards through the hole entrance, whilst with trepanning, the melt is mostly flushed downwards through the hole exit. The latter has the benefit of reducing the amount of spatter (resolidified molten or vaporized material around the hole periphery) and the thickness of the recast (molten or vaporized material that is not completely expelled and accumulated on the hole side wall, lining the hole).

The issue of hole quality is very important and is judged on a number of different characteristics including geometric factors (hole roundness and taper) and metallurgical factors (oxidation and recast layer thickness). The recast layer is the melted material that was not ejected from the hole by vapour pressure generated by the laser pulse, and coats the wall of the hole leaving a thin layer of solidified metal. This layer can generate micro-cracks, which can propagate into the parent material.

Testing Hastelloy X

Both cast and wrought nickel based superalloys are the main materials used in the hot section of almost all modern jet engines and industrial gas turbines, due to their high temperature mechanical properties. Driven by the increased firing temperatures of the gas turbines and the need for improved emission control, significant development efforts have been made to advance the combustion hardware, by way of adopting sophisticated materials and processes. The primary basis for the material changes that have been made is improvement of high temperature creep rupture strength without sacrificing the oxidation/corrosion resistance.

Hastelloy X, solid-solution-strengthened nickel based superalloy with a high creep strength is commonly used in gas turbine engine components due to its high temperature strength and oxidation resistance. However, this alloy exhibits a relatively high susceptibility to microcracking in the recast layer and parent material during laser drilling. It is believed that the formations of the mircocracks in the parent material is generally caused by microstructural segregation due to a relatively large solidification temperature range of the alloying elements of nickel-based superalloys in the heat affected zone. This leads to formation of brittle phases at regions that experience low solidification rate and stresses induced by laser drilling will cause these phases to crack. However, the parameters that affect the thermal cycle and heating flow, such as heat input and cooling rate, can influence the generation of tensile stress at the grain boundaries during cooling.

A detailed study of laser drilling was carried out to develop laser and processing parameters to gain a better understanding of the factors contributing to cracking, which is vital in developing better procedures for eliminating or minimising cracking during laser drilling of Hastelloy-X. An optical microscopy image of Hastelloy-X microstructure is shown in Figure 1; the microstructure of the alloy is composed of an austenite matrix and M_6C carbide enriched in Mo element [2].

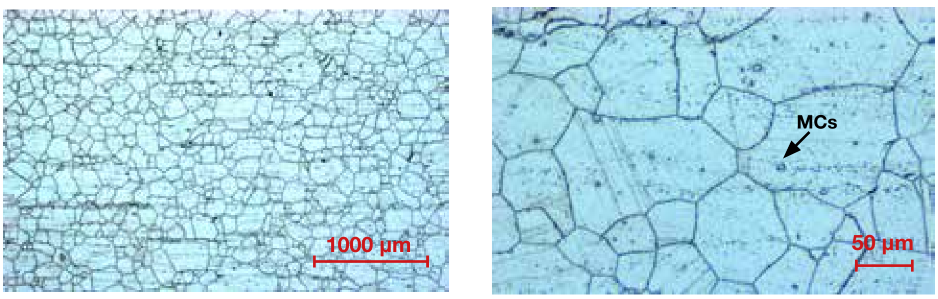

Figure 1: Optical microscope image of Hastelloy X composed of equiaxed grains and MC (metallic carbides)

Holes were drilled with various laser and processing parameters on 2.25 mm thick Hastelloy-X nickel based superalloy to quantify recast layer, taper, oxidized layer and cracking. These tests were intended to produce holes with diameters from 0.6 mm to 0.9 mm at 30⁰ to the surface. All the drilling tests were performed at focus with respect to the workpiece with a QCW fibre laser. The spatial characteristics of the focused beam are shown in Figure 2. The drilled holes were sectioned, polished and electrolytically etched in 10% oxalic acid for <10 seconds to examine the recast and oxide layer as well as micro cracks in both recast layer and base metal.

Results

A relationship was established between laser parameters for both base metal cracks and amount of recast layer within a hole after drilling. The results were very similar for both trepan and percussion drilled holes. This relationship can be employed to control metallurgical characteristics of the drilled holes and improve the overall whole quality. Both recast layer thickness and cracking was <45 µm for trepanned holes, whereas for percussion drilled holes the recast layer thickness was on the high side 60-75 µm and average crack length was 50 µm.

Figures 3-5 show the influence of peak power with a pulse width of 1.1 ms on the formation of base metal cracks and recast layer cracks. The formation of the base metal cracks was very similar for both percussion and trepanned drilled holes.

Conclusions

Laser drilling of Hastelloy- X superalloy was carried out with varying laser and processing parameters at 30⁰ to the workpiece surface. The main conclusions from the present study are:

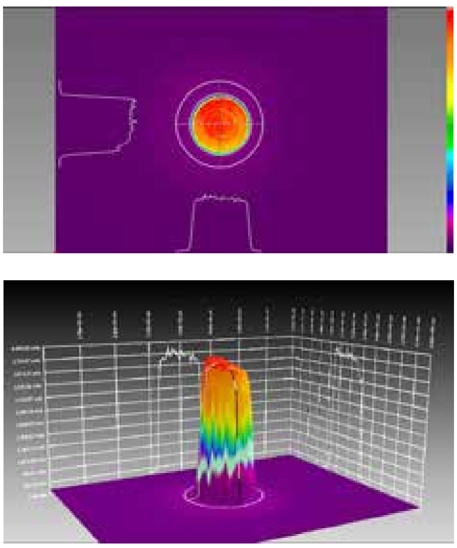

Figure 2: Beam profile at focused with respect to workpiece; 300 mm focal length lens; 214 µm spot size. Top: 2D profile, bottom: 3D profile

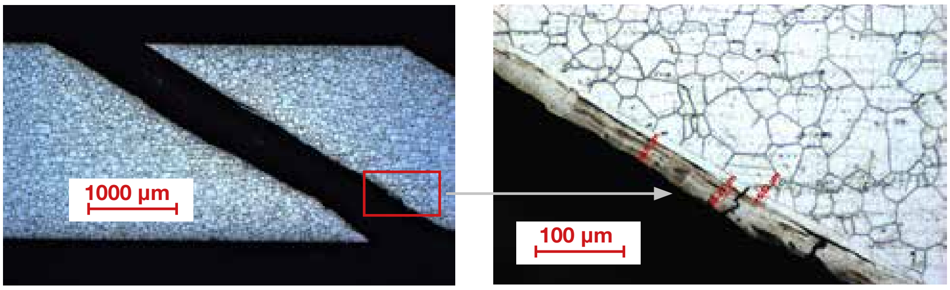

Figure 3: Percussion drilled hole; 3 kW peak power; average recast layer 50 µm; recast layer crack 40.25 µm; base metal crack 15.62 µm.

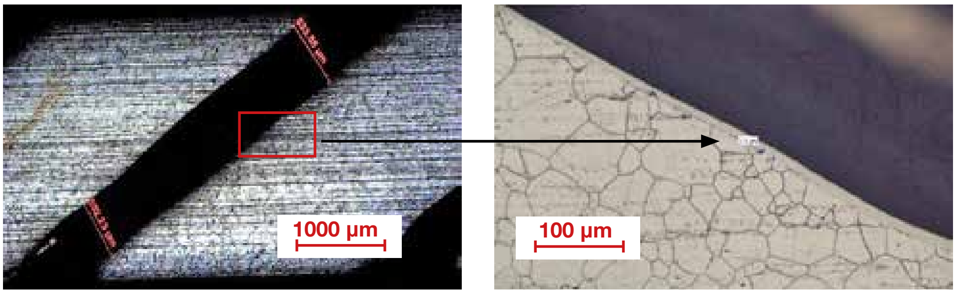

Figure 4: Percussion drilled hole; 11 kW peak power; average recast layer 35 µm; recast layer crack 14.25 µm.

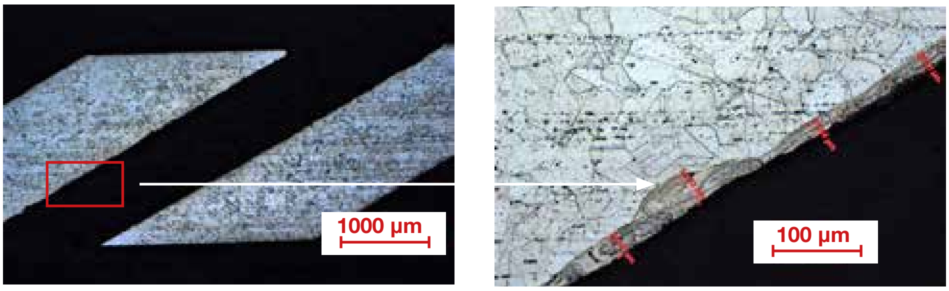

Figure 5: Trepanned drilled hole; 13 kW peak power; average recast layer 36.11 µm; recast layer crack 8.25 µm; no base metal cracks.

- The hole quality, in terms of metallurgical characteristics, is influenced by key laser variables like pulse energy, pulse width and peak power.
- Holes drilled between 11-15 kW peak powers exhibited no base metal cracks.
- The geometrical features (% hole taper) and metallurgical characteristics were very similar for both percussion and trepanned drilled holes.

Work in progress

The LASERDYNE S94P control which includes a full complement of standard hardware and software features for better laser control to produce smart material processing solutions for cutting, welding and drilling to produce defect free parts in production. One such software feature is pulse shaping. To date very little work has been carried out on laser drilling with pulse shaping using QCW fibre lasers. Early work carried out at Laserdyne with laser temporal shaping of a percussion drilling pulse shown to produce consistent drill holes in terms of metallurgical characteristics. Results from this study will be published in the near future.

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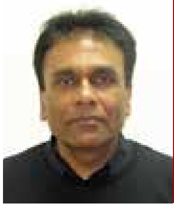

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SEE OBSERVATIONS P28

LASER SHOCK PEENING USING THE DIPOLE LASER SYSTEM

JAMES NYGAARD

The tools of the blacksmith have remained largely unchanged for thousands of years yet a modern innovation using high-powered lasers is challenging the traditions of manufacturing and metalwork: laser shock peening delivers a real impact in material performance and now a new laboratory has been commissioned to further develop this advanced surface treatment.

The Science and Technology Facilities Council (STFC) is one of 7 UK Research Councils that operates and develops a collection of world-class large scale research facilities. The fundamental scientific research conducted within STFC's Central Laser Facility (CLF) involves some of the most powerful laser sources in the world, capable of generating extremely intense beams of photons for probing the internal structure of matter under extreme conditions, and recreating the plasma temperatures found at the centre of our own sun. Harnessing such powerful technologies allows us to develop new scientific understanding and better solve real-world engineering problems too. We can explore novel uses of short pulsed lasers for the repair of critical components and maintenance of industrial infrastructure. An advanced materials processing laboratory has recently been commissioned at the CLF to investigate and develop laser shock peening, powered by our in-house laser platform DiPOLE: "Diode Pumped Optical Laser system for Experiments" (featured in The Laser User, Issue 83, Winter 2017).

Introduction

Laser shock peening (LSP) is an innovative process that uses nanosecond pulses of laser light to compress the surfaces of materials and enhance their mechanical performance. High-power incident radiation impinges on the target surface ablating a small volume of energetic plasma which rapidly expands sending shockwaves deep into the material. These shockwaves compress the atoms in the material, densifying the crystal structure and strengthening it by introducing lattice defects called dislocations. The deformed region of material remains locked in a state of compression, even after the shockwave has passed through, leaving behind what is called "residual stress". The surface becomes more resistant to subsequent damage and the material is effectively strengthened at all locations containing this compressive residual stress. Blacksmiths have long exploited this phenomenon to work metals and add strength using traditional tools like the peening hammer. With LSP, the laser becomes our tool, providing significantly deeper compression and a more intelligent process that can target precise locations such as welds and rivets for added strength. Using the DiPOLE laser system we can even tailor the shockwave itself.

Laser peening has been adopted by certain specialist sectors like aerospace and nuclear power generation where material performance is a critical concern. Example applications include aircraft engine fan blades, which are laser peened along their leading edges. Elsewhere, in the large pressure vessels of nuclear reactors, corrosion resistance is improved by laser shock peening the internal cladding material.

Experimental setup

The DiPOLE laser is a diode-pumped solid-state laser system (DPSSL) utilising a cryogenic gas-cooled amplifier head containing multi-slab Yb:YAG gain media producing 1030 nm wavelength output with nanosecond pulses at a maximum energy of 10 J and a maximum repetition rate of 10 Hz. The 5 mm x 5 mm square beam is incident on a target sample which is rastered through the fixed beam using motorised translation stages (Figure 1).

The flexibility offered by DiPOLE allows full control over the laser peening variables enabling us to better understand the specific influence of changing energy, pulse duration, beam diameter, repetition rate and overlapping shocks on the residual stresses produced.

Residual stress and material compression

There are a number of ways we can measure the residual stress state that exists within a sample that has been subjected to LSP. Non-destructive methods, such as X-ray diffraction can be used to probe the interatomic distances between atoms and reveal strain in the crystalline lattice but the shallow penetration depth of photons in metals make this technique only surface sensitive. In some cases we must physically cut open the target to relieve the internal stress whilst measuring the material relaxation using digital image correlation or simple strain gauges. Using this approach with help from collaborators at the University of Coventry, the residual stress state in a number of test alloys was measured after laser peening at CLF (Figures 2 & 3). Compressive stresses are produced at depths exceeding 1mm beneath the treated surface and the magnitude and depth of this compression can be increased by applying repeat shocks with higher intensity pulses.

The use of a transparent medium like water acts to trap the plasma produced during LSP, confining and directing the shockwave deep into the material. For this reason, water is routinely included in many LSP treatments, either by complete immersion of the target in a liquid bath or by flowing water over the target surface as a continuous thin layer. This latter arrangement has been used during testing at the CLF.

Figure 2 contains residual stress data demonstrating the critical role played by the water confinement layer, amplifying the shockwave for

Figure 1: The laser shock peening laboratory showing target station apparatus.

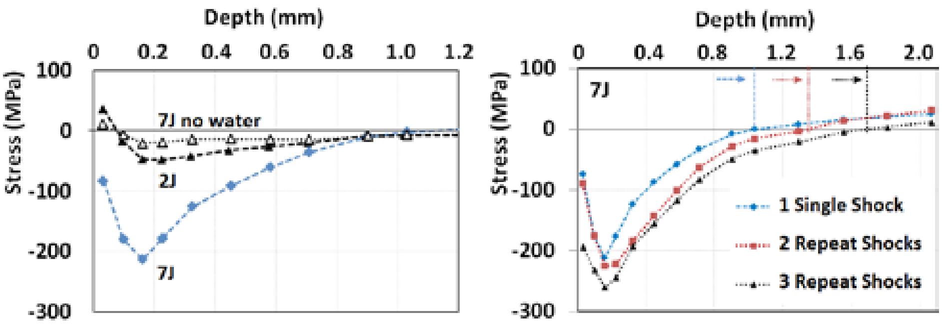

Figure 2: Residual stress data after laser shock peening of Al 7075 with different parameters.

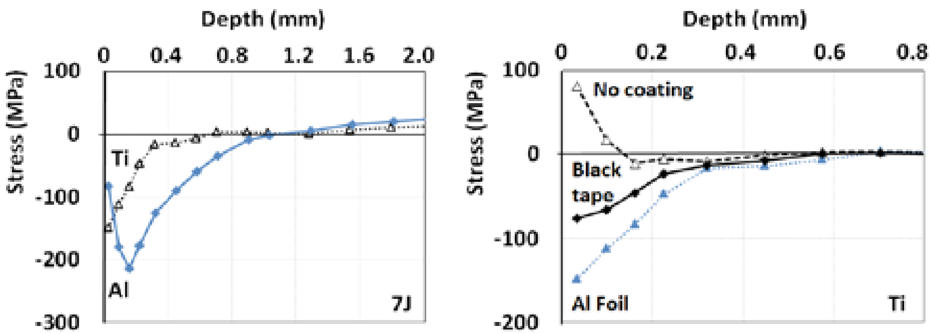

Figure 3: Residual stress data after laser shock peening for different sample materials and coatings.

an order of magnitude increase in compression at 7 Joules. Also shown is the added depth benefit of delivering multiple repeat shocks. Figure 3 demonstrates how materials respond differently under identical laser peening conditions, with aluminium alloys displaying a greater depth of compression compared to higher strength titanium alloys at the same laser energy of 7J.

The density and acoustic impedance of these materials influences the pressure wave propagation behaviour, and their thermomechanical properties dictate whether the target will plastically deform or even melt for a given intensity. Optimal conditions are achieved when the material is elastically deformed with minimal permanent deformation, as any plastic yielding could relieve the elastic compression. If surface melting occurs it is often accompanied by a detrimental tensile residual stress formed upon resolidification and cooling, similar to that of a heat affected zone in a weld. Our studies have identified the optimal coatings for use during LSP that can prevent surface damage whilst still imparting the beneficial compression deep into the sample. Thin aluminium foil achieves the best results, coupling well with the metal target for good shockwave transmission, whereas black tape absorbs the IR radiation well but attenuates the shock more than foil (Figure 3).

Surface condition and additive manufacturing

The appropriate use of sacrificial ablative coatings helps to protect the sample surface by minimising heat transfer and preventing unwanted distortion. Maintaining a high quality surface condition is often critical for engineering components in industrial environments where surface imperfections can act as stress concentrations which initiate fatigue failure or pitting corrosion cracks. To demonstrate that a high quality surface finish remains after LSP, measurement of the surface roughness before and after treatment is performed with a simple visual inspection for signs of sample discolouration or burning.

When no coatings are used it is possible to ablate the target material itself, causing vapourisation at high intensities and melting of the near surface. Despite encouraging tensile stresses as described earlier, there may also be some advantages to this effect. Intentional remelting of a shallow surface layer can smoothen out uneven topography and polish a rough surface to a uniform shine (Figure 4). This method of surface polishing shows promise and may be particularly suitable for additively manufactured components. Commonly called 3D printing, additive manufacturing (AM) of components from metal powders is an exciting new tool which is finding widespread appeal across high-value industrial sectors. One issue with AM built parts however is their surface condition is typically rough and granular, often requiring additional post-process machining. The CLF is investigating using LSP as a novel solution to polish 3D printed surfaces and help improve material quality in AM components.

Automation and innovation

Industrial engagement with LSP is about building confidence in the repeatability, reliability and cost efficiency of the technique. Not only must the surface treatment provide consistent performance improvements, but it should also be flexible enough to adapt to a variety of real component shapes and sizes. At CLF, a recent expansion of the LSP facility includes the addition of a second target station to deal with these concerns: the expansion integrates a six-axis robotic arm for 3D sample manipulation offering a large working envelope and the ability to peen complex sample geometries including curved surfaces found on most industrial components.

Combining high-speed, automated sample manipulation with the high repetition rate 10Hz pulses from the DiPOLE laser system will expedite treatment of large sample surfaces and increase throughput, saving costs on energy expenditure and proving more attractive to industry. A fully synchronised robotic system, triggered directly by the DiPOLE laser is a future goal, along with docking stations for multiple sample changeover. But the real game-changer will be to incorporate in-line laser shock peening with additive manufacturing for hybrid build processes; a laser combination set to provide this already disruptive 3D printing technology with a real shock!

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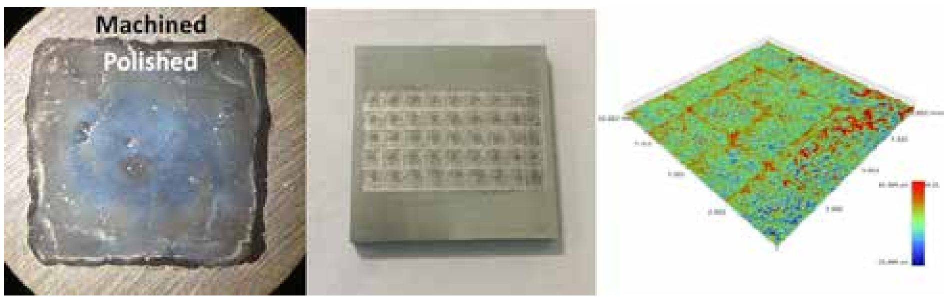

Figure 4: Surface condition after laser peening with a roughness topography map.

James Nygaard is a development scientist working at the Rutherford Appleton Laboratory on laser processing of advanced materials.

SEE OBSERVATIONS P28

MOTION CONSIDERATIONS IN LASER MICRO-SINTERING APPLICATIONS

PATRICK WHEELER

Selective laser sintering (SLS) is a broad topic encompassing many different solutions. In the most general sense, it is the act of selectively turning a powdered material into a solid structure without first turning that powder into a liquid. In practice, the phase transition from powdered solid to liquid mass to solid mass happens, but very quickly, because of the speed with which an industrial laser allows for the application and dissipation of large concentrations of thermal energy. In terms of manufacturing, a system must be able to accurately deliver both the metal powder and the laser power to the same locations over a 3D space. Positioning the powder and the laser requires high motion accuracy as feature sizes continue to decrease in order to make more precise products (Figure 1).

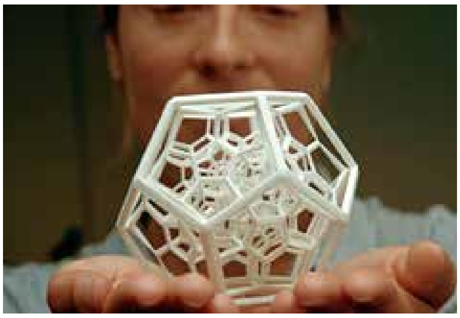

Figure 1: Sculpture produced by selective laser sintering.

As product features move toward a limit of 30 µm or less, all of the elements of an SLS system are critical to achieve the accuracy and repeatability needed. There are two main types of powder metal delivery used in SLS. The first is where a powder bed is melted layer by layer (Laser Metal Fusion). The second is where a powder feed is attached to the welding nozzle (Laser Metal Deposition) to carry out the sintering process. For either one of these processes to produce micro level laser sintering, the powder must be sized appropriately, the laser spot size must be small enough to create the required heat affected zone, and the motion system must be accurate and repeatable enough to be in the right location for each and every point. In this article, the system design of a powder bed system (Laser Metal Fusion) will be considered.

Start at the beginning…

Good motion system design begins with the end result in mind. What acceleration, velocity, accuracy, repeatability, and tracking error are required? For this stage of the evaluation, the mechanical solution (whether gantry, XY galvo scanning head, simple stacked-stage solution, or any combination) need not yet be considered as the move specifications will provide guidance into the optimal mechanics.

Machine base assembly

The first consideration is to design a machine base which is adequately stiff and heavy, to prevent ground vibrations being transmitted to the focal point. Proper leveling feet, a stiff metal structure, and an adequate isolation system between the machine base and the base plate are required. Base-plate material can significantly affect machine performance. Typically the choices are steel, aluminum, and granite. Often granite performs best for damping, weight and flatness (Figure 2). Disadvantages of granite are cost, requirements for special inserts (versus drilling and tapping holes), and having a different coefficient of thermal expansion than the mechanics mounted to it. Ultimately, the material choice depends on performance, but can also come down to costs and availability.

System mechanics

Once a preliminary base design is complete, the next decision is the type of mechanics for the motion system. For the example in this article, a 300 x 300 x 150 mm XYZ motion system over a powder bed with a special powder addition and leveling system below is required.

The work envelope requires three dimensions of motion and must span the powder bed. The system design will consist of linear stages in all three directions (X, Y, and Z) and will be a traditional gantry configuration (Figure 3) – meaning dual axes carrying a single bridge axis. The controller can only position a stage to be within an accuracy specification limited by the encoder's resolution, the mechanical resolution of the bearings, and the location of the encoder with respect to the work point, leading to potential errors or limitations. Luckily there are techniques to mitigate some of these errors. For example, for the gantry system under discussion, parallel gantry base axes or "spars" on either side of the powder bed carry a single gantry bridge (also linear motor driven) over the top of the powder bed. These parallel base axes may not be perfectly orthogonal to the bridge axis, but the right controller choice can "force" orthogonality by applying an offset to one of the base axes or "spars", to minimise angular errors. Additionally, each encoder must be calibrated to achieve the highest level of accuracy at the work point. This calibration procedure involves placing reflective optics mounted to the XYZ motion system at the laser work point.

A laser interferometer is used as the master position reference as the axis being calibrated is moved along its travel. Calibrating an optical linear encoder with laser interferometer feedback at the work point will increase performance in two ways. First, it corrects for the magnitude of error along the axis being calibrated due to angular error motion of that axis, which is magnified by the distance between the encoder

Figure 2: Granite selective laser sintering base plates.

Figure 3: Gantry-style motion system incorporating an XY galvo scanner.

and the work point. It should be noted that the angular element of that error vector is not corrected. However, with symmetric Gaussian or top-hat laser spots, the angular aspect of this error is not an important consideration. Second, it increases the raw linear accuracy imparted by the stage at the work point. Moving to multiple positions along the travel of the stage tracks the differences between the native encoder and the more precise interferometer feedback. The difference in measurements between the two devices is used to generate a calibration file. A controller will use this calibration file to ensure that a commanded motion of, for instance, 10 mm will be as close as possible to 10 mm at the work point, not necessarily at the encoder.

The velocity requirements of the process requires a scanning speed of a few meters per second, so XY galvo scanning heads are chosen as the proper tool for fast beam steering. The only issue is that the galvo scanning head has a field of view of 100 x100 mm while the part is 250 x 250 mm in XY. Also, the accuracy of the scanning head is ±50 µm, and that is after a theoretical f-theta lens correction file is applied.

There are several ways to address the limited field of view of galvo scanning heads. The first is to implement a step and scan technique. This technique means that the very high-speed moves are made with the galvo scanning head, followed by indexing steps with the servo axes. During scanning, the servo axes hold the galvo scanning head in position. Using this method, process moves that are longer than the galvo field-of-view (FOV) are "stitched" together at the edges of each FOV. Also, one must consider that the scanning mirrors move the laser beam towards the extents of an f-theta lens, spot size distortion occurs, and higher levels of positioning error also occur. For this reason, it is desirable to find an industrial controller that can blend servo and galvo motion together, which has two advantages. The first is eliminating any stitching errors. The second is maintaining quick processing times while limiting the FOV of the galvo scanning axes to the more accurate and less distorted central region of the lens. Slower servo moves under a galvo scanning head constantly "re-center" the part, which allows for this desirable behavior.

Controller evaluation

Now it's time to evaluate motion controllers. Considering all the controller features required to operate this mechanical system has narrowed our choices. Some key considerations include: What type of controller can manage five axes of coordinated motion? Can the controller continuously process a large part and, if so, how painful is that part to program? How will the controller interface with the laser? Can the laser be pulsed based upon distance and/or constant velocity? How will the pulse width be controlled? How will the controls required for machine functionality interface with those required for processing?

Correctly answering these questions with the right controller will determine whether or not the machine will operate as envisaged. For this reason, it is important not only to understand the interaction of the powder material with the laser, but also to understand how that interaction will manifest in 3D space.

In light of that, coordinating galvo scanner motion and servo motion together for the purpose of eliminating stitching, maximising throughput, and processing in the center of the f-theta lens are all noble goals. The laser spot size and pulse must be consistent, and distortion will be hard to tolerate. Stepping and scanning has the undesirable impact of starting and stopping what should be continuous process moves. Also, using a galvo head allows for some unique features such as rapid laser oscillation (wobble) to create "thicker" paths. The very high acceleration of the galvo head allows for more effective cornering operations, which is helpful when parts have many changes in direction. If these changes in direction exist, timing laser pulses based upon constant velocity will be very difficult. A controller that can track distance travelled and fire pulses based upon vector distance may be helpful in implementing this process.

A final look at the galvo scan head and f-theta lens combination reveals that the accuracy is ±30 µm over the central 25 x 25 mm region of the lens, even after a theoretical correction table is applied. The motion is very repeatable, just not accurate enough. Is there a way to calibrate this region to achieve more accurate results, based upon real world measurements? The accuracy of the galvo scan head/f-theta lens system is in addition to the servo system which carries it, so the less error the better. How can the galvo scanner be calibrated not only for the highest level of accuracy, but also to be aligned with the servo axes that carry it? There are still a lot of questions.

Summary

Moving from SLS towards micro-SLS (30 µm and below) requires a new set of considerations. Smaller powder particles and a smaller spot size are both required to make smaller features. The ability to control the pulsing of the laser to control energy input is another requirement. Conceptually, these requirements are easy to understand.

The motion system proposed in this article has a total of five moving axes, each contributing its own unique errors. Although many items were discussed, many more were not addressed. These include: managing the leveling of powder beds between layers, managing the consistency of powder beds as powder material particle size decreases, the ability to program a part profile in three dimensions and to execute the profile with five moving axes. The list goes on. For this reason, it is important to consider your motion system requirements carefully to achieve the accurate placement of the beam. As these motion requirements become more technical, it is important to realise which tasks can remain in-house, and which require the assistance of a partner to guide you in the right directions.

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Patrick Wheeler is a Product Manager of hardware and software products with Aerotech, Inc. in Pittsburgh, PA. He has over 12 years of industrial experience in engineering and management roles.

MICRO-WELDING WITH LASER-GENERATED ULTRASOUND

ANDREW HOLMES ET AL.*

We have investigated a novel thermosonic (TS) bonding process employing laser-generated ultrasound with potential applications in electronics manufacturing and in particular flip chip assembly. As a proof-of-concept demonstration we have used the new process to attach copper-bumped silicon test chips to silver-metallised substrates. Laser Doppler vibrometer measurements and numerical modelling have also been carried out to characterise the ultrasound generation process.

TS bonding uses a combination of heat, pressure and ultrasonic energy to facilitate the formation of strong metal-metal bonds. It is widely used in electronics manufacturing for attaching bond wires to silicon chips where it offers a number of advantages including high reliability, simplicity in terms of materials (no solder or adhesive required), and lower bonding temperature than thermo-compression bonding.

Another important potential application for TS bonding is flip chip assembly [1] where the silicon chip is mounted face-down with connections being formed directly between conducting "bumps" on the chip and circuit tracks on the substrate or package. Flip chip processes based on solder attachment have been established for many years. However, with the continual drive for miniaturisation in the electronics industry they are approaching their limits in terms of interconnect density.

TS bonding could form the basis of a highly reliable, ultra-fine-pitch flip chip technology. However, up until now it has proved challenging to develop robust processes, mainly because of high sensitivity to alignment errors and bump height variations which can lead to bond strength non-uniformity or even damage to the chip. These issues become more severe as the chip size increases, and consequently conventional TS flip chip assembly has been limited to applications involving small devices.

In this work we have explored a new approach to thermosonic bonding for flip chip assembly based on laser-generated ultrasound [2]. It relies on the stress transients produced by confined ablation of a sacrificial layer or "tape" placed in close proximity to the bonding interface. This mode of stress wave generation is well-known in applications such as metal peening and materials inspection [3, 4]. However, to our knowledge it has not previously been applied to solid-state

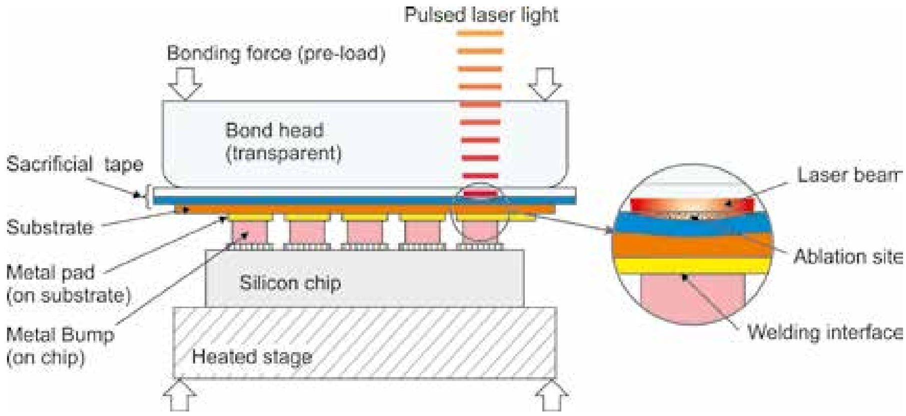

Figure 1: Laser-thermosonic micro-welding process as applied to flip chip assembly.

micro-welding. A potential advantage is that the ultrasound generation is localised, opening up the possibility of varying the applied ultrasonic power with position on the bonding interface to compensate for other effects such as bump height variation. Figure 1 shows the concept of the new process as applied in this work. Light from a high-power, high-repetition-rate, short pulse laser passes through a transparent bond head and is focused onto the sacrificial tape which is sandwiched between the bond head and the substrate. Pressure transients due to confined ablation of the sacrificial tape are coupled through the substrate to the bonding interface where they facilitate bonding.

Bonding trials

Proof-of-concept experiments were carried out using a custom flip chip bonder as described in [2]. The sample platform and the bond head on this system are both windowed allowing illumination of the workpiece from above and below. The system is equipped with two infrared lasers: a 20 W maximum average power, 1064 nm wavelength, nanosecond pulsed fibre laser (SPI Lasers type SP-020P-A-EP-Z-A-Y), and a 30 W, 970 nm wavelength fibre-pigtailed laser diode operated in CW mode. The pulsed laser beam, which drives the confined ablation, is delivered from above via a galvo scanner fitted with an f163 mm f-theta lens; this gives a focal spot diameter of around 55 µm at the sacrificial tape. The CW beam is delivered from below and is used to heat a small stage on which the chip is mounted for bonding.

For the experiments described here, the substrate was taped to the underside of the bond head window with the sacrificial tape being sandwiched between the window and the substrate. The sacrificial tape consisted of a 75 µm-thick tungsten foil with a 1 mm-thick glass cover layer to protect the bond head from laser damage. Inspection of these layers after bonding revealed that ablation damage had occurred in both materials.

Bonding trials were carried out using copper-bumped silicon test chips and silver-metallised substrates. This copper-silver (Cu-Ag) material combination is of interest for certain advanced packaging solutions as well as for printed electronics. The test chips were 4.1 × 3.6 mm^2 in size with147 copper bumps of either 60 or 120 µm diameter distributed over the top surface, all bumps being 50 µm in height. The substrates were 200 µm-thick stainless-steel foil coated with a 12 µm-thick layer of stencil printed and sintered silver. Prior to each trial the chip and substrate were pre-etched to remove oxide layers.

The key process variables for the new process are the pulsed laser parameters (pulse fluence, duration and repetition rate, and burst duration), the bonding force and the bonding temperature. In these initial trials a series of 10 ms-duration pulse bursts was applied to each assembly, with each burst comprising a train of 28 ns FWHM pulses at 80 kHz repetition rate. The burst duration was chosen to be similar to the typical formation time of thermosonic bonds, while the bonding force was maintained at ~100 MPa which is similar to that typically used in conventional TS bonding. Pulse bursts were applied at 528 sites arranged in a 24 × 22 array on a 0.25 mm pitch; the exposure sites were not precisely aligned to the bump positions on the test chip. With a pulse fluence of ~8 J/cm^2 incident on the sacrificial tape, this being the maximum for which the ablation damage did not fully penetrate the glass cover layer, it was found that successful bonding could be achieved at a

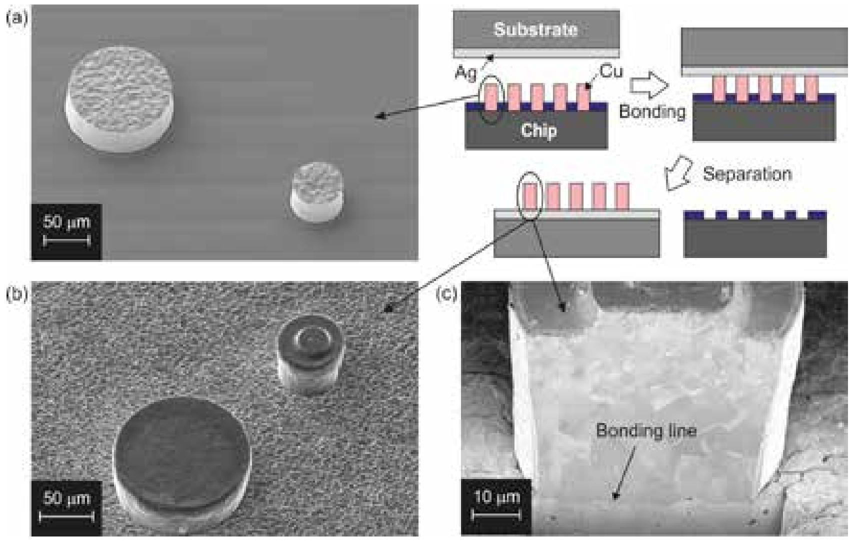

Figure 2: SEM images showing: (a) Cu bumps on chip prior to bonding; (b) Cu bumps on substrate after bonding and separation; (c) FIB-SEM cross-section showing Cu-Ag bonding line.

minimum bonding temperature of 150°C. This is within the range of bonding temperatures typically used in conventional TS processes.

Bonded assemblies were prised open using a scalpel and then examined by scanning electron microscope (SEM). It was found that most of the bumps separated from the chip and remained welded to the silver layer on the substrate, indicating that the newly formed Cu-Ag bonds were stronger than the original bump-chip bonds. Figure 2 shows SEM views of Cu bumps before and after bonding, along with a FIB-SEM (focused ion beam SEM) cross-section showing the Cu-Ag bonding line. Shear testing was carried out for a number of individual bumps and showed an average shear strength of 116 MPa.

Vibrometer tests and modelling

Laser Doppler vibrometer measurements were carried out to explore the ultrasound generation process in our bonding setup. For these tests a 1 mm-diameter disc of 75 µm-thick tungsten foil was sandwiched between 1 mm-thick glass plates and clamped between the bond head and bonder platform. The vibrometer (Polytec type OFV 534, 24 MHz bandwidth) was mounted to monitor the epicentral deflection on the underside of the foil. Two distinct regimes of operation were observed in these experiments. At low pulse fluences, the foil exhibited a purely thermoelastic response, deflecting upwards at the centre due to the laser-heating of its upper surface (Figure 3a). In contrast, at higher pulse fluences the deflection was much larger and of opposite sign being driven by the pressure transient of the confined ablation (Figure 3b). All bonding trials in which successful bonding occurred were carried out at pulse fluences corresponding to this second regime.

Numerical modelling of the laser-material interaction was also carried out, using Comsol™ finite element analysis software. For the low-fluence regime a purely thermomechanical model was employed which gave close agreement with the vibrometer measurements. For the high-fluence regime, a semi-empirical approach was used with a pressure pulse (Gaussian with exponential tail) being applied to represent the ablation pressure. For the experimental data in Figure 3b, a good fit was obtained with a peak ablation pressure of around 600 MPa which is in the range of published data for confined metal ablation experiments using similar laser intensities and pulse durations [5].

Discussion

We have explored the basic feasibility of a novel solid-state micro-welding process based on laser-generated ultrasound. Our initial results indicate that such a process is indeed feasible.

Based on the vibrometer measurements and numerical modelling, the transient stress levels at the bonding interface appear to be relatively low compared to those found in conventional TS bonding. Nevertheless, we were able to form strong Cu-Ag bonds at lower temperatures and timescales than would normally be required for thermo-compression bonding. Future work will be aimed at developing a better understanding of the process and to exploring its applicability to different material systems and applications.

Acknowledgements

This work was funded by EPSRC under grant no. EP/L02232X/1. We are grateful to SPI Lasers UK for the loan of a fibre laser, to Dr Jicheng Gong (Oxford University) for assistance with FIB-SEM analysis, and to Inseto Ltd for assistance with shear testing. The test chips and substrates were kindly provided by Kevin Cannon of CSR plc.

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[5] R. Fabbro et al., J. Appl. Phys., vol. 68, no. 2, pp. 775–784 (1990).

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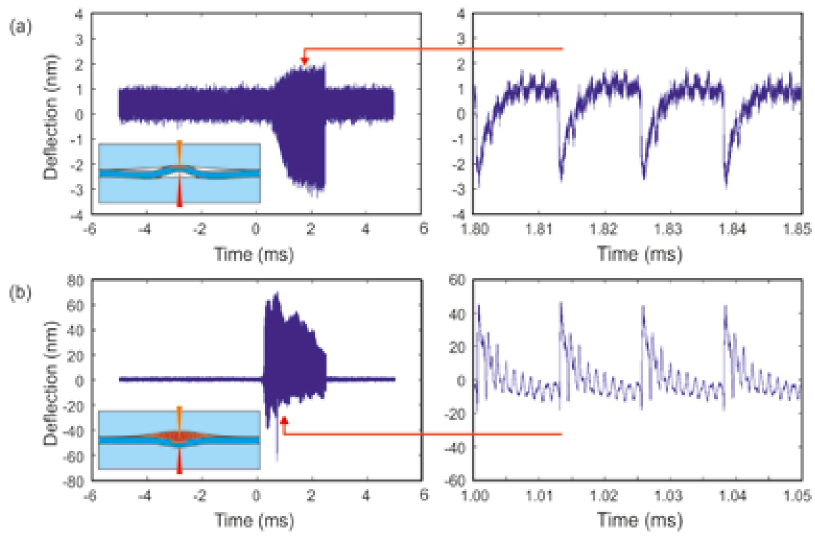

Figure 3: Vibrometer tests showing foil responses for (a) low pulse fluence (~1 J/cm²) and (b) high pulse fluence (~8 J/cm²). Positive reading corresponds to downward deflection of foil.

Andrew Holmes is Professor of Microelectromechanical Systems in the Department of Electrical and Electronic Engineering, Imperial College London.

SEE OBSERVATIONS P28

LASER DRILLING OF CRACKSENSITIVE SUPERALLOY

Mohammed Naeem & Chris Rasmussen

This is an interesting article that is demonstrating that the QCW fibre laser has displaced the flashlamp pump pulsed Nd-YAG lasers that I believe both the author and I cut our teeth on in the late 80s/early 90s and became the standard source for laser drilling of superalloys especially in jet engine manufacture.

The similarities in laser parameters though can be seen in this article. Pulse lengths of 1.1 mS are quoted with peak powers of 11–15 kW and a focal spot size of 240 µm. Very much similar to the parameters you would expect to be quoted from a JK704TR laser.

But instead of a <3% wall plug efficiency, large power supplies and substantial chilled water requirements, we are talking about efficient fibre laser technology.

With the hints of pulse shaping and a paper to be published, then I would welcome a follow up article for the magazine from Naeem with a bit more detail on the parameters themselves and more description of the benefits of using a QCW fibre laser source.

Martin Sharp, LJMU

Mohammed Naeem's article provides a good insight into Quasi-CW laser drilling process and highlights one of the challenges faced during laser drilling of some aerospace nickel alloys like Hastelloy-X, which are prone to thermal cracking.

Though laser drilling is extensively used in aerospace applications, the issue of the crack generation still persists in some Ni Alloys, especially during laser drilling of holes at shallow angles. I am glad that Mohammed Naeem's have tried to provide a solution based on parametric investigation.

In the "work in progress" section of the article, Mohammed had mentioned about the significance of pulse shaping in laser drilling. It will be interesting to know if pulse shaping can be used to further control the crack formation during laser drilling of Hastelloy-X.

Sundar Marimuthu, MTC

LASER SHOCK PEENING USING THE DIPOLE LASER SYSTEM

James Nygaard

The development of the DiPOLE 10J prototype system by the Central Laser Facility for Advanced Laser Shock Peening applications is some progress. It will not only help to open new avenues for undertaking laser shock peening research, but will also prove to be a good tool to provide solutions to the UK's manufacturing industry, for effectively surface treating components to beneficial effect.

The cost of this technology is still somewhat high and once we are able to reduce this, the implementation of this process will certainly open new doors for strengthening components form wide range of sectors. This is particularly so for applications requiring induction of deep compressive residual stresses within thick sections where complete protection is difficult to provide within the bulk of the material using conventional techniques.

We are taking the correct steps within the UK to progress further in this line of work, and the plans to undertake hybrid manufacturing assisted by this process will prove to be valuable in future years to come.

Pratik Shukla, Coventry University

MICRO-WELDING WITH LASER-GENERATED ULTRASOUND

Andrew Holmes et al.

This article by Andrew Holmes et al. provides a good description of the novelty aspects of laser-generated ultrasound, for metal-to-metal joining in advanced electronics manufacturing. The present study nicely illustrates how the laser technology can offer significant benefits over conventional processing methods, in terms of addressing high precision processing, highly localised heat input and flexibility in application. These factors become even more critical when joining is required in products employing miniature devices and features.

The laser-generated ultrasound thermosonic (TS) bonding method appears to allow a more localised control of bonding parameters, compared to the more conventional TS bonding technique. It is also interesting the approach of pre-heating the interface locally by laser, to maximise control of thermal loading.

f further consolidated, I can see why this technique presents good potential of finding use in a wide range of applications in electronics manufacturing, including Micro-Electro-Mechanical Systems (MEMS) and optoelectronics, where joining of delicate parts is required.

It is also positive to see the extended capability of nano-second pulse laser sources, covering more and more joining applications in addition to micro-machining. I really enjoyed this article and I will watch this space!

Paola De Bono, TWI

AILU WORKSHOP - LASER CLEANING
13 SEPTEMBER 2017 FANUC, COVENTRY

Worshop speakers (l-r): Tony Jones (Cyan Tec), Zheng Kuang (ALT), Diashu Qian (ALT), Ioannis Metsios (Andritz Powerlase), Tian Long See (MTC), Louise Partrigde (SPI Lasers), Lin Li (University of Manchester), David Lawton (Lasermet), Stan Wilford (IPG Photonics), David Gillen (Blueacre Technology), Michael Kuhn (FANUC). Also presenting was Clive Grafton-Reed (Rolls Royce).

The event was hosted by FANUC UK in their brand new facilities at Ansty Park, Coventry. Laser Cleaning is a technology that has recently become more widely applied as fibre laser sources have improved the economics and efficiency of the laser cleaning process, making it suitable for wider application. This was the first AILU workshop dedicated to laser cleaning after a very successful and popular session at ILAS 2017.

Lin Li opened the day with a summary of work carried out at Manchester University with Jaguar Land Rover showing how laser cleaning reduced or removed porosity when welding aluminium. Daishu Qian of Advanced Laser Technology (ALT) covered the cleaning of moulds which are used in the manufacture of composites – the removal of release agents, epoxy and other contaminants as an attractive alternative to using a wet chemical cleaning process which requires manual skilled labour and carries health and safety risks.

Stan Wilford of IPG Photonics then went on to show in more detail the comparison between chemical cleaning and the clean laser alternative, pointing out the more stringent controls of chemicals which are being introduced in legislation. Stan also covered rust and paint removal, discussing the options of square spots and finer or larger beams to work in detail or at highest speed. TianLong See from the nearby MTC introduced a novel adaptive (closed loop) system which using advanced sensing technology can be set to remove coatings from mechanical drills and cutting tools – stopping the cleaning process once the total coating removal is achieved. A lively discussion about wavelengths and pulse durations followed to answer the questions of throughput and heat input.

After a tea/coffee break and a chance to visit the 12 exhibitors in the foyer, Clive Grafton-Reed from Rolls Royce Aerospace talked about paint removal from an end-user perspective. Clive discussed how researchers at Manchester University investigated several different laser types before selecting the source, and how the degree of cleaning can be measured using the “water break method” and how to avoid “over cleaning” using an acoustic feedback mechanism for which a patent has been applied. Leo Sexton of Laser Age gave a comprehensive round up of applications that have been successfully demonstrated with a large number of videos showing the cleaning process on different components. Ioannis Metsios from Andritz Powerlase presented improvements in paint rust or oxide removal rates with the goal of achieving the flexibility and commercial viability desired by heavy industries like ship repair. Louse Partridge of SPI Lasers showed the specific product enhancements for paint and rust removal as well as the interesting application of polishing to achieve an enhanced surface finish, particularly of interest on non-flat 3D surfaces.

A buffet lunch allowed the delegates and exhibitors plenty of opportunity to network and some time to ask questions or make new introductions. After lunch a second talk from ALT, this time from Zheng Kuang, covered the use of laser cleaning of painted high speed trains, in particular aimed at reducing the possibility of spark generation – a critical issue when using flammable material with fine particulate sizes. David Gillen of Blueacre Technology talked about the investigative work he had carried out looking at outdoor cleaning of bricks, tiles and architectural stoneware for use in homes, gardens and buildings to remove soot and moss. David Lawton from Lasermet discussed the implications for laser safety of working with hand held or robot carried laser cleaning heads – and the legislation and supervision required. Finally, hosts FANUC made a presentation on their range of robots and laser solutions and introduced the site prior to the factory tour. A large number of delegates stayed for the factory tour and feedback on the day was very positive.

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SOURCES AND SYSTEMS

LASER 2000 LAUNCHES BLUE LASER MODULE

Laser 2000 recently launched its blue fibre-coupled laser module AO-150, by Nuburu. Blue light has a number of advantages over infrared lasers in materials processing and 3D printing, such as greater absorption, higher resolution, and increased processing speed.

A large number of non-ferrous metals, such as copper and yellow metals, have up to 20 times greater absorption in the blue region of the electromagnetic spectrum compared to the infrared region.

Blue light can also focus to a significantly smaller spot (up to five times smaller) than infrared light. This improvement on the resolution, combined with greater absorption, provides better control of the processing window and increased processing speed.

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BYSTRONIC'S SHEET AND TUBE CUTTING

Sheet metal working equipment manufacturer, Bystronic, has introduced a new rotary axis for processing tube on its ByStar Fiber flat-bed laser cutting machine, which offers up to 10 kW of fibre laser power. The new equipment enables users to switch between sheet and tube processing in a few simple steps. The factory-fitted rotary axis, together with a retractable tailstock, enables tubes from 30 mm to 315 mm in diameter and in a variety of lengths to be machined. The operator inserts the tube either from the outside through a hatch in the ByStar Fiber's housing or directly into the machining area through the sliding door along the side. Unloading of cut parts is similarly rapid.

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HIGH POWER ADDITIONS TO COHERENT'S RANGE

New, high power ultraviolet (355 nm) and green (532 nm) additions to Coherent's AVIA industrial nanosecond laser family extend and improve the performance of microprocessing applications in microelectronics, photovoltaics and related industries. AVIA ultraviolet lasers are used for cutting flex substrates and thin printed circuit boards (PCBs) where higher lateral resolution (i.e., precision xy features) are a critical consideration. AVIA green lasers are used for scribing films, drilling holes and slots, and cutting flex substrates that efficiently absorb green wavelengths, including certain PCB substrates, semiconductors, and photovoltaic components.

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PRODUCT NEWS

LASERCUBE AVAILABLE FROM TLM LASER

Manufactured by IPG, LaserCube is a flat bed cutter which is the ideal cutting tool for metals, including mild steel, stainless steel, aluminium, copper, brass and exotic alloys. Ideally suited to smaller part sizes, prototypes and smaller production runs, the LaserCube provides the most cost-effective capacity addition and lowest cost of ownership of any professional laser cutter. The system is ideally suited to applications within the Aerospace, Medical and Automotive sectors and is available from TLM Laser.

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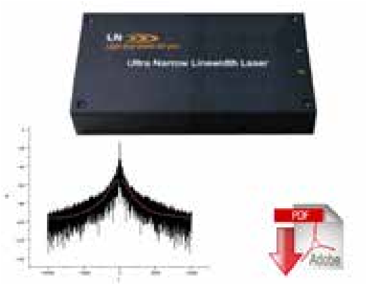
www.tlm-laser.com

LATEST ADDITION TO THE ELUXI LASER RANGE

The LN-UNNL is a 1550 nm ultra-narrow line-width fibre laser and is the latest addition to ELUXI's laser range. The newly designed ultra-narrow optical fibre filter guarantees the single frequency feature of this fibre laser.

Additionally, the temperature control technology and vibration-proof structure reduce the impact of external temperature changes, vibration and shock to maintain a stable single longitudinal mode output and prevent mode hopping. The output power of the monochromatic ultra-narrow line-width fibre light source is up to 50 mW, with additional options available.



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ANCILLARIES

NEW LASER DEFLECTION UNIT FROM RAYLASE

RAYLASE has enhanced its AXIALSCAN-30 laser beam deflection unit with a digitally controlled high-speed Z axis. High-precision positioning of the laser process is guaranteed. The linear translator module offers minimised power loss and minimised heat development. This reduces drift values significantly. It also eliminates the need for cost-intensive water cooling. Scribing, cutting, perforating, welding and drilling are all natural applications for the unit, as are micro-material processing, the processing of textiles and moving parts, and 3D applications.

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SIGMATEK RELEASES NEW TUBE CUTTING SOFTWARE

SigmaTEK Systems, a CAD/CAM software company, has released the latest version of their automated tube-cutting software, SigmaTUBE X1. The latest release offers new features and significant improvements which are a result of SigmaTEK's on-going commitment to delivering elegant, effective software through continuous innovation.

SigmaTUBE helps tube fabricators complete mission-critical work. It is a complete tube cutting solution for 4, 5 and 6-axis cutting machines that automatically processes and programs entire assemblies.

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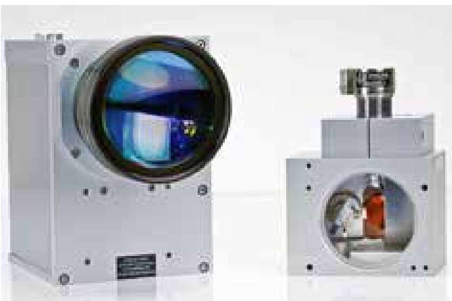
SCANLAB: MORE PRECISION FOR AM

SCANLAB GmbH is rounding out its tried-and-proven intelliSCAN product family. The soon available intelliSCANse 20 and 30 scan heads are systems with 20 and 30-mm apertures for a larger working field.

Their integrated digital encoder technology ensures highest dynamics along with high resolution and long-term stability. These factors make the systems especially interesting for applications such as 3D printing, micro-structuring and micro-processing.



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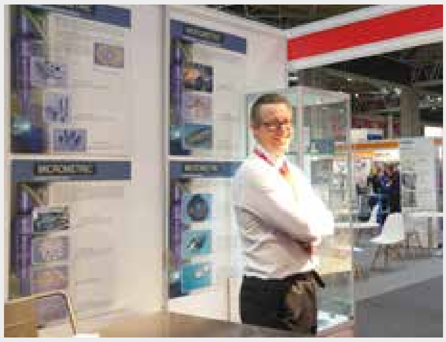
ADVANCED ENGINEERING 2017 IN PICTURES

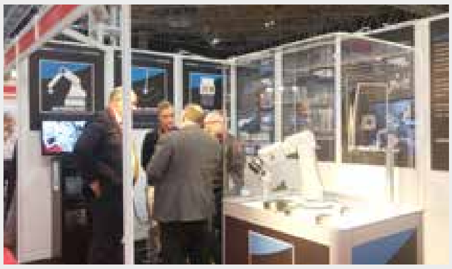
AILU notched up a first at Advanced Engineering 2017, where 13 AILU members formed the Laser Manufacturing Hub at the NEC, Birmingham. The AILU team joined members for the 2-day show on 1 & 2 November.

Day 1 started well, with a good attendance at presentations by Dave MacLellan (AILU), Jon Blackburn (TWI) and Chris Sutcliffe (University of Liverpool/Renishaw) but the show seemed rather subdued in the afternoon. Things picked up considerably on Day 2 with many more enquiries, interesting conversations and a general buzz around the Hub. Spurred on by this increase in interest Dave had discussions with the event organiser about increasing the size of the Hub next year and improving it's layout and position. If you are interested in finding out more or securing a stand please contace Dave (dave@ailu.org.uk).

Following are a selection of images from the AILU Hub and from member stands in the vicinity.



Micrometric



Cyan Tec

AILU

TLM Laser

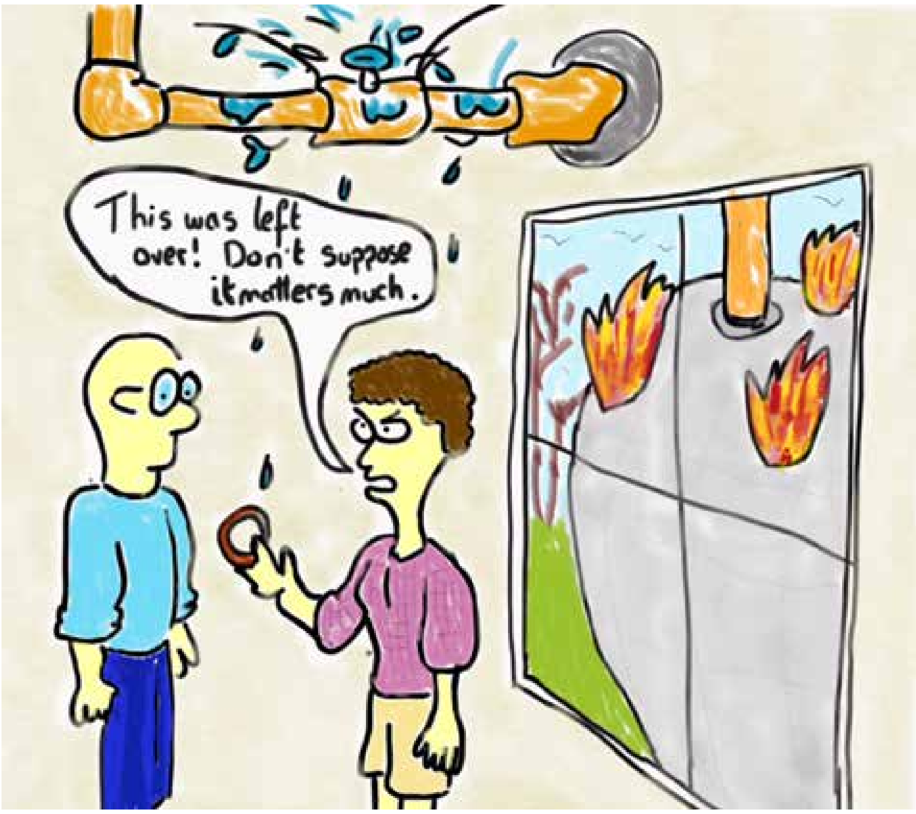
Laser Lines

Carrs Welding

Laser 2000

Renishaw

KEEPING COOL ...



Having worked in the laser industry and before that in power electronics, I have learned that high capacity power supplies and laser sources have to get rid of a lot of heat. Not only that, but if you remove the cooling from them, you can have a sudden and catastrophic failure with or without an accompanying flash, bang or fizzling sound. One of the early frustrations of direct diode systems was that the inherent reliability experienced in the telecoms industry didn't translate to diode laser systems life – largely as a result of micro-channel cooling and the erosion and corrosion caused by the cooling water.

Most people will remember well the failure of the Space Shuttle Challenger in 1986 when it was decided to proceed with the launch even though the temperature was 20 degrees colder that day than previous launches and below the safe design limit of some of the critical O-rings. Recently, I think in the context of global warming, I spotted an image of a placard saying "At the start of every disaster movie there's a scientist being ignored". Just think about Jurassic Park…

Fortunately, laser component failures are usually inconvenient and not life-threatening. Nevertheless, the engineer in power supply design faces the challenges of removing heat and stopping things from "going bang". During my own early career we had the habit of using "water fuses" as a way of reducing the cost of failures. I guess that modern-day development labs would not allow such a thing – basically a thin copper wire is stretched between 2 terminals and submerged in a large plastic water container. The fuse works because when it reaches a certain temperature, the water around the wire boils and the cooling effect of the water is removed – making it melt. Each strand carries around 25 Amps so it is possible to make multiples of 25 by using 2 or 3 strands. Should something fail, the fuse blows with a fairly loud bang and a blue flash visible from a few metres away. It also makes you jump!

On one afternoon, in the power electronics lab, there was a professional photographer taking some shots of another piece of equipment with 2 or 3 stand mounted flash guns. Unfortunately, several times I was about to attach a probe at the same moment he triggered the flash. I had to go over and explain to him that it was making me jump and not good for my nerves – eventually he agreed to give me a 3…2….1 count-down, which overcame the issue.

Modern laser systems are much more efficient and reliable, but it is surprising how many failures are ultimately caused by a poor cooling design or poor air filters allowing dust or particles to get inside sensitive electronics or optics, causing normal conditions to be compromised – resulting in a fault. It doesn't matter how many places you monitor and measure or how expert your software is. Indeed the O-ring can still be a weak link in the chain when trying to seal around hot optics with cold water cooling. The moral of the tale might be that small and uninteresting parts of the system can be the most important – and temperature is one of the most important things to control.

Dave MacLellan
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WOULD YOU LIKE TO WRITE FOR 'THE LASER USER'?

We are looking for new content to make The Laser User more interesting, relevant and entertaining to read.

If you would be interested in contributing to the magazine, we would love to have your input and we will do our best to use your words and high resolution images.

To submit content contact cath@ailu.org.uk

We need:

- Press releases
- Business news
- Technical articles
- Observations
- Anecdotes
- Case studies
- Interviews
- Tips and tricks

AILU WORKSHOP

Presentations, Exhibition, Networking

LASER MANUFACTURING OF LIGHTWEIGHT STRUCTURES

23 NOVEMBER 2017

International Digital Laboratory,
Warwick University

Programme

08:30	Registration, refreshments, exhibition
09:15	Introduction
09:25 - 10:45	Session 1
Laser joining developments for light-weighting	Sullivan Smith, TWI
Fibre laser joining next generation alloys and dissimilar materials for automotive body-in-white and powertrain applications	Mark Thompson, IPG
Lightweight design software for Additive Manufacturing	Luke Ambrose, Materialise
IR, Green and UV Lasers enhance manufacture of lightweight and composite materials used in automotive	Ioannis Metsios, PowerLase
10:45 Refreshments	
11:15 - 12:45 Session 2	
Remote laser welding of Al alloys	Darek Ceglarek & Pasquale Franciosa, University of Warwick
Plastic laser welding for car door panels	Sergio Saludes Rodil, CARTIF, Spain
Laser joining of titanium	Bryan Humphreys, CAVAT
ATI's technology strategy for UK aerospace	Edward Andrews, ATI
Roadmapping the future. Understanding low carbon technology trends	Jon Beasley, APC
Opportunities and support for enhancing innovation	Louise Jones, KTN
12:45- 13:45	Lunch
13:45 - 15:05	Session 3
Use of lasers for joining plastics and thermoplastic composites	Ian Jones, Laserweld Plastics
Laser processing tools and sensor technology for lightweighting applications	Markus Kogel-Hollacher, Precitec, Germany
Dissimilar materials joining using non-laser techniques	Andre Oliveira, NSIRC
15:05-15:30 Refreshments	
15:30-16:15 Tour	
16:15 Departure	

For more information go to www.ailu.org.uk/events

DATE	EVENT	LOCATION
23 November 2017	AILU WORKSHOP *LASER MANUFACTURING OF LIGHTWEIGHT STRUCTURES*	Warwick University
27 January - 1 February 2018	SPIE PHOTONICS WEST	San Francisco
9-13 April 2018	MACH 2018	NEC, Birmingham
5 - 7 June 2018	LASYS 2018	Stuttgart
25 -29 June 2018	LASER PRECISION MICROFABRICATION (LPM 2018)	Heriot-Watt University, Edinburgh