LASER SOURCES & BEAM DELIVERY: LATEST TECHNOLOGY IMPROVES EFFICIENCY
Cover image: Laser brazing automotive steel. A three core beam delivery (Tri-focal) fibre optic provides a main spot and two satellite spots for improving the quality of brazing hot-dip zinc coated steel which is widely used in automotive applications, especially in roof joining and boot/trunk-lid joining. The 2 leading spots are smaller and lower power to remove the coating at the edge of the seam, the centre spot has the main power and is 6x larger diameter to melt the brazing wire.

Image courtesy of IPG Photonics
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FIRST WORD

Setting up my own business has reinforced to me the importance of networking and growing the number of connections that really know who you are and what you do. In this case I am not talking about LinkedIn, although that is an excellent way to keep in touch and maintain your network, rather I am talking about the people you perhaps meet once per year or once every 2 years at events, exhibitions and conferences.

Personally, I find events like Laser World of Photonics in Munich are ideal in this respect, although I have learned that too many members of the laser material processing community appear to live in one kind of “ivory tower” or another, with a tendency to move in the same circles and a lack of hunger for expanding contacts or making new introductions. In particular, there seems to be a limited amount of mentoring and supporting of the next generation going on, and this is something that ALLU wants and needs to help with.

On the one hand we have the growing inter-connectedness that keeps us in touch with the world 24 hours a day, and on the other hand we are so busy being bombarded with communication that taking time out to meet face-to-face needs to be intentional.

At recent ALLU events we have developed and used a standard feedback form, and I have been encouraged to see that at every event there are several people who state that they have made 5 or more new contacts. Let me recommend to you the best opportunity to catch up with existing contacts and meet new ones, and that is ILAS 2017 on 22-23 March...

Why not take the opportunity to meet your peers, make new connections, listen to new information and extend your supply chain or find new collections? You might find a new employee, a new employer, a partner for a project or a competitor you can learn from. All ALLU events have extended breaks and lunchtimes where the most important part of the day often unfolds. See you next month at lunchtimes where the most important part of the ALLU events will be the networking and socialising.

As I write, the UK Industrial Strategy has been given some air time and I am certainly optimistic that Photonics in general and Laser Processing specifically are in a good position to benefit, think Industrial Digitisation and how lasers might play into that field. Keep an eye out for the Industrial Strategy Fund announced towards the back end of last year. Our colleagues at the Photonics Leadership Group are doing a good job keeping tabs on the action and I encourage you to take a look at their website now and again www.photonicsuk.org.

The new All Party Parliamentary Group in Photonics that I mentioned last time has now been formally approved and will be chaired by Carol Monaghan MP, a strong and active supporter of photonics in the UK. I reiterate again that laser processing is already listed as a potential topic for discussion by this group and I am happy to help channel any suggestions and ideas you might have through the Photonics Leadership Group.

So our flagship event ILAS (22-23 March 2017) is now occupying the ALLU team 24/7 and they have done an excellent job in bringing together a very impressive program of talks and networking sessions. I really do encourage you to register and attend ILAS.

The venue is fantastic, the people incredible and the opportunity to learn new things second to none. I am looking forward to seeing as many of you as possible at ILAS in March and I trust you will enjoy the magazine in the meantime.

Ric Allott
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PRESIDENT’S MESSAGE

Welcome to the winter edition of The Laser User. I say winter, but judging by the sunshine streaming through my window today I am feeling encouraged that perhaps spring is on the way, it only in small steps. Last time I mentioned the US election date was fast approaching and who knew what would happen, and well, there we go, another “surprise” result. We shall have to see over the next few months what this all means for us and our industry. There appears to be a little more clarity on Brexit but I fear the waters are still turbid and our crystal balls somewhat hazy.

Why not take the opportunity to meet your peers, make new connections, listen to new information and extend your supply chain or find new collections? You might find a new employee, a new employer, a partner for a project or a competitor you can learn from. All ALLU events have extended breaks and lunchtimes where the most important part of the day often unfolds. See you next month at lunchtimes where the most important part of the ALLU events will be the networking and socialising.

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Ric Allott
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SHARP COMMENT

Early in January I attended the meeting of the UK Photonics Leadership Group (PLG) in London (as mentioned in Ric’s column above). It was good to see that our particular branch of photonics, laser materials processing, was well represented by Ric and Duncan Hand as well as myself. A range of topics were discussed, with a general theme of ensuring that the Photonics sector gained its fair share of government and other support, and to recognise the cross-cutting and enabling nature of the photonics sector.

The PLG Chief Executive, John Lincoln, talked of the efforts put in to establish an All-Party Parliamentary Group (APPG) on Photonics. It was also interesting to gain an insight into how these groups work, and their potential to influence government policy. Its official purpose is “To raise awareness of the photonics industry, recognise the impact it makes on the UK economy and its potential for future economic growth.”

Some of the outcomes of the government’s recently-launched UK Industrial Strategy will be to identify industry strategy challenges, to tackle these by funding business-led R&D activities, and to encourage business and the research community to seek solutions.

The challenges are being developed as I write, and recently I found myself at a well-attended meeting in Liverpool where business leaders and academics worked through a collection of challenges, identifying priorities and where necessary suggesting some changes to these issues. The Liverpool meeting was one of about 9 being held around the country with around 100 delegates attending each. In the short term the aim is to identify those challenges that should become the subject of some form of funding competition in the next financial year. And while laser processing or even photonics were not explicitly highlighted in the challenges under consideration, manufacturing was being well supported, and laser processing could certainly provide components to a successful project addressing such manufacturing problems.

This illustrates the lobbying that is needed to ensure that the government, BEIS, and other agencies are aware of the importance of photonics, and our own part of this, laser processing. And while the result of this lobbying may at times seem to have fairly minor direct impacts, without it there might be no impacts at all. The connections with the current PLG and APPG will ensure that the government and other agencies will have sight of these outputs and see the impact and strength of the UK in the field of laser materials processing.

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OBITUARY: PETER THOMPSON

It was with great sadness that we learned of the recent death of Peter Thompson, a very well-known and loved member of the laser community with a long career in laser material processing. Peter died, aged 69, following a cardiac arrest on January 4th, 2017. At his side, were his wife Pam and sons Lee and Marc.

Peter was born in Blackpool, the eldest of three sons, and held degrees in electrical and mechanical engineering. Starting his career with Compton Parkinson, then moving to Lucas Aerospace, he spent most of his working life living in Rugby, where his laser career started at Lumonics (JK Lasers). There he worked on applications development over a period of 10 years where, among numerous career highlights, he worked on laser pulse shapes for drilling (which resulted in a patent) and developed the ground-breaking process of drilling cooling holes in aerospace engine components for Rolls Royce during the 1980s.

Peter moved on from Lumonics to start his own firm, aptly named Laser Experience, offering his laser material processing application experience to many other organisations (too numerous to mention all of them) around the world including Micrometric and Microkerf in the UK, Lastec in Switzerland, and Prima Power Laserdyne in USA, where he held the position of Technical Director for many years until he retired recently to spend more time in Rugby with his family.

In a career spanning 40 years, Peter Thompson had a no-nonsense approach to laser material processing and was able to achieve the best results in the shortest time when facing a new or challenging application. Largely unsung, he was a modest person who was not concerned with selling himself – his reputation and referrals by word-of-mouth spoke for themselves. He devoted his time to trouble-shooting laser processes, training operators and engineers and turning his hand to whatever he could. He also contributed many technical articles and spoke at several laser conferences worldwide.

Peter enjoyed motor sport, as well as being a keen aviator who had his own pilot’s licence and would fly around Europe combining business and pleasure. On one occasion apparently, after the French Grand Prix he was observed to fly himself away from the circuit in his chartered plane ahead of the planes carrying most of the drivers. He also once flew to a Laserdyne customer in France with Clive Grafton-Reed, having figured out it was cheaper for him to rent a light aircraft and fly down rather than get commercial flights, rent cars etc. They flew from Coventry to a very small airfield near the customer’s site. On radioing the tower, Peter received no response, so checking everything was clear landed without further ado. On checking with the tower, the controller said, “You looked like you knew what you were doing so I left you to it”. When it was time to leave, the owner of the shop asked when the return flight was. Peter replied “when we get there” and explained the details. The owner was so impressed he insisted on driving them to the airfield, helped them wheel the plane out and waved them off.

Terry VanderWert, president of Prima Power Laserdyne said, “Peter was not only a colleague, but a close personal friend of my family. He spent many days and nights living at our home when he was working in the USA for extended periods. Even today, my wife Joy, our children and granddaughters speak of the great times they had with Peter. My wife often tells the story of frequently picking up Peter at Minneapolis airport with our 70-pound dog, Ranger, riding along. On one occasion, Ranger was so happy to see Peter when he arrived that he crawled onto his lap and rode that way in the front seat of the car. Peter seemed genuinely honored by the dog’s affection which was a tribute to Peter’s caring and warm personality. The ride together became a regular ritual for both Peter and Ranger.”

Mark Barry, Vice President of Prima Power Laserdyne, reflected on the cordial working relationship he had with Peter Thompson over many years by saying, “Peter was more than a colleague to me and to most people who had the pleasure of meeting and working with him. Peter had all the time in the world for people that sincerely requested his help. Even during his too short “retirement” he was available to those seeking his advice and help. His wonderful family and all who knew him in the industry will miss him.”

Martin Sharp, Liverpool John Moores University writes: “I joined Lumonics in 1987 and Peter taught me most of what I know about processing with pulsed YAG lasers and was undoubtedly an expert in laser drilling. I know many people who worked with Peter over the years, and the thoughts were all very much the same, we had lost not only an expert in the field, but one who would happily pass that knowledge on, and help people get the best from laser processing and drilling in particular. He will be missed and I remain grateful for all he taught me.

With thanks to Mark Barry, Terry VandeWert, David Gattward, Clive Grafton-Reed, Martin Sharp and others for their reflections.
This recent workshop at Heriot-Watt University attracted a broad audience from industry and academia to listen to the international line-up of speakers from the USA, Netherlands, Germany, and the UK.

The presentations included three from laser companies, namely Coherent, IPG and Lasertel, each addressing their quite different technologies and applications whilst also considering the importance of beam delivery and beam shaping. Daryl McCoy from Coherent discussed their fibre-enabled commercial ultrafast laser technology, that uses mode-locked fibre seed sources. He went on to describe example applications of these systems, including glass cutting and flexible electronics.

Stan Wilford from IPG meanwhile focused on the delivery of nanosecond and longer pulsed fibre lasers using optical fibres, beam switches, and also the use of multiple fibres to create more complex patterns at the workpiece, with some interesting laser welding applications. Devin Crawford from Lasertel provided details of their high power diode laser technology and how this makes use of laser-machined optics from Powerphotonic (see below) to provide the highest possible beam quality. The applications of these diodes are wide ranging, not only in manufacturing but also in defence, medical and imaging. From a manufacturing standpoint these lasers are used both as high power pump sources for other high power lasers (e.g. where higher beam quality and/or shorter pulses are required) and directly for processing materials e.g. in Additive Manufacturing.

Somewhat lower on the TRL scale three ‘future laser technology’ talks were presented, providing details of some potential commercial technologies of the future. Jacob Mackenzie from University of Southampton demonstrated the use of a high power laser process (pulsed laser deposition) in the manufacture of new designs of high power lasers, in order to target key missing parameter sets: 1ns, 10 kHz, 10 mJ; and 0.5-1 ps, 1 MHz, hundreds of μJ. Daniel Esser from Heriot-Watt described work to address other key missing laser parameters for manufacturing, in this case high power 2 μm ultrafast and short-pulsed lasers. Jonathan Phillips from STFC meanwhile described a truly monster laser system, DiPOLE, capable of generating pulses >100 J. Whilst this is a highly specialised system with many applications in cutting edge physics and engineering, there is also potential to develop related technology for laser shock peening applications.

The other four talks concerned different aspects of laser beam delivery. Björn Wedel of Photonic Tools described their work to develop industrial fibre beam delivery systems based on micro-structured optical fibres capable of delivering the very high peak power and high average power (>100 W) ultrashort (picosecond) pulsed laser light, being provided by the latest commercial ultrafast lasers. Lars Penning of Next Scan Technology provided details of the challenges in (and their solutions to) manipulating the beam of a very high repetition rate (~1 MHz) laser to provide uniform processing whilst avoiding unwanted thermal effects. Adam Brunton from M-Solv described the use of scanned mask imaging, a technique the company have developed to provide both the resolution and throughput normally associated with a high running cost excimer laser system, but using a frequency tripled Nd:YAG system. Matthew Currie of Powerphotonic described the company’s bespoke refractive beam shaping technology (itself laser-manufactured) that has applications in high power diode lasers (see Lasertel, above) and directly in manufacturing applications such as welding and Additive Manufacturing.

The workshop was supported by an excellent small exhibition, with good interactions over lunch and coffee breaks, and many attendees also took the opportunity to visit some of the relevant research laboratories at Heriot-Watt. Many positive comments were received about the workshop, including the high standard of presentations and number of new contacts made.

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A €45M PARTNERSHIP
STFC’s Central Laser Facility and scientists from the Czech Institute of Physics are working together on a new “Centre of Excellence” for the industrial exploitation of new laser technology.

The €45 million venture is co-funded by the European Commission and the Czech Ministry of Education, Youth and Sports and will be one of the first projects to be funded under the “Widespread Teaming” programme within Horizon 2020.

The project will further laser development based on the needs of high-tech industry and support the transfer of STFC know-how in effective cooperation with companies.

The new Centre of Excellence will be based at the HILASE facility near Prague. HILASE incorporates advanced solid state laser systems that are ideally suited to high-tech industrial applications, opening up new processing techniques for surface hardening, semiconductor processing and micro/nano-machining, for example.

A PIONEERING 1 KW LASER

The “DiPOLE 100” - a fully diode pumped nanosecond solid state laser (DPSSL) designed and constructed at STFC’s Central Laser Facility (CLF) at Rutherford Appleton Laboratory was delivered under contract to the HILASE Centre in the Czech Republic. In mid-December 2016 it achieved its full design performance, operating at an output energy of 100 J per pulse at 10 Hz (1 kW).

John Collier, Director of the CLF, said “This result is a vital milestone that moves the performance of high peak power lasers beyond the limits of conventional flash lamp pumping, pointing the way forward to important new applications in surface engineering, materials processing, advanced imaging and fundamental science.”

Tomas Mocék, Head of the HILASE Centre, said “This achievement is truly world leading and fully justifies our confidence in choosing DPSSL technology as the driver for applications-oriented RTD. My HILASE and CLF colleagues and I are looking forward to further successes as the system moves into the operational phase.”

POWERPHOTONIC PARTNERS PRECITEC

PowerPhotonic has announced an exclusive partnership with Precitec to supply beam shaping optics for high-power industrial laser cutting applications. Novel optics have been co-developed with Precitec to improve the cutting performance in high-power industrial processing machines.

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www.powerphotonic.com

AILU MEMBERS TAKE TWI INDUSTRIAL MEMBERSHIP

SPI Lasers and Carrs Welding have recently become TWI Industrial Members. Industrial Membership of TWI is for companies involved in materials joining and engineering technologies. TWI helps member companies by undertaking project work, training and providing advice and consultancy in joining, engineering and allied technologies.

For further information go to:
www.twi-global.com/membership

ATTICA ACQUIRED BY JAMES BALDWIN LTD

Jim Fife and Lee James (Joint Managing Directors) are pleased to announce the acquisition of Attica Components Ltd by James Baldwin Ltd. Attica thereby joins Metalite Ltd and Taylor Aerospace Ltd in a highly successful group of precision engineering companies.

The Directors believe that the acquisition will provide the opportunity for Attica to grow as a UK-based manufacturer supplying the medical device, electronics, petrochemical and instrumentation industries with precision miniature tube, machined and laser processed parts. Business operations will continue from the North Leigh site, with all existing management and employees retained. Plans for 2017 include improvement of the Quality Management Systems and significant investment in new laser processing and CNC machining capability.

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CYAN TEC SYSTEMS LTD

As part of its ongoing growth and expansion into new markets, Tec Systems Ltd has recently changed its name to Cyan Tec Systems Ltd. The company continues to supply high-tech laser systems and industrial automation, and is expanding its portfolio to include digital inkjet printing systems which is where the Cyan name comes from.

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JENOPTIK RECEIVES INNOVATION AWARD

Together with the American automotive supplier Magna Exterior Inc. and the automotive manufacturer GM, Jenoptik received the “SPE Automotive Innovation Award” in the category Process, Assembly and Enabling Technologies during an official ceremony. The award honors the unique process for robotic laser cutting and welding of class A exterior fascia. The previous production technology for producing class A exterior bumpers was replaced by high-tech laser machines from Jenoptik.

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For further information go to:
www.twi-global.com/membership
AMPLITUDE’S NEW FEMTOSECOND LASER
Amplitude extends its industrial femtosecond laser product range with the new Yuja, a versatile high energy laser especially designed for quality cutting and drilling of delicate materials. Delivering more than 100 μJ pulse energy, with a flexible repetition rate from 100 kHz to 2 MHz, the Yuja is ideally suited for the high speed drilling of various geometries that require micrometer-range accuracies.

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ROFIN’S HIGH QUALITY DIODE LASER
At EuroBLECH 2016, ROFIN’s fibre-coupled multi-kilowatt diode laser was presented in the new HQ version (High Beam Quality) for the first time. With an output power of 4 kW and a 600 μm fibre, the DF 040 HQ complements the DF Series as a cost-efficient tool for keyhole welding in addition to brazing and surface treatment that require higher beam quality.

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QUANTUM CASCADE LASERS FROM ELUXI
ELUXI now supplies mirSense lasers - off-the-shelf quantum cascade lasers for industrial and defence applications. Also in the mirSense range is the multiSense laser-based spectrometer for multi-gas device development.

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AEROTECH’S GALVO SCANNER CONTROL
The Nmark® GCL controls Aerotech’s AGV series scanners resulting in industry-leading settling times, long-term thermal stability, and micron-level tracking accuracy due to advanced features such as full state feed-forward, 200 kHz servo rates, and look-ahead-based velocity control.

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BYSTRONIC INTRODUCES NEW 10 KW FIBRE LASER
Bystronic has introduced a new 10 kW fibre laser to increase the speed with which sheet metal parts can be produced, the previous maximum power being 6 kW. Compared with the industry-standard 4 kW fibre laser, the 10 kW source increases cutting speed by up to a factor of four. The greatest speed benefits are achieved in material thicknesses between 3 and 12 mm, although the high power also enables productive cutting of sheet thicknesses up to 30 mm. This will be of benefit to manufacturers that rely on fibre laser technology for all their cutting requirements.

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LVD ADDS NEW MODELS TO PHOENIX LASERS
LVD has expanded its fibre laser portfolio with the Phoenix FL 4020 and Phoenix FL 6020, two new laser cutting machines designed to handle sheet dimensions of 4000 x 2000 mm and 6000 x 2000 mm respectively. Available in 3, 4 and 6 kW versions, the new Phoenix models offer high versatility as all-round machines able to deliver first-class cut quality in both thin and thick materials in standard steels, as well as non-ferrous materials and process large sheets quickly and economically.

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META COMPACT LASER SYSTEM FROM COHERENT

The META family of laser machine tools from Coherent is a small form factor yet flexible CO2 based laser system for cutting and engraving. Available in 150 W, 250 W, 400 W and 1000 W power levels and inclusive of both CAM and HMI software, the META family delivers productive performance for a broad variety of applications. These machines are useful tools in R&D labs, universities, job shops, and production facilities. The CO2 laser enables the ability to easily set up jobs to cut and engrave metals, non-metals (e.g. acrylic, wood, plastic) and films such as biomedical substrates.

META COMPACT LASER SYSTEM FROM COHERENT

TRUMPF’S LASER SYSTEM FOR WELDING GLASS

A femtosecond laser system by TRUMPF facilitates economical, high-quality glass welding. The system replaces conventional joining processes such as gluing, with the advantage that no additional materials that are susceptible to evaporation or embrittlement are required. This reduces costs and increases durability as well as the stability of the seam.

Glass components that were previously glued to each other can now be economically welded with high-quality results, as TRUMPF has demonstrated in its own production of laser light cables. Until recently, the lids of the protective caps for the laser light cables were glued on. Now, lasers are used to weld them on.

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CONTACT: Roy Harris
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www.coherent.com

TRUMPFF’S LASER SYSTEM FOR WELDING GLASS

ACSYS INTRODUCES NEW PIRANHA MODEL

The new PIRANHA®μ PICO is equipped with a latest generation of a picosecond laser. Optionally, the modular design of the system also allows configuration with a femtosecond laser or a current fibre laser system.

The PIRANHA®μ PICO is also capable of being equipped with a second laser source as a dual laser system. With a footprint of less than 2.5 m² the PIRANHA®μ PICO is extremely compact and flexible.

ACSYS INTRODUCES NEW PIRANHA MODEL

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Aerotech’s New Nmark AGV-HPO GALVO SCANNER

Accurate • Stable • Flexible • Scalable • Economical

Accuracy
Single-digit micron accuracy
Stable
Consistent performance over long operating periods
Configuration Flexibility
10 to 30 mm apertures at multiple laser wavelengths
Ease of Integration
No wiring interference with laser beam delivery
Economical
Open-frame design reduces cost
ANCILLARIES

NEW AM MODULE FROM RAYLASE

The Additive Manufacturing process depends on accurate control of the laser source, as well as deflection and focusing of the laser beam. The AM-MODULE from RAYLASE takes this process to a higher level and is based on the SUPERSCAN IV and SUPERSCAN V laser deflection units developed by RAYLASE with ultra-light mirrors, and powerful galvanometers with 100% digital control, enabling dynamic beam guidance and high accelerations. The absolute repetition accuracy in the high-performance version is 2.96 μm.

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NEW SOFTWARE TOOL FROM CONCEPT LASER

With the CL WRX Control software the five most important process settings can be viewed and varied without any additional costs to LaserCUSING machine purchasers.

The five factors that can be fine-tuned are: laser power, scan speed, trace spacing, spot size and offset to original contour. These configuration options enable the user to achieve application-based optimisations for a perfect result.

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HAMAMATSU’S NEW INFRARED DETECTOR

Hamamatsu Photonics K.K. has developed an uncooled InAsSb (indium arsenide antimonide) photovoltaic detector that offers high-speed and high-sensitivity detection of infrared light in the 3 to 11 micron wavelength range.

This new device extends the upper limit of sensitivity of Hamamatsu’s InAsSb detectors from 8 microns to 11 microns, which will enable users to measure molecules that absorb longer wavelengths of light and therefore analyse more compounds with a single device.

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NEWS FROM II-VI INFRARED

POLYGON SCANNER MIRRORS INTRODUCED

II-VI Infrared now offer precision polygon scanner mirrors. New applications in the healthcare, aerospace and automotive industries require scanning systems operating at higher powers and increased speeds. II-VI Infrared’s polygon scanner mirrors address the facet geometry, flatness and roughness requirements for next generation fast scanning systems.

NEW OPTICS LINE

The II-VI Infrared Division of II-VI Incorporated has announced the introduction of a new line of optics designed for 10 kW class fibre and direct diode lasers. The next generation fibre and direct diode lasers have surpassed 10 kW output power as they broaden their range of applications in metal cutting and welding, as well as additive manufacturing. II-VI Infrared’s improved lens quality enables these lasers to maintain high reliability at high power levels and over long periods of time.

INTELLIGENT APP FROM SCANLAB

SCANLAB GmbH, experienced in developing and manufacturing high-quality scan solutions, now simplifies scan system selection via its SCANcalc calculation app.

This free iOS/Android app lets users select appropriate scan heads for their specific requirements at the touch of a button. For example, the app instantly calculates scan system spot size and precision at a definable focal length. SCANcalc also integrates other helpful functions, formulas and a terminology glossary.

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www.scanlab.de

POWERPHOTONIC’S NEW LASER BEAM SHAPERS

PowerPhotonic announced the launch of a new family of axicon array beam shapers for use with multi-mode lasers. Capable of handling very high peak and pulsed power (<20 kW CW) with very high efficiency (>98%), the arrays can be used to generate ring-shaped spots, a typical requirement for materials processing applications. An axicon is a specialised type of lens that has a conical surface. These beam shapers have an array of axicons typically arranged in a hexagonal pattern, which in combination with a collimated multi-mode input beam form a ring-shaped spot. By precisely controlling the angle of the axicon and the tip radius, PowerPhotonic can adjust the ring diameter, the level of extinction in the centre of the ring, and the width of the ring.

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MBA LAUNCH ONLINE PARTS SHOP

MBA Engineering has introduced its new online parts shop. Opening the doors to all Kimia, Bystronic and other laser users their parts and accessories are now available at the click of a button.

MD Bradley McBain said “I wanted the online shop to look great, be easy to use and allow purchasers a quicker and simpler way of ordering their laser consumables and spare parts.”

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CASE STUDIES

CONCEPT LASER PROVIDES PARTS ON DEMAND

Jung & Co. Gerätebau GmbH, a specialist in stainless steel components, relies on Additive Manufacturing to ensure that spare parts for beverage filling plants are available quickly. Flexibility of the filling plant is important due to the different sizes of bottles or cans that need to be filled. Food law dictates that cleanliness and hygiene are the most important requirements. This is why stainless steel is one of the preferred materials used in the industry. Production rates of 40,000 – 80,000 bottles or cans per hour are not unusual.

An additive solution can mean great freedom of geometry, coupled with a CAD design that suits the process. In addition, parts or entire assemblies can be created as a one-shot design. If the filling company requires a new can filler valve, the components can be manufactured promptly using CAD data and fitted at the customer’s premises so that the downtimes are promptly using CAD data and fitted at the customer’s premises so that the downtimes are drastically reduced.

Additive Manufacturing has been added to the CNC manufacturing range at Jung & Co. since 2015. AM currently takes place on an M2 cusing Multilaser machine with 2 x 400 W laser sources from Concept Laser.

SIMPSON TECHNOLOGY PROVIDES EXPERTISE

When precision fabricator Fitzpatrick’s UK needed advice to purchase a fibre laser they turned to Simpson Technology for help. Mark Fitzpatrick, MD of Fitzpatrick’s UK, said “We have spent over £250 K on laser-cut parts every year for the last 5 years. It has been a strategy that has served us well. When quoting work we would “add our bit on” to the laser price and do what we do best which is the fabrication. In the early days of laser cutting we were making good money on existing parts because it saved us so much time. That margin has diminished each year as laser-cutting has become the ‘norm’.*

Mark decided to buy a laser system and asked Scott Simpson, MD of Simpson Technology, for advice. Mark said, “I like to buy kit that gives us the edge. When Simpson Technology first mentioned the Mitsubishi I thought it would not be able to compete with the big brands but I did a lot of research. I found out that Mitsubishi are a world leader in machine tool manufacturing and that they have been involved in making lasers for decades, one of their main markets being the USA. I went on many forums in the USA and the most common word used to describe the Mitsubishi laser was reliable.”

The new fibre technology represented the leap in technology that Mark Fitzpatrick was looking for to give a competitive edge. The rest of his concerns were answered by Simpson Technology because “they know the product like the back of their hand but not only that, Simpson Technology also understood the laser process and the little important things that other suppliers couldn’t explain. Good products sold by honest people is always a winning combination in our experience”.

TRUMPF TRUPRINT 1000 INSTALLED IN UK

LPW Technology Ltd develops, processes and supplies cutting-edge metal powder solutions for Additive Manufacturing (AM) The company has taken delivery of a new TRUMPF TruPrint 1000 metal AM machine. The first machine of its kind in the UK, the TruPrint 1000 is set to enhance LPW’s AM R&D capabilities.

TRUMPF’s TruPrint 1000 is a compact machine for the production of small metal components by laser melting on a powder bed. Also known as laser metal fusion (LMF), the process works by using metal powder and laser light, quickly producing components of virtually any geometric shape. This plug-and-play machine majors on intuitive operation, high process speeds, a generously proportioned process chamber and a complementary MobileControl App for remote operation and monitoring. The machine is expected to add important capability to LPW’s well-established metal powder expertise.

The TRUMPF TruPrint 1000 will form part of a new metal AM lab that is being created by LPW. “We are delighted that the TruPrint 1000 enables us to showcase and continue to develop PowderLife, our metal powder lifecycle management system that controls risk and traceability for manufacturers,” says Mr Ian Brooks, LPW’s Applications Manager.

“The future lies in understanding data throughout the AM process, from beginning to end, linking together all the processes and data that affect the powder and ultimately, reproducible build quality,” he adds. “Our PowderSolve software package, as part of PowderLife, adds insight into this process. In conjunction with TRUMPF, we are looking to enhance our knowledge and specification of AM process parameters.”
With the recent launch of 10 kW fibre laser cutting technology by Bystronic, has the last possible reason to buy a CO₂ laser cutting machine, namely to process thicker materials economically, been removed? This question is addressed by Jon Till, joint owner of Accurate Laser Cutting, Oldbury, which has recently become a fibre-only subcontractor.

June 2015 saw the introduction of fibre laser cutting at the company, with the installation of a 6 kW BySprint Fiber with 4 m x 2 m capacity. A 10 kW ByStar Fiber for processing sheet up to 3 m x 1.5 m has just been added, the first machine of such high power to be installed in the UK.

The first point Mr Till makes is that 6 kW is the practical limit for CO₂ laser cutting, as higher power would burn the optics. Even power sources below this limit take their toll on the lenses and mirrors, leading to frequent downtime to clean them, expensive periodic replacement, and production downtime while all this is carried out.

CO₂ laser machines are difficult to maintain, not only due to the condition of the optics but also the tendency of the optical path to move out of alignment, necessitating time-consuming correction if quality is to be maintained. At the best of times, especially on larger machines with a 4 m x 2 m bed and above, accuracy in one corner of a sheet is very hard to replicate at the diametrically opposite corner, entailing lengthy operator intervention to try to correct the discrepancy.

Mr Till bemoans the fact that one can spend hours identifying a problem with a CO₂ laser cutting machine when quality or speed of cut declines. First recourse is to tweak the parameters at the control, followed by taking off the head and cleaning the lens, and perhaps swapping the lens at a cost of £270 each time, typically eight times per month, if it is not maintainable by the operator. Mirror alignment is then scrutinised and adjusted if necessary.

Finally, if none of that works, it may be that the purity of the assist gas is too low, which is detrimental to beam quality. This is very difficult to predict and is the last thing that is checked, yet nevertheless will typically happen twice per year.

Fibre laser cutting, on the other hand, avoids all of these problems. The solid state technology directs the beam down a fibre optic cable, so there is no wear and tear on conventional optics and the laser beam does not degrade. Machine running costs are significantly lower, as electricity consumption is 60% less for a fibre machine, and there is no need to use expensive nitrogen, helium and carbon dioxide as laser assist gases.

Mr Till finds that productivity is dramatically increased using fibre. He says, “Our new 10 kW ByStar Fiber cuts 1 mm mild steel at 60 m/min, faster than our old CO₂ laser was able to position its head (50 m/min) to start cutting. The speed and hence productivity advantage when processing thinner sheet is around three times, reducing for thicker materials.

“Clean cutting is also much quicker, where nitrogen rather than oxygen is used as the cutting gas to prevent oxidation of the cut edge. When processing 5 mm mild steel, for example, the fibre machine is four times the speed of our last CO₂ machine.”

Cutting capacities of the 10 kW fibre laser source (and the 6 kW ByLaser CO₂ source in brackets) are 25 mm (25 mm) in mild steel, 30 mm (25 mm) in stainless steel and 30 mm (16 mm) in aluminium, so CO₂ technology has already been overtaken. A fibre laser copes with cutting reflective materials much better than CO₂, hence the superior performance in aluminium. For the same reason, the 10 kW fibre can cut 15 mm brass and 12 mm copper, materials that CO₂ cannot process at all without the risk of back reflections damaging the optics.

Mr Till’s final analysis brings in the costs of the two machines: typically £750,000 for a 10 kW fibre laser cutting centre and £500,000 for a 6 kW CO₂ machine. In his opinion, the higher capital investment in fibre laser cutting is easily outweighed by the extra expense of running a CO₂ machine and the latter’s very low residual value towards the end of its life.

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There are currently a number of challenges around Unique Device Identification (UDI). Manufacturers face the challenge of finding a physical space on small implants such as plates or screws, to place a 2D code and the human readable content. A UDI starts with a minimum of 14 characters and, based on current readability requirements, a UDI 2D code would have to be at a minimum 5 mm by 5 mm. It is clear that this in itself may be a challenge on some devices or implants.

Having achieved the requirement to produce the UDI code, it is essential to be able to validate these tiny marks before the product is transferred to the next production stage or released to market.

Validating these marks is as critical as their placement. There is however a well-established automation principal which is to perform as many operations as possible whilst you have control of the part.

This concept has been embraced by FOBA within their holistic vision-assisted laser marking process called HELP (Holistic Enhanced Laser Process). This combination of pre-mark verification, followed by laser marking and then post-mark verification in a closed loop is unique as it is among the only known fully integrated commercial products that delivers all the above in a simple fully integrated user interface.

Within the medical device manufacturing industry this solution delivers a clear advantage from its uniqueness and performance over existing technologies. Having all of the required processes in a closed loop not only ensures compliance with the latest UDI regulations, but generates cost savings by eliminating false marking which in turn can cause expensive parts to be scrapped.

Although the HELP concept was driven by the increasing regulatory demands of the medical sector, any manufacturer who is producing parts with a number of variants and a requirement to marking them and validate the content could benefit from the capabilities of HELP. As an example, safety critical aerospace or automotive parts would fall into this category.

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OpTek Systems was formed in 2000 at the peak of the dot-com boom by Mike Osborne, Laurie Forrest and Mike O’Key – who had previously worked at AEA Technology, Culham. Initially focused on the new applications of laser cleaving and laser lensing for terminating optical fibres, OpTek achieved rapid initial growth with tools for optical fibre termination within the telecoms industry. Now the applications and markets for laser micromachining addressed by OpTek are more diversified and the largest sector is medical, with aerospace, electronics and energy industries also strong contributors.

In recent times the company has doubled in size every 3 to 5 years and now employs close to 100 staff globally, with turnover around $20 million, having manufacturing facilities in the UK, the USA and China with a joint venture in Korea. With over 85% of their tools being exported from the UK, OpTek has won the Queen’s Award for Enterprise: International Trade twice, once in 2011 and again in 2016 in recognition of strong export performance.
Q. How do you see the market for laser micromachining in the UK?

The economics of producing very high volume devices has driven the manufacturing of micro-electronics to the territories that offer lowest labour costs. Although the UK has skills in developing the applications and building the tools for laser micromachining, the bulk of the resulting equipment is exported outside the UK. So there is a good opportunity for creating employment in the UK for highly skilled engineers and also the opportunity to export UK-built or UK-designed equipment. Laser processing is, by necessity, separated from operator interaction which makes it eminently “automatable”, meaning that manufacturing in higher cost-base regions becomes attractive again – and I very much look forward to witnessing more evidence of this in future!

“Manufacturing in higher cost-base regions becomes attractive again”

Q. You offer a subcontract service and turnkey systems, how do they balance out?

I would say that our strength derives from the development effort and expertise put into optimising micromachining performance. Often the quality and precision achieved in laser micromachining are as much a result of application know-how and advanced optimisation as they are about the performance or specification of the laser source. Most of our revenue comes from selling the tools to manufacture with lasers, although we are happy to provide a micromachining service in the initial stages as volumes ramp up and before the point is reached where the process is brought in-house on the client’s own tool, or one placed with one of their contract-manufacturers.

Q. With fibre lasers replacing many other laser sources, do you still see a solid future for CO₂ laser applications?

We use everything from UV/excimer through to the far IR wavelengths and, since we are not a source manufacturer, we have the freedom to choose the right wavelength and pulse duration from the major global laser manufacturers. In the fibre cleaving and lensing applications, we have discovered that the CO₂ laser is still the best choice, and precision is not an issue as we can achieve and guarantee shape tolerances of <250 nm when required - I am not aware of many (indeed any?) other laser micromachining systems that routinely operate to tolerances of 1/40th of the laser wavelength, and often in less than perfect operating environments. The lasers used are competitively priced and reliable, but the stability comes from the system design as all laser sources, of whatever type, exhibit some variability and inevitably show ageing effects. Of course, we are also using nanosecond, picosecond and where needed femtosecond laser sources. As in the example cited above, OpTek philosophy is to employ novel optics, applications know-how, and process feedback to achieve the desired result with the most cost-effective (and industrially-proven) laser type. Most of our applications to date have not required pulses shorter than a picosecond, although femtosecond systems have represented a not-insignificant fraction of the company revenues in recent years, and this is a growing trend. Since many of our systems are installed in locations distant from our factories, we are always keen to ensure that our installed systems require minimal maintenance and achieve high uptimes in 24/7 manufacturing.

Q. What are some of the material processing challenges you face?

Customer material! We are doing micromachining, typically with tolerances of the order of 1μm. Demonstrating the required features slowly, on perfect samples, well-presented in a laboratory environment may be the first step. But the real world brings other challenges. Sometimes the challenge is in the volumes and speeds – for the medical market we have machines processing half-a-million parts per shift, in other markets we have systems processing one-million miles of material per year. In another medical application, each part needs 200 million 5μm holes to be produced in 15 minutes (that’s 250,000 hole per second to save you doing the maths). Other times the challenge is material properties – for example handling 1.2 μm polymer film reel-to-reel without stretching it. And sometimes it is feedstock variability – for example in adjusting the laser processing to make parts which physically vary by 100 μm behave electrically as though they were accurate to 2 μm. Of course, making the desired feature is generally only part of the story – you need to prove that what you have done is good. And implementing checks and inspection at these dimensions and at these rates can be as much of a challenge as carrying out the machining in the first place and often results in us developing new and unconventional on-line inspection techniques.

Q. Tell us about your recent Queen’s Award.

It was fantastic to be recognised for a second time for our growing export sales, in the year of the Queen’s 90th birthday. Especially, events like this give an opportunity to publicly celebrate success and for the whole team to share in the reward and recognition of the hard work over many years that so many people in the company have undertaken.

“Solutions need to be embodied in properly-engineered tools”

Q. What difference did funding from InnovateUK make?

OpTek has always invested heavily in developing capabilities that meet up-coming customer requirements. Being a privately owned company ensures a tight focus on near-term prospects, but places a limit on longer-term horizons. OpTek, and indeed the UK in general, is capable of generating good technical solutions to production challenges. However, if we are to reap the commercial reward for this ability, these solutions need to be embodied in properly-engineered tools which are immediately available at the time they are needed. This is where InnovateUK can, and has, helped, to the demonstrable benefit of both employment and export earnings.

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COMMUNITY ARTWORK ON DISPLAY

MIDTHERM LASER MAKES AN IMPACT

Improving the appearance of the urban landscape and seeing your work on display are positive outcomes for many subcontactors. Midtherm Laser has been involved in several recent projects involving laser cutting of steel. The main image (above) show a seating area in Crombie Country Park, Angus, where large butterfly profiles were cut from 10 mm mild steel. Another seating design can be seen below, where large head profiles were cut from 15 mm mild steel. Coloured glass was added and the seat is in position at Everest Community College, Basingstoke.

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CIRRUS LASER CUTS COPPER TREE

Cirrus Laser have recently been commissioned by metal sculptor Paul Badham to assist him in producing several large palm trees made entirely of copper. The trees were for the British make-up artist, Charlotte Tilbury, to use throughout her stores. Each of the 6000 individual leaves were cut with a fibre laser. This method has to be used due to the reflective properties of the material.

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CARRS INCREASES AEROSPACE ACTIVITY

Welding for the aerospace industry requires an extremely high level of precision. For products to work under a zero gravity atmosphere, air tight joints are essential, making laser welding the perfect choice.

Carrs are currently involved in welding part of the reaction wheels used by New Space Systems. These wheels are increasingly popular for use in satellites and spacecraft for full three-axis manoeuvrability and accurate speed control. The wheels have been exported to the USA, Indonesia, China, Spain, Germany and Italy.

Contact: Phil Carr
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A design for oddly shaped panels with slots was cut from 5 mm mild steel. Once assembled in the correct order and erected on the river Tay Promenade in Dundee, the resulting pictures could be seen (below).

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CUTTING TECHNOLOGIES AID PAVILLION DESIGN

Cutting Technologies has teamed up with designer Clementine Blakemore to help create a stunning pavilion at the newly relocated Design Museum, London. 6 mm aluminium was laser cut to provide connection pieces which secured the ‘double curve’ hyperbolic paraboloid beech roof.

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Satellite reaction wheel

For the 4th year, Carrs Welding has passed aerospace audit AS 9100 which allows it to weld components that fly above the skies. Carrs now welds various sensors, active sticks for planes and reaction wheels for space. The company works with Esterline, Ametek Aerospace and Defence, BAE Systems, Curtiss-Wright and New Space Systems amongst others.

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2016 is already long gone and many would say should soon be forgotten. It was a very odd year. We lost many well-loved celebrities, and we have seen a huge shift in the political landscape especially in the UK and USA, with the EU referendum vote and the American Presidential election. So although there are plenty of reasons for many of us to try and forget 2016, for us in the Job Shop industry the mood is more mixed. For most of us it started slowly but the general consensus, amongst the AILU committee at least, was that the second half of the year picked up and was better than the first.

I don’t believe Brexit or Trump can actually be credited with any of these slight indications of positive economic change, but more likely companies and individuals can wait no more. Often I notice that our orders slow during the build up to holidays or political events and we had two pretty big ones in 2016. Perhaps people are worrying about the implications, “should we really place that order or sign that contract… until we know which way this vote is going to go?” Then after the vote they make the decision. The problem here, unlike the annual budget for example, is that we all have very little idea how these political changes are actually going to change anything. Apart from:

- The NHS is definitely not going to get the £350 million/week the Leave campaign promised, which is making lots of people very angry.
- Trump really is trying to do at least some of the crazy things he promised in his election campaign, which is making even more people angry.

Theresa May has finally released her Brexit plan, which may as well say “I plan to try and have my cake and eat it” as she attempts the impossible task of trying to keep Joe Public happy by pushing the button to leave the EU whilst trying not to totally ruin the country’s economy.

We love to hate the Banking sector but it’s pretty obvious that it is the UK’s main source of income. For example, according to the BBC, 80% of all foreign exchange transactions in the EU are carried out by UK banks. That accounts for trillions of pounds per day. PER DAY! You don’t need to be a mathematician to work out that if you can earn a tiny percent in fees for carrying out those transactions, it probably works out to quite a lot of money. However, currently the UK can carry out these transactions due to “passporting” as we are in the EU, once we leave that may well be a different story. The other EU counties have lusted after this profitable industry for a long time and guess who gets to decide if we can keep that “passporting” ability if we leave the EU, I’ll give you a clue, not us.

So if the worst does happen and the economy does start to suffer, the one thing I can be absolutely sure about is that the Government will revert back to its default plan B motto, ‘manufacturing will save the UK economy’. The problem with that, as we all know, is that unless the economy is in crisis, the Government totally ignores UK manufacturing. There is little to no investment and they are totally unsympathetic to our struggles. That may well change very rapidly in the next year or two and some of you may be thinking that might sound like good news, but we may all have to work a lot harder and smarter to make enough widgets and what-nots to collectively compensate for any significant reduction in the Banking sector. The events of 2016 will be felt for a long while to come, whatever happens there will be many challenges but most importantly, opportunities in the coming years.

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The University of Nottingham boasts an array of laser research themes across fundamental optics and source generation through to laser research in support of materials science and manufacturing technologies. With a strong focus on innovation in support of industrial activity, a number of dedicated teams are pushing the capabilities of the laser for a wide range of applications.

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www.nottingham.ac.uk

ADVANCES IN CUTTING, DRILLING & CLADDING

Dr Katy Voisey’s work concentrates on understanding the fundamentals of laser based manufacturing processes including cutting, drilling and cladding as well as exploring, and extending, the capabilities of our 2 kW fibre laser. Connor Jones is currently using high speed filming to characterise rear ejection during laser drilling. Hasanain Atiyah is investigating energy losses during fibre laser cutting. Other current work includes investigation of dilution measurements in laser cladding, fibre laser drilling of non-metallic materials for devices and the influence of pulse train shaping on fibre laser drilling. Recent publications can be found on eprints.nottingham.ac.uk. Aspects of this work will be presented at ILAS 2017.

PULSED LASER ABLATION

The inverse problem in Pulsed Laser Ablation (PLA) consists of defining the control parameters, in particular the 2D beam path (position as a function of time), to arrive at a prescribed solution (freeform surface). The inverse problem is usually solved for this kind of process by simply controlling the dwell time in proportion to the required depth at each single pixel on the surface. A new approach is developed under the EPSRC project EP/K02826X/1 by using a discrete adjoint optimisation algorithm and non-straight passes. Several tests are performed to validate the proposed method and the results show that tracking error is reduced typically by a factor of two in comparison to the pixel-by-pixel approach and the classical raster path strategy with straight passes. The tracking error could be as low as 1-2% depending on the complexity of the target surface.

ADDITIVE MANUFACTURING

Lasers-based Additive Manufacturing methods form a large part of activity within the Additive Manufacturing and 3D Printing Research Group at Nottingham. This group of over 100 members was founded in the early 1990s and is one of the oldest 3D printing research groups in the world. Prof Tuck and Dr Goodridge lead selective laser melting (for metals) and selective laser sintering (primarily for polymers) activities respectively. Currently researches projects in AM processes are focusing on materials, design/optimisation and modelling. For more information visit the group’s webpage (www.nottingham.ac.uk/research/groups/3dprg).

SPATIALLY RESOLVED ACOUSTIC SPECTROSCOPY

In support of research efforts to develop in process monitoring methods for additive manufacturing researchers at Nottingham have made use of optical coherence tomography and a novel laser ultrasonics method; Spatially Resolved Acoustic Spectroscopy (SRAS). Developed by Dr Steve Sharples at Nottingham this method has been used with great effect to detect typical defects which emerge during SLM of high value materials including nickel and titanium alloys. The team which also includes materials scientists and NDT specialists is tasked with incorporating this technology into a next generation machine tool.

Dr Richard Smith demonstrates SRAS to the next generation of laser users

LASER CLADDING & DIRECT METAL DEPOSITION

Researchers at Nottingham maintain an active interest in laser cladding and Direct Metal Deposition for the creation and repair of components fabricated from high value materials. Recent highlights include the development of new material feedstock blends which allow for in-process alloying and functional grading of part properties. First contributions to the literature have been made in TiAl, TiB2 which serve to create robust engineering components and coatings. Our IPG 2 kW fibre laser is equipped with an environmental chamber and can operate with both powder and wire feeding simultaneously. This places us in a unique position to develop bespoke nanocomposite claddings with superior properties for extreme wear, high temperature oxidation and corrosion along with the creation of functionally graded components which exhibit multiple material properties within a single volume.
### WEDNESDAY 22 MARCH

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<tr>
<td>08:00 - 09:00</td>
<td>Registration</td>
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<tr>
<td>09:00 - 09:15</td>
<td>Welcome to ILAS 2017</td>
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<tr>
<td>09:15 - 10:15</td>
<td>Plenary Presentations</td>
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<td>10:15 - 10:45</td>
<td>Refreshments &amp; Exhibition</td>
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<td>10:45 - 12:15</td>
<td>Additive Manufacturing 1 (Powder bed)</td>
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<td>Macro Metal Cutting</td>
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<td>Surface Engineering</td>
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<td>12:15 - 13:45</td>
<td>Lunch (sponsored by IPG Photonics) &amp; Exhibition</td>
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<td>13:45 - 15:00</td>
<td>Additive Manufacturing 2 (Wire &amp; powder feed)</td>
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<td>Ultra-Short Pulse Applications</td>
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<td>Drilling</td>
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<td>15:00 - 15:30</td>
<td>Refreshments &amp; Exhibition</td>
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<td>15:30 - 17:00</td>
<td>Marking &amp; Ablation</td>
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<td>Ultra-Short Pulse Applications continued</td>
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<td>Safety</td>
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<td>17:00 - 18:00</td>
<td>Poster session with wine reception</td>
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<td>Symposium Dinner &amp; Awards</td>
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### THURSDAY 23 MARCH

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<td>10:30 - 12:00</td>
<td>Macro Welding 1</td>
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<td>Precision Micro-Fabrication</td>
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<td>Cleaning</td>
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<td>12:00 - 13:30</td>
<td>Lunch (sponsored by IPG Photonics) &amp; Exhibition</td>
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<td>13:30 - 14:45</td>
<td>Macro Welding 2</td>
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<td>Sources &amp; Beam Delivery</td>
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<td>Additive Manufacturing 3 (Repair &amp; manufacturing)</td>
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<td>Refreshments &amp; Exhibition</td>
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<td>15:15 - 16:45</td>
<td>Micro Welding</td>
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<td>Surface Engineering Research</td>
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<td>Additive Manufacturing 4 (Wire &amp; powder feed)</td>
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<td>16:45</td>
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<td>Welcome to ILAS 2017 - Ric Allott, AILU President</td>
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<td>Anti-counterfeiting security markings for metal goods - Wyman Ultrafast Limited.</td>
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<td>Material processing at imaging plane using dynamic, ultrashort shaped laser beam - Loughborough University</td>
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<td>Laser metal deposition in a commercial environment - Paul Goodwin</td>
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<td>Underwater laser cutting for decommissioning purposes - Al Khan, TWI</td>
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<td>High-speed imaging of the powder-bed and shield gas during metal PBF additive manufacturing</td>
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<td>Effects of 40kHz ultrasonic vibration on gas delivered powders for side feed cladding</td>
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<td>Fire suppression systems for the protection of automated laser machinery</td>
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<td>How active laser guarding systems work to protect personnel and machinery</td>
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<td>09:00</td>
<td>Plenary 1: Hybrid subtractive and additive femtosecond laser 3D micro machining</td>
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<td>10:00</td>
<td>Plenary 2: The magic of nonlinear ultrafast laser processing in transparent media</td>
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<td>Tools for laser welding – take a closer look into successful solutions</td>
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<td>Remote laser welding of aluminium - Stephan Colmer, TRUMPF GmbH, Germany</td>
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<td>Comparison of laser and electron beam welding for safety-critical space applications - Chris Allen, TWI</td>
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<td>Practical application of the power factor model for keyhole laser welding - Sonia Mecio, Cranfield University</td>
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<td>Future nuclear welding developments: the potential and challenges for lasers - Neil Irvine, University of Manchester</td>
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<td>Multi-positional laser welding of stainless steel, nickel based alloy and titanium alloy - Tony Pramanik, TWI</td>
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<td>Laser-laser hybrid welding for joining of challenging materials - Wojciech Suder, Cranfield University</td>
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<td>Laser narrow gap welding of thick section dissimilar metals of 40 mm thickness - Tapio Vaisto, University of Manchester</td>
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<td>Thermosonic micro-welding with laser-generated ultrasound - Malcolm Gower, Imperial College London</td>
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<td>Dissimilar metals joining using nanosecond pulsed fibre lasers - Adam Rosowaki, SPI Lasers</td>
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<td>High speed laser welding of aluminium and copper dissimilar metal joint for electrical connections - Choon Y Kong, TWI</td>
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<td>Study of laser metal interaction for pulsed nanosecond fibre laser - Julio Coroado, Cranfield University</td>
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<td>16:45</td>
<td>Weldability of 316 stainless steel - Neil Main, Micrometric</td>
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## EXHIBITORS

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## SUPPORTING ORGANISATIONS

![cbm logo](image1)
![CLP logo](image2)
![EPIC logo](image3)
![KTN logo](image4)

![MWT LiM 2017 logo](image5)
![MTA logo](image6)
![PHOTONICS leadership group logo](image7)
The variety of industrial laser sources available today opens up a wide range of efficient laser material processing applications. Laser users can use either ultrafast (fs, ps) or short pulse (ns) lasers with the emission wavelengths spanning from near IR to UV, offering end users and integrators an opportunity to optimise their process in the wavelength windows around 1064 nm, 532 nm or 355 nm. Contemporary ultrafast laser material processing systems are made from three key building blocks; laser, scanning head and adaptive optics. For an efficient and cost effective laser machining system, high throughput, high reproducibility and low running costs are paramount and adaptive optics are a key enabling element in the system.

Spatial light modulators (SLMs) or deformable mirrors are two leading technologies deployed for waveform control. Deformable mirrors can offer superior damage thresholds (several J/cm²), however they show poorer stability which reduces reproducibility. In comparison, spatial light modulators can offer good damage thresholds (in excess of 0.2 J/cm²), excellent resolution and an unmatched stability over extended periods of time (>10 hours).

For a decade, the Laser Group at the University of Liverpool have had a long-standing collaboration with Hamamatsu Photonics UK and have exploited their liquid crystal SLM technology for research on laser materials processing. This has involved both static and dynamic wavefront and polarization control for a range of applications. Hamamatsu’s phase-only devices have been at the heart of this effort, combined with high peak power ultrafast laser systems. These reflective SLMs have been able to handle both high peak intensities >10 GW/cm² and average powers in excess of 10 W without external cooling so that industrial applications of SLM technology, especially dynamic DOE, are now appearing. The remarkably high damage thresholds result from the use of superior, highly reflective dielectric coatings providing reflectivities R > 98% and average power handling due to careful thermal management. With appropriate Computer Generated Holograms (CGHs), SLMs can split the incident beam to many parallel beams with optimum fluence, or shape an incident Gaussian beam to any desired intensity distribution to optimise laser-surface processing in specific applications. They can also dynamically modulate polarization in real time, a very useful tool in precision material surface patterning.

The latest generation of SLM devices are designed to extend power handling boundaries via a re-engineered thermal management and integrated copper heatsink enabling liquid cooling. These technological advances are purposely integrated to enable handling of average laser powers, in the range exceeding 100 W, for an accelerated industrial deployment.

Examples of high throughput processing at University of Liverpool

Ablation of thin film SiO₂ on silicon

High speed opening of back contacts of SiO₂ on silicon wafers for solar cell applications has been developed in conjunction with Coherent Scotland and Oxford Lasers Ltd as part of an Innovate UK project. Energetic, 10 ps, 532 nm pulses with laser repetition rate 100 kHz from a frequency-doubled laser (Coherent Talisker) were diffracted into 16 uniform parallel spots, scanned at a speed of 7.5 m/sec across the wafer. The energetic, 10 ps, 532 nm pulses with laser repetition rate 100 kHz from a frequency-doubled laser were diffracted into 16 uniform parallel spots, scanned at a speed of 7.5 m/sec across the wafer. The energetic, 10 ps, 532 nm pulses with laser repetition rate from a frequency-doubled laser were diffracted into 16 uniform parallel spots, scanned at a speed of 7.5 m/sec across the wafer. Figure 1: High speed fabrication of back contacts on Silicon solar cells (left), contacts with diameter Ø = 8 μm (right)

Micro-structuring of flexible Al/PET

Thin film metal patterning of Cu, Au, Ag and Pt using picosecond and nanosecond solid state and UV Excimer lasers on polymers such as PET, polyimide, PEN and PMMA is employed in the fabrication of displays, RFID antennae, biosensors, photomasks and micro-fluidic devices.

An application of Al/PET patterning is demonstrated in Figure 2 which shows light emission from an ACEL display from a sample of our ps laser micro-structured Al/PET film. A thin, ~300 μm wide rectangular area was scribed, isolating the internal from the external area, Figure 2(a). The sample was then coated with the electro-luminescent layer and a transparent conducting oxide (TCO), acting as top electrode. The finished device, Figure 2(b) produces a large, uniform light source (coated at Brunel University).

Figure 1: High speed fabrication of back contacts on Silicon solar cells (left), contacts with diameter Ø = 8 μm (right)

Figure 2: (a) ps laser patterning of Al/PET to create a rectangular, electrically isolated inner region of dimensions ~30x50 mm, (b) Image of an AC electro-luminescent display created at Brunel from the patterned Al/PET film in (a)
High speed parallel beam ablation of 30 nm thick aluminium on flexible PET was then demonstrated with 8 spot patterning with no damage to the sensitive PET substrate, Figure 3. Patterning rate was ~0.5 cm²/sec using 5 W (200 kHz) of energetic 10 ps pulses from a Coherent Talisker at 532 nm combined with an SLM, type X10468-04 and advanced Aerotech Nmark AGV-14HP galvo combined with Nmark CLS controller. Dynamic patterning was demonstrated using a series of 30 (previously calculated) CGHs producing 5 spots with varying separation, run in real time to create circuit electrode type patterns while synchronised to the scanner motion controller (Nmark-CLS), Figure 4. The scan speed was kept constant at 10mm/s with 10 kHz laser repetition rate, resulting in clean Al film being removed with a continuous line pattern. The region where the electrode dimensions widen had 28 CGHs, applied at 10 Hz, close to the present bandwidth limit with CGH synchronisation.

**Dynamic polarization control using phase-only SLM**

When incident linear polarization is rotated to 45° on the SLM, a phase CGH can then alter both intensity and polarization simultaneously since the electric field component Eₓ, parallel to the liquid crystal director, suffers a variable phase delay relative to Eᵧ. Hence, a CGH with a constant phase (grey level) creates an elliptically polarized reflected beam which can be converted to a rotated linear polarization when transmitted through a quarter wave plate. Dynamic polarization rotation is then achieved by synchronising the CGHs with appropriate grey levels to the laser and beam scan system. Figure 5 shows the experimental set up used to achieve this using a 50 kHz, High Q, 10 ps laser system operating at 1060 nm with Hamamatsu’s X10468-03 SLM.

**Dynamic polarization control with two SLMs**

The use of two SLMs allows for the creation of more complex polarization states - vector beams such as plane wave Radial and Azimuthal polarizations and carrying Orbital Angular Momentum (OAM) with twisted wavefronts in the same experimental set-up shown in Figure 6. Figure 7 shows the phase CGHs required on the SLMs used to create these states, confirming the fidelity of the polarizations. Real time surface micro-patterning with these 4 states was demonstrated by exposing a polished steel sample with this four states, confirming the fidelity of the polarizations.

**Femtosecond laser internal inscription of Volume Bragg gratings in PMMA**

A unique area for femtosecond laser micro-structuring with pulse durations below 200 fs is internal modification of transparent dielectrics for the production of Diffractive Optic Elements (DOEs). Femtosecond laser inscription, initiated by multi-photon absorption has extended the field of micro-structured materials to almost all dielectrics including glasses and polymers. Volume Bragg gratings are used in a wide range of interesting applications such as astronomical spectroscopy, ultrafast laser compressors, wavelength division multi-plexing (WDM), narrowband filters for Raman spectroscopy, line narrowing and stabilisation of high power diodes. We have concentrated on VBG fabrication in polymers such as clinical grade PMMA. Figure 10 (left) shows white light diffraction from 15 μm pitch, 5 x 5 mm high quality VBGs. Diffraction
efficiency in the first order exceeded 95% at 532 nm with 4 mm thickness and fabrication time was approximately 40 minutes.

Line spacing was recently reduced to 2.5 μm, therefore reaching 400 lines/mm and we are now working towards fabricating efficient VBGs with >1000 lines/mm.

Conclusions
Hamamatsu's SLMs have proven to be sophisticated devices for both dynamic phase and polarization control, opening up new areas of research in laser-materials interactions. The development of SLM technology to handle high average powers, which already exceeded average powers of 200 W, will undoubtedly accelerate an industrial uptake of this remarkable technology. As ultrafast laser technology keeps advancing with both higher peak and average powers, many current precision laser micro-machining processes will become much more efficient and cost effective for the end-user. It is highly likely that this will result in entirely new applications, when combining advanced laser sources with Hamamatsu SLM technology.

Acknowledgement
W.Perrie (UOL), would like to thank former Ph.D students of the Laser Group, University of Liverpool for providing some of the images used in this article. He would also like to thank Hamamatsu UK for their continued collaboration.

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Walter Perrie is Senior Research Fellow in the Laser Group, University of Liverpool and visiting scientist to the Photon Science Institute, University of Manchester.
Multi-Joule, multi-hertz pulsed laser systems present a multitude of opportunities for industrial applications, scientific research and medical systems. We at the Science and Technology Facilities Council (STFC), through the Central Laser Facility’s Centre for Advanced Laser Technology and Applications (CALTA) have been researching and developing multi joule amplifiers for a number of years.

High energy laser systems at the Central Laser Facility

The Central Laser Facility (CLF) is located at STFC’s Rutherford Appleton Laboratory (RAL), one of the UK’s premier civilian research laboratories. Its core mission is to provide large-scale research facilities and infrastructures for experiments in pure and applied science by UK academic and industrial communities and their international collaborators. RAL is at the centre of the Harwell Campus, a vibrant and active science, technology and innovation hub. Exposure to this diverse community offers a great opportunity for cross-disciplinary engagement and interactions at the interface of numerous scientific and technical endeavours.

Over the past 40 years, the CLF has developed a dynamic and closely-linked user community that has been served successfully by the two petawatt-class laser facilities (Vulcan and Gemini) and the CLF’s three other facilities (Artemis, Ultra and Octopus), Figures 1 and 2.

DiPOLE 10 J Amplifier

In order to increase the repetition rate of high energy laser systems, a number of key factors have to be controlled, of which cooling of the gain medium is critical. Thermal management of the gain medium can be achieved in a wide variety of schemes depending on the shape and composition of the gain media, the pumping method etc. The scheme developed by scientists and engineers at CALTA is based on cryogenically cooled helium gas. The DiPOLE 10 J Prototype system was constructed as a test bed for a 10 J, 10 Hz cryogenically cooled diode pumped solid state laser (DPSSL) system. The main amplifier consists of four slabs of Yb:YAG gain medium which was cooled with helium gas at 175 K. The gain medium uses longitudinal variable doping concentrations of the slabs to evenly distribute the gain and heat in each slab. A schematic of the amplifier head is shown in Figure 3. The disks are cooled by the helium gas which can be controlled at different flow rates and pressure to maximise cooling efficiency. Laser diodes are used to pump the gain medium at the absorption wavelength. The beam from the diodes is introduced to the amplifier head by the use of dichroic mirrors to allow the transmission of the 1030 nm lasing wavelength and the reflection of the pump beam into the amplifier. The amplifier is seeded with a fibre laser, fibre amplifier, a regenerative amplifier and also a multiple pass amplifier producing 100 mJ at the output. This is passed through the amplifier six times, and each pass is image relayed by a 1:1 telescope. The telescope system has vacuum spatial filters for spatial cleaning the beams in order to stop the production of hot spots; which could cause damage in the gain medium. The DiPOLE system has produced 10 J, 10 ns at 10 Hz (DiPOLE has also been run for 40 hours at 7 J, 10 Hz in a number of greater than 4 hour periods) and importantly the technology used on DiPOLE can be scalable to 100 J, 1 KJ and 10 KJ.

DiPOLE 100 – the next step

Following the successful operation of the DiPOLE 10 J prototype system CALTA secured a contract to deliver a 100 J system to the HI-LASE Centre in the Czech Republic. HI-LASE is focused on development of high-repetition rate lasers and laser systems that will find use in industry, in small – medium scale research laboratories and in the future European large-scale facilities that will be part of the European Research Area (ERA).

The DiPOLE100 amplifier system consisted of a front end with an output of 150 mJ at 10 Hz with a variable pulse width of 2-10 ns, including an arbitrary shape resolution of 0.2 ns. The front end seeds an optimised DiPOLE amplifier system that uses seven passes through the cryogenic amplifier. The output of this was then used to seed a 100 J amplifier with four passes. This amplifier produced 107 J at 1 Hz, 10 ns at the output. The system includes a number of diagnostics to monitor the near and far field of all passes for alignment and uniformity of the spatial beam shape. A novel dark-field technique was implemented that operates interleaved with the active amplification to provide additional machine safety for two cryo-amplifiers. The DiPOLE 100 system was successfully commissioned, then delivered to HI-LASE in the Czech Republic at the end of 2015. We have achieved the design goal of the DiPOLE 100 by running the system at HI-LASE at 102 J and 10 Hz. STFC has announced this achievement by issuing a press release which can be found at this URL.
allowing us to explore the physics and materials methods. At CALTA we have secured funding laser shock peened materials over those treated These results in improved damage tolerance of a depth of 1-2 mm beneath the treated surface. can enable compressive stresses to penetrate to

of the technique using a transparent layer of resistance to fatigue crack growth. Optimisation stress which offers benefits such as improved strain and is left in a state of compressive residual material. The near surface undergoes plastic rapidly expands sending a shock wave into the surface material creating energetic plasma which

5). The laser pulse ablates a small volume of such as gears, turbines and fan blades (Figure

is employed to strengthen engineering materials, apply a technique known as laser shock peening. One industrial use of the multi joule laser is to apply a technique known as laser shock peening. This is a surface treatment by which a laser pulse is employed to strengthen engineering materials, such as gears, turbines and fan blades (Figure 5). The laser pulse ablates a small volume of surface material creating energetic plasma which rapidly expands sending a shock wave into the material. The near surface undergoes plastic strain and is left in a state of compressive residual stress which offers benefits such as improved resistance to fatigue crack growth. Optimisation of the technique using a transparent layer of water to confine the shockwave and a sacrificial ablative coating to amplify the energy absorption can enable compressive stresses to penetrate to a depth of 1-2 mm beneath the treated surface. These results in improved damage tolerance of laser shock peened materials over those treated using more traditional mechanical shot peening methods. At CALTA we have secured funding allowing us to explore the physics and materials science behind laser shock peening using the DIPOLE 10 J platform to probe a variety of engineering materials whilst varying the laser parameters. A newly commissioned laboratory space dedicated to laser shock peening at RAL will help demonstrate the benefits of this novel surface treatment for adding value to UK industry and manufacturing.

Space Debris Removal
There are currently hundreds and millions of space debris fragments orbiting the Earth at speeds of up to several kilometres per second. Space debris can be described as junk from the collection of defunct man-made objects in space and fragments from disintegration, erosion and collisions of satellites. A process known as the Kessler syndrome, is especially insidious because of the domino effect and feedback runaway wherein impacts between objects of sizeable mass spalls off debris from the force of the collision. This could affect useful momentum, shifting the target into an orbit such that it is burnt up in the atmosphere. For a ground-based laser system this would require a kJ laser amplifier with a repetition rate at 10 Hz. A beam accuracy of 0.1–1.0 μrad is required for targeting the space debris, a 1.0 μrad has already been demonstrated using the guide stars for earth based telescopes. The target would need to be continuously ablated for several orbits of the earth. DIPOLE has the ability to

Figure 5 The mechanical properties of aircraft engine fan blades can be enhanced by laser shock peening

Further Applications of Multi Joule, Multi Hertz Laser Systems
A 100 J amplifier running at 10 Hz can be used to pump either an Optical Parametric Chirped Pulse Amplifier (OPCPA) or a Ti:Sapphire based amplifier. With these systems a picosecond/femtosecond temporal source can then be produced to produce high energy electrons, X-Rays, Gamma rays, protons/ions and also neutrons. These multi-modal Laser Driven Sources have many applications, for instance high energy protons can be used in a new class of oncology treatment. High energy X-Rays at 10 Hz can be used to probe deep into engine cavities and freeze-frame high speed moving components. A combination of laser-driven gamma ray and neutron beams can be used to image nuclear waste barrels with unparalleled spatial resolution.

Future projects
Future projects for CALTA include the construction of a second 100 J, 10 Hz amplifier for use at the European XFEL in 2018. This will create high densities of matter which are then probed with the X-Rays from the free electron laser (X-FEL). We will investigate higher energy scaling options to 150 J of the cryogenic amplifier and also repetition rates up to 100 Hz at 10 J. We will look into using chirped pulse amplification for direct production of picoseconds at 1030 nm in addition to pumping Ti:Sapphire amplifier to coproduce femtosecond pulse widths. The future of multi hertz, multi joule amplifiers presents opportunities to discover many new fields of exploration as well giving extra impetus to current areas of research.

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P. Jonathan Phillips is a laser scientist researching high power lasers at the Central Laser Facility in the Science and Technical Facilities Council.

Figure 4: HiLASE 100 J Amplifier; detailing the Front End, 10 J Cryo-Amplifier, 100 J Cryo-Amplifier

www.stfc.ac.uk/news/uk-laser-czech-republic/. The 10 J is currently being used for laser damage testing and other scientific experiments. The 100 J output is also going to be used for various experiments in the next few months, once characterisation has been completed. A layout of the Dipole 100 J amplifier is shown in Figure 4.

Laser Peening
One industrial use of the multi joule laser is to apply a technique known as laser shock peening. The 10 J is currently being used for laser damage testing and other scientific experiments. The 100 J output is also going to be used for various experiments in the next few months, once characterisation has been completed. A layout of the Dipole 100 J amplifier is shown in Figure 4.

Figure 3: Schematic of the DiPOLE cryogenic helium cooled gas, main amplifier concept

Figure 4: HiLASE 100 J Amplifier; detailing the Front End, 10 J Cryo-Amplifier, 100 J Cryo-Amplifier
Cleaning and pre-treatment of the surface of metals is an important prerequisite for a high-quality adhesive bond area. Using the laser process, dirt particles, oxide layers and other contaminations are vaporised, using only laser light.

Laser pre-treatment leaves the metallic surface free of contamination and fully prepared for bonding, without surface damage. Metallic materials can be "modified" within the upper boundary layer, using appropriate laser parameters. This means the surface of the substrate can be modified to meet the requirements of the specific bonding process. By targeted modification of the surface, the corrosion behavior of light alloys can be improved significantly. The substrate actually becomes more resistant to ageing and environmental damage.

**Laser pre-treatment of metals**

The laser light removes oxide layers including superficial contamination from light alloy surfaces. The near-surface zone in the area of typically ~ 1 μm is re-melted within a few nanoseconds, the melt quickly being cooled almost simultaneously. By dissolving the grain boundaries and due to the heat capacity of the part a "quenching" occurs. This results in a new micro-crystalline amorphous and rough boundary layer (adaptive layer) with significantly decreased corrosion behavior. The modification process is automatic when exposed to air without any protective gas. The new passivation oxide layer on top of the melt forms a very stable bond with the adhesive used in the bonding process. Short-term re-melting leads to additional "microcraters" that cause a significant surface enlargement and thus an increased load transmission particularly under shear load.

Combined with the decreasing electro-chemical potential of current aluminium and magnesium alloys, this leads to long-term, age-resistant bonds. The aluminium surface micro-structured by cleanLASER features an increased roughness and passivation of the surface.

**Operating principle**

The laser generates a directed and monochromatic beam of light, focused to a small spot size in order to create a high power density. At the focal point, the intense laser beam is absorbed by the contamination or paint and thermally incinerates or sublimates the target material, i.e. paint or contaminations (see Figure 1). This incineration or vaporisation will, in combination with the resulting micro thermal shockwave, remove the target material as long as the target material is able to absorb the laser energy. The better the target material absorbs the energy, the faster it can be removed.

Colour, chemical composition and thickness of the target layer all have a direct impact on the effectiveness of the process. The removal process automatically stops once a metal substrate is reached, since metal surfaces reflect the laser beam and do not generally absorb the laser energy. The heat transfer into the substrate material can be a critical factor. To minimise this effect, many laser equipment manufacturers use pulsed laser sources. The laser intensity, known as the laser power per spot area is a critical parameter for the heat transfer into the substrate material. Very short laser pulses with a pulse duration of only a few nanoseconds (ns) in combination with a very small focus diameter (less than 500 μm) result in a minimal heat transfer into the substrate material. Under normal operating conditions and with the right process parameters, damage to the substrate material can be eliminated. The heat transfer factor of continuous wave laser systems is much higher and might result in substrate temperatures that will damage the substrate. Test results with a handheld pulsed Nd:YAG laser with an average laser power of 500 W (peak power of over 400 kW) on an aluminium sheet resulted in maximum substrate temperatures of 80° C.

Pulsed laser systems generate laser power levels well beyond the average power of the laser source. A pulsed 150 W solid-state laser can generate a peak pulse power of over 160 kW. This high peak power and the above mentioned beam parameter results in a power intensity removing many target materials with acceptable production rates.

Currently, there are three different kinds of laser sources available for surface preparation works. The main difference is the laser generation and the resulting beam delivery configuration. Respecting the automation and integration possibilities, Solid-state Nd:YAG lasers offer special advantages in automated applications for the Automotive or Aerospace industries for instance.

The operating wavelength of 1064 nanometer (nm) lies within the transmission bandwidth of common optical glass and enables the use of...
fibre optic cables for beam delivery. Fibre optic beam delivery dramatically increases the flexibility of the laser system. Nd:YAG lasers can be used for work on hard to reach areas. Currently, the maximum fibre optic length is 50 metres.

Nd:YAG lasers are nearly maintenance free and very simple to operate. Pulsed systems for surface preparation use, reach average laser power levels of up to 1,000 Watts.

Current application fields for laser cleaning technology

Currently, a wide range of industrial application fields are applicable for cleanLASER surface treatment and cleaning technology (see Figures 3-7):

- Cleaning of metal parts, especially aluminium for subsequent production processes
- Pre-treatment of metals prior to painting
- Adhesive bonding and pre-treatment of aluminium for long term stability
- Welding and brazing preparation
- (Precise) de-coating and ablation of layers for joining or electrical bonding of plated aluminium
- Modification and structuring of (metal) surfaces for enhanced performance

Pre-treatment of components for bonding

Light alloy components, such as aluminium are particularly well suited for laser processing. In numerous studies, it was found that for certain parameters extremely high, especially long-term stable adhesive strength is achieved. Due to the reduced corrosion, the results are up to five times better when compared to chemical processes. The surfaces are residue-free, including oils/greases and oxides, resulting in excellent bonding or welding. If needed, micro-roughness or surface modifications can be produced. The process can be exactly reproduced, both within manual and especially within automated processes.

Conclusion

Advantages of the pre-treatment of parts with the laser are an improved resistance to aging, improved bonding quality, reproducibility, process monitoring and the possibility of integration into existing production lines. The laser deployment can be fully automated using robots or gantry systems where needed. This opens up the opportunity to process large items or large surface areas or indeed cleaning specific smaller areas on the large surface. Furthermore, savings due to the reduction of transport costs are possible due to decentralised cleaning and in-line integration.

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There are, of course, great benefits for the environment due to the laser being a chemical and media-free process and also not forgetting that the energy consumption of a laser is incredibly low, giving excellent cost of ownership figures.

In addition to energy and fuel savings, the elimination of waste cleanup time and the removal/dealing with solvents/chemicals can lead to sustainable environmental relief.

Laser cleaning is carried out precisely and exclusively by light. For this reason there is no need for any cleaning media. The technology is almost maintenance free and is easy to integrate into and/or automate production processes.

Typically, the achieved results and quality would be difficult or sometimes impossible with conventional methods.

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Cylindrical laser micromachining has been a standard means of stent production for some time. Typically, 2 servo controlled stages are used – namely, a rotary axis carried by a linear axis – positioned beneath a fixed laser beam delivered through a co-axial gas assist nozzle. The specific stage choices have gradually developed, beginning with belt- or screw-driven linear and worm-and-wheel rotary stages, and eventually converging on direct drive technology for both axes. While this evolution has offered substantial process time and part accuracy improvements, the basic architecture itself may be approaching its fundamental optimisation limit.

A careful analysis of today's cylindrical laser micromachining systems yields some immediate conclusions:

1. Two established performance metrics are cycle time to produce a single part, and overall form error of the final part. Furthermore, a comparative curve of cycle time versus form error (Figure 1) is a natural parameter to optimise for any given stent-cutting system.

2. Achievable acceleration values are constrained by the moving mass-to-motor force ratio of the linear stage, and (similarly) the rotating inertia-to-motor torque ratio of the rotary stage.

3. All dynamic errors induced in the part arise from changes in axis velocity (i.e. acceleration and deceleration). At constant (or zero) velocity, no dynamic errors occur.

4. Combining points (2) and (3), we may ascertain that as mass-to-force or inertia-to-torque ratios degrade, part throughput and/or cycle times will suffer.

Intervventional cardiac and neural device technology has progressed toward smaller diameter stents, which worsens the cycle time versus form error plot referenced in conclusion (1) above. Smaller stents infer a less favorable inertia-to-torque ratio, as the workpiece holder (typically a precision collet) becomes substantially more significant compared to the inherent inertia of the (presumably smaller) rotary stage. Furthermore, the smaller circumferences of these devices require more rapid acceleration of the rotary stage to maintain the same surface speed on the part as seen by the laser. As detailed above, higher acceleration means larger errors.

A number of new challenges face the medical device manufacturers, including faster throughput requirements, new material introduction and new laser sources.

**Faster throughput**

When a new medical device is first developed, manufacturing costs are not the primary driver. However as a device matures, there is pressure to improve efficiency by reducing manufacturing costs. To achieve this, higher throughput without significant capital expenditure is the goal, though this must never be at the expense of accuracy.

**Novel materials**

Bare metal stents (BMS), based on stainless steel, were introduced as a means of providing mechanical support and preventing artery walls closing up after balloon angioplasty. Stainless steel was substituted by biocompatible shape memory alloys such as Nitinol, which improved stent delivery and expansion within the artery. Although bio-compatible, it was found that BMS could lead to thrombosis and inflammation and new methods to prevent these secondary complications were needed. One method was to coat the BMS with a degradable polymer, releasing combative drugs over time. These so-called Drug Eluting Stents have overtaken BMS as the stent of choice.

A third route is to remove the metal component altogether and make stents from bioabsorbable materials, such as magnesium, zinc or polylactic acid. These materials require non-standard laser cutting techniques to ensure low heat input, high tolerance manufacture.

**New laser sources**

Initially BMS were cut with YAG-based laser systems, which were suitable for stainless steel. The introduction of Nitinol coincided with the increased use of fibre-based laser cutting systems. Fibre lasers could be pulsed at up to 60 kHz, giving finer control of heat input, allowing stent strut width to be decreased even further with sub-100 micrometers widths becoming the norm. Stents typically go through a series of post-processing steps, to ensure that the material is passivated and rough edges are removed. This requirement reduces throughput and increases manufacturing costs.

The arrival of short pulse lasers provided two new advantages for stent production. First, short pulse lasers have lower heat impact on the material, reducing the buildup of surface debris, a major marketing tool for their introduction. That said, there is a lack of evidence that using short pulse lasers reduces post-processing costs. Edges still need to be smoothed through electro-polishing, and given the high cost of short-pulse lasers, a stronger economic argument needs to be made for their widespread acceptance.

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**Figure 1: Peak path following error as a function of cycle time for various Aerotech motion systems**
Second, and more importantly, short-pulse lasers tend to be material-independent and it is now possible to machine almost any medical device material with a sub 10 ps laser source. This is important when looking to machine materials such as polyactic acid, where absorption at 1 μm is non-existent.

One important characteristic of short-pulse lasers that has not been fully utilised in stent manufacturing is the high repetition rates (up to 500 kHz). This factor allows the laser to be moved at high speed, measured in meters per second, relative to the stent while still maintaining sufficient pulse overlap. Traditional stent manufacturing with linear stages is limited by system dynamics and cannot reach these high speeds, limiting one of the main benefits of a short-pulse laser.

Achieving the required increase in overall system dynamics while maintaining part accuracy seems impossible with traditional linear and rotary axes. So, what can be done?

**Advancing stent production technology**

One potential solution lies in new rotary stage design. As workpieces become smaller (or stay the same size, but require multiple processing passes) the rotary axis is typically the limiting factor when compared to the linear stage. A smaller rotary stage with reduced inertia could be devised, or perhaps a different work piece holding strategy from the precision collet mechanisms currently in use. However, smaller holders will not be as stiff, and will have smaller closing surfaces, imparting greater axial and radial errors during clamping and processing. Solving these problems simultaneously seems unlikely in the near future.

Another solution is to devise a fundamentally different strategy for delivering the laser to the part. Instead of using a static “tool” (the laser spot) and moving the workpiece, why not instead-offload some of the required high-speed motion to the “tool”? In other words, consider the use of a high-speed galvanometer system mounted above the work piece, and move the laser beam instead of moving the part. A linear and rotary stage will still be required, but their required dynamics will be much less, essentially eliminating their contribution to the dynamic error. We can accomplish this in at least 2 different ways.

### Sub-pattern processing

In Sub-Pattern Processing, the complete stent pattern is broken into each of its individual sub-patterns which are then processed individually by the 2-axis galvanometer. The linear and rotary stages are only used to move from one sub-pattern location to the next. Once at the correct location, the associated sub-pattern contour is called and the galvanometer cuts out the shape.

This galvanometer can move the laser beam at very high speed, cutting the material in a multi-pass process. Given the high scan speed and multi-pass cutting strategy, heat input is minimised and strut thicknesses of 20 μm can be obtained, see Figure 2.

As all the acceleration associated with cutting is performed when the linear and rotary stages are stationary, it is mainly the dynamic response of the galvanometer mirrors that will affect accuracy, and given the low mass of these mirrors, accuracy is optimised.

There are many advantages related to the sub-pattern process. However, these advantages come tradeoffs that need to be considered. The use of a galvanometer inherently allows off-axis cutting to be performed, which can give functional benefits to many medical devices. However for stent manufacturing, it will mean that strut walls will have variations in taper. This strut taper, which means walls are no longer orthogonal, may cause issues for stent placement, which without testing could have either a positive or a negative effect.

### Constant rotation galvanometer scanning

A second method of employing galvo scanning technology for stent fabrication is to convert the stent vector pattern into a bitmap image (for example, Figures 3 and 4) and raster scan the laser, issuing pulses at the appropriate pixel sites along each pass [1]. Post processing of the image converts the bitmap into an array of points (black-and-white or grayscale) which define the pixels.

As the beam is scanned back and forth axially along the stent, the rotary stage rotates unidirectionally underneath to continue exposing the entire circumference of the stent to the scanning beam spot. One axis of the scanner (major axis) performs the linear scanning while the second axis (minor) compensates for the rotation of the workpiece during a single raster line (that is, making sure that the line is not diagonal on the workpiece.) “Mark-on-the-fly” features native to some modern advanced motion controllers facilitate synchronisation between the rotary stage and the minor scan axis.

The linear axis does not move at all during part processing, and the rotary stage moves at constant velocity (no acceleration). As a result, the coarse axes do not contribute to dynamic errors. The major scanner axis does not accelerate during part processing, as it reverses scan directions “off-board” of the actual pattern. The minor axis has some trivially-small acceleration vector, but certainly not large enough to contribute errors in the order of servo-stage dynamics.

Increased part throughput – in the face of ever-greater technical challenges – must be met with new and innovative manufacturing tactics. The methods outlined above offer some revolutionary thinking on the subject, and could poised the industry for exciting future growth.


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The steadily growing demands on product properties and quality, as well as growing global competition, increasingly require innovations in areas such as energy generation and transformation, mobility, infrastructure, and safety. The development of new metallic construction materials specifically tailored to the requirements of individual tasks is an approach to realise innovative future technologies. Conventional material development processes require a high level of resource use and extensive experimental investigations to determine the material properties. For a target-oriented, model-based bottom-up solution, a basic understanding of the relationships is necessary. However, due to many different demands placed in today’s world of materials, models are missing. Consequently only a low number of experiments are possible, so that the procedures are mostly predictive and discovering completely new materials is problematic.

Novel approach for material development

For significantly higher efficiency in the discovery of new materials, or even material classes, a novel method based on a high throughput procedure is proposed (see Figure 1). Micro samples are generated and, after developing microstructure by thermal, mechanical or thermo-mechanical treatments, the micro samples are examined with respect to so-called descriptors. Descriptors are quickly-measurable values which allow conclusions about material properties to be drawn. This new method includes the consideration of the microstructure which is important for construction materials, in the determination of mechanical properties. The transfer of these descriptors to macroscopic material properties is carried out by a heuristic predictor function, which requires only a few macro samples. This innovative approach is intended to provide target-oriented and resource-efficient alloy compositions for new metallic construction materials. These meet a requirement profile specified by the user regarding material properties such as flexural strength, toughness or machinability.

**Alloy variants with high-throughput**

The challenge is to generate reproducible, homogeneous alloy compositions for a high throughput process. For this purpose, the penetration depth as well as the homogeneity of the melt pool must be controllable. In this context, research is carried out using a methodology based on two laser based processes in a process chain. First, alloy element layers are pre deposited on the base material by selective laser melting (SLM). Second, the alloy element layers are re-melted and mixed with the base material by a scanner guided laser deep alloying process [1]. Figure 2 illustrates two different strategies for depositing the element layers.

To ensure high reproducibility, a defined melt volume (and thus a defined alloy composition) of the melt pool must be controllable. For this reason, the penetration depth should be determined directly in-process using low coherent interferometry. This method has already been used in investigations of the penetration depth during deep penetration laser welding. A close match of the measured results with the actual penetration depth could be achieved [2]. In situ detection of the emission spectrum of the process-induced plasma will be carried out to determine the homogeneity of the material composition. This measurement method assumes that the characteristic lines of the spectrum in a fixed area no longer change when a uniform dilution of the melt pool is achieved [3]. The beam modulation strategy has a direct effect both on the geometry of the melt volume and on the uniformity of the dilution. Studies on wire-based laser alloying have shown that circular oscillation is best suited for a homogeneous dilution [4]. Other studies into the influence of the scanning strategy and further process parameters on the distribution of hard particles during laser deep alloying have shown that the homogeneity of the melt volume is also caused by the additional material used [5].

**Impact of beam modulation**

Results from preliminary investigations show how different movements of the laser beam affect the deep alloying process. The spatial modulation of the laser radiation is a superimposed movement of the laser beam on the component.
surface. The movement of the component corresponds to the feed rate. In addition to the feed direction the laser beam is deflected in such a way that different modulation strategies are generated (see Figure 3). Compared to pure linear feed movement, superimposed beam movement patterns lead to a turbulent melt pool flow. In this way, a homogeneous mixing of the pre-deposited alloy elements with the base material can be achieved. Depending on the processed material system, the resulting melt pools have a different viscosity. Therefore, different movement forms and feed rates must be adapted appropriately for a stable and controllable deep-alloying process.

Steel (C45E) acted as a substrate material in the experiment to analyse the influence of the scanning strategy. Powdered nickel 99.9 was pre-deposited with a layer thickness of 500 μm. The size of the nickel particles was less than 49 μm. The laser deep-alloying process was carried out with a disk laser (TRUMPF TruDisk8002, max. power of 8 kW) using a 3D Scanner-Optic (TRUMPF PFO, f-theta lens with a focal length of 450 mm). The scanner optic was moved with a constant feed rate of 1 m/min. The laser beam was modulated circularly by the scanner optics applying a figure of eight shape. Increasing laser power leads to higher penetration depth and melt pool width. In addition, regardless of the modulation strategy cracks occur in the alloyed bead starting at a laser power of 4 kW. Possibly they are caused by the large heat sink of the surrounding material and the rapid cooling as well as by the large penetration depth. However, the cracks are not relevant for the evaluation criteria of the alloyed bead, which are examined here. Figure 4 shows cross sections generated by different modulation strategies and a laser power of 4 kW. The cross sections show that the beam modulation influences the alloyed bead geometry as well as the heat affected zone. Compared to the alloyed bead without modulation of the laser beam, a thicker seam is produced with circular modulation. Using “eight forward” modulation, on the other hand, results in a narrow seam.

Alloy element distribution within a micro sample

In order to determine the homogeneity of the alloy element distribution within the melt pool, a deep-alloyed micro sample was examined by electron microprobe analysis. The base material of this sample also consisted of a quenched and tempered alloy steel (C45E). A master alloy (X2CrNiMo17-12-2) powder was pre-deposited on the base material by selective laser melting. The laser beam was modulated by the scanner optic in a modified form of the “circle overlaid” modulation strategy (see Figure 5 (a)) with a constant scanning speed of 10 m/min and a laser power of 6 kW. Analysis of the results shows the concentration of the elements nickel and chromium distributed over the entire cross-section of the micro sample. In the upper zone of the microstructure, there is a constant nickel content between 2% by weight and 3% by weight over the entire sample width. The same nickel content was also measured in the middle and lower zone of the micro sample (see Figure 5 (b)). The chromium concentration is also constant between 2% by weight and 3% by weight in the upper sample zone. In the middle and lower zone, the chromium content is 3% by weight (see Figure 5 (c)).

Conclusion

Within this paper, a novel method for a higher efficiency in the discovery of new materials based on a high-throughput strategy was presented. Results from preliminary investigations show that different movements of the laser beam affect both the melt pool and the geometry of the alloyed bead. A scanner-guided laser deep-alloying process was performed, after pre-deposition of alloy element layers on the base material by selective laser melting. Experimental results show a uniform distribution of alloy elements with a low scatter over the entire micro sample. The laser deep alloying process using pre-deposited element layers and beam modulation is a suitable method to achieve alloys with a homogeneous dilution of alloy elements.

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The high capability of pulsed laser ablation to generate small features enables the micro-machining of a large variety of difficult-to-cut materials, such as ceramics (e.g. SiC, Al₂O₃) and superhard materials (e.g. cubic boron nitride, diamond and related materials). The development of parts with complex geometries (e.g. cutting inserts, dressing/truing tools, ink-jet holes) for which conventional (turning, grinding and milling) and other non-conventional (e.g. abrasive water jet, electrical discharge) machining processes might not be appropriate, is driving the increased use of pulsed laser ablation. Furthermore, the decrease in capital and ownership costs for high power lasers makes pulsed laser ablation a viable machining method for high value-added industries such as medical devices, aerospace and defence.

The need for a step change in the control of the processing parameters

Despite the ever-increasing use of pulsed laser machining in industry, the generation of innovative freeform parts with laser often requires lengthy and costly experimental studies to estimate the optimum process parameters (beam path, power and feed speed). The development of parts with complex geometry normally requires an iterative process for which part conformity (shape tolerance) and quality (thermal damage, mechanical properties) need to be assessed at each step to enable the optimisation of the process parameters. The costly and complex optimisation process could limit the acceptance of the technology for micro-machining, especially for industries that need to create innovative freeform structures.

In this context, the avoidance of a “trial and error” experimental approach requires the development of a computationally inexpensive model for pulsed laser ablation, capable of generating freeform surfaces in parallel with the development of numerical tools for automatic optimisation of the process parameters. The lack of such a model has been previously recognised as an issue for the acceptance of pulsed laser machining [1-2]. However, little attention has been given to computationally efficient modelling of pulsed laser ablation compared to models focused on the fundamental mechanisms of laser-material interaction, which are mainly restricted to the study of single pulse ablation. Recently, a novel method has been developed by researchers at the University of Nottingham to estimate the geometrical effects demonstrated on pulsed laser machining of carbon-based materials [3]. The model distinguishes itself by using a small amount of experimental data to determine the ablation rate and providing accurate prediction (average error < 5%) of the geometrical effect of the machining for a wide range of machining conditions in terms of power and feed speed. In contrast to models focusing on the fundamental mechanisms of laser-material interaction and those using a pulse-by-pulse evaluation, simulation of the machining of several mm² surface using this new model can be completed in less than 10 seconds on an engineering computer.

The model for pulsed laser ablation needs to be implemented in an efficient and user-friendly way to enable end-users to integrate these models into CAD/CAM packages. Thus, it is necessary to develop a preliminary software tool capable of generating tool paths appropriate for 3D shapes and to develop a consistent representation of complex 3D surfaces, in order to optimise the tool path generation process while making use of available models. This article presents a unified software platform based on a 3D footprint profile of an energy beam against a target material that can predict the 3D geometry of the workpiece generated as a result of “milling”, i.e. a controlled-depth material removal process. The software uses deterministic models to predict the average footprint profile of the process, and displays the final 3D machined surface by interpolating the footprint profiles in each time step. It includes some features for real machining conditions, such as non-flat surface machining, variable feed speed and overlapping. Laser machining simulations are fully supported and calibration parts are also covered, which makes the software general purpose for most laser beam machining processes.

Machining simulation process

The correct use of the software requires the following steps to be processed:
1. The tool path is read from a specified file using the position and speed as a function of time. The software provides a visual confirmation of the beam path.
2. The beam type is defined.
3. The user can load a specific (non-flat) workpiece file into the software if required.
4. A file containing model parameters is uploaded by the user, then the software derives the erosion rate.
5. The beam path is verified by comparing it to the size of the workpiece.
6. The software simulates the machining process, then the final surface is plotted for the user to examine in the GUI (see Figure 1). The final surface is also saved for future use in EBSIm or other surface analysis software such as Mountains Software from Digital Surf.

Model and calibration implementation

The model used in EBSIm requires a calibration procedure to provide accurate results, with the depth of the surface, feed speed and generic erosion profiles, together with some constants, being extracted from experimental data.

The calibration procedure is simplified in the event that the user requires only one power for machining. The user measures a series of

![Figure 1: Graphical User Interface for an example of the Nottingham logo machining](image-url)
the presence of dust or uncontrolled variation of the machining parameters (e.g. pulse-to-pulse energy, feed speed), see Figures 2-3(c). The presence of dust and variation of the machining parameters can be reduced by averaging over a surface that has been machined with the same parameters, see Figure 2. It is clear that the average profile depth is free of large variation. It must be noted that error is also present around high slope areas, see Figures 3(a)-(b), suggesting that the error is due to reliability of the galvanometers to control the speed correctly during high accelerations. Without considering the area affected by previously described defects, the model shows good agreement with the experimental results with an error less than 1 micron, see Figure 3(a). Finally, the freeform surfaces are correctly predicted in both cases, validating the model for freeform machining.

Conclusion and future works
The software presented in this article provides a generic tool for predicting the outcome of micromachining by Pulsed Laser Ablation (PLA). The tool provides a step change in the generation of complex freeform surfaces, enabling numerical tests of various beam path, feed speed and power, and therefore drastically reducing the cost of innovative freeform surfaces for costly materials such as diamond and related materials. The Machining and Condition Monitoring (MCM) research team at the University of Nottingham is a leading developer of microtooling in ultrahard materials such as diamond and cubic boron nitride, as well as the machining of aerospace materials such as nickel superalloy. Current research focuses on the automatic generation of the tool path, thus providing a complete CAD/CAM package for PLA machining, extending applicability of the model to a wider range of materials such as metals and ceramics, as well as providing tools for the estimation of the depth variance during machining processes.

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SPANP LIGHT MODULATORS IN ULTRAFAST LASER PROCESSING

Walter Perrie & Vojtech Olle

The fabrication of micro- and nanostructures within bulk materials or on the surface of metals, polymers or semiconductors, is an established laser processing technique, enabling inscription of customised shapes or patterns. Spatial light modulator (SLM) technology allows for manipulation of the profile of a laser beam using holographic methods so that both the intensity and/or phase of an optical beam are controlled and modified for spatial and temporal beam shaping. Here, adaptive wavefront correction for phase and polarisation control can also be employed, offering high throughput and optimum light-use efficiency at a given laser pulse energy.

Dr Perrie is one of the leading experts in ultrafast-pulsed laser materials processing and the development of Hamamatsu SLM technology to handle high average powers comes at an exciting time for laser users. This could indeed allow for many current precision laser micro-machining processes to become more efficient and cost effective, leading to new application.

Amin Abdolvand
University of Dundee

DIPOL: DESIGN, PERFORMANCE AND APPLICATIONS

Jonathan Phillips

The generation of high energy laser pulses (> 10 J) at moderate repetition rates (> 5 Hz) is one of the major challenges in laser technology. Traditional laser systems with energies of few joules rely on cooling methods based on rod/slab geometry, active mirror, or total-reflection active mirror. However, none of them is able to reach the kW level of average power, i.e. high energies and high repetition rates. The two main key factors to be controlled are the cooling system and the geometry of the main laser amplifier. This article reports on a very promising and scalable concept of a 100 J/10 Hz laser system based on multi-slab architecture. Here, the gain medium is divided into a number of relatively thin slabs with He-gas as coolant flowing between them. The concentrations of the dopant can be chosen such that overall thickness is reduced and the heat load in the individual slabs equalised.

Solid-state lasers delivering high average powers will find applications in a wide variety of fields, ranging from high-tech industrial technologies to remote sensing and laser particle acceleration.

In the area of material processing, one of the most interesting applications of multi J lasers is the so-called Laser Shock Peening (LSP). This surface enhancement process is used to increase the resistance of metals to surface-related failures, such as fatigue, fretting fatigue and stress corrosion cracking.

The broad range of applications covers a number of areas where increase of resistance is essential, such as aircraft gas turbine engines, automotive parts, orthopedic implants and tooling. Multi J lasers will also find important applications in measuring the laser induced damage threshold of critical optical components. Therefore I believe that the demonstrated 1 kW laser system described here will offer excellent opportunities for new industrial applications and scientific research.

Antonio Lucianetti
HILASE Centre, Czech Republic

The development of the DIPOL 10J prototype system by the Central Laser Facility for Advanced Laser Technology and Applications is a real breakthrough. 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 to effectively surface treat components to beneficial effect. 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. In addition, plans of scaling up this technology to deliver high energies and shorter pulses will also make new leaps into surface engineering materials and introduce new possibilities which are currently unknown.

What is more, space junk and undirected will continue to rise, especially at low Earth orbits. The use of this technology for space debris removal will also contribute to the international scope of possible clean-up solutions to reduce space junk which has accumulated over time - endangering, aircrafts, satellites, and orbiting space equipment.

Pratik Shukla
Coventry University

CLEANING WITH LIGHT – SURFACE PREPARATION OF METALS

Edwin Büchter

Very good generally summary of the laser cleaning process and potential advantages it can offer to its users today. Some clarifications would help the reader identify the different ways the process can be used to achieve the necessary results. Indicative values for performance comparison will help a user to assess the applicability of the process for the intended purpose. See below some comments indicating areas where further clarifications would benefit the reader.

It would be interesting to explain how the surface becomes more resistant to corrosion, is it via oxidation? Does this actually help adhesive bonding or opposes it?

Did surface energy measurements take place on processed surfaces? What are those results? Also high and long term adhesive strength is mentioned? Any measurements, indicative bond strength values for comparison?

In order to form micro-craters, spot sizes <250 μm are necessary with the pulse energies being used for laser cleaning. Typical average roughness of the metal surface before laser processing is much higher than 1 μm (e.g. Ra = 10 μm), so micro-craters of 1 μm do not provide any extra surface enlargement. Hence there are two modes of processing possible. Minimal substrate penetration with surface modification detectable to depths of 1 to 3 μm and surface structuring by micro-craters, with detectable penetration depths of 5 to 20 μm and HAZ possibly reaching 50 to 80 μm.

What happens with metal particle contaminations typically arising from the machining process? They normally reflect the laser light energy. Will the cleaning process naturally stop at them like it does when it meets the metal substrate?

Resulting maximum substrate temperature after processing with a 500 W laser must be “residual” temperature. Obviously on the top few micrometers, the metal reaches melting point (700°C).

Pulsed systems for surface preparation are typically available today at 1000 Watts power level, but can reach 4 kW at 1064 nm wavelength.

Ioannis Metios
Powerlase Photonics

GALVANOMETER-ASSISTED STENT PROCESSING

David Gillen & Scott Schmidt

The motion solution presented is an interesting concept for stent cutting. For full disclosure I’ve seen this system demonstrated at their Pittsburgh facility and we use Aerotech LT1 and LT5 products on our own stent and tube cutting system. The question is where does this new concept fit in with the future requirements for the stent industry.
As a quick aside I would argue some of the material processing observations regarding femtosecond lasers (rather than picosecond) for ROI justification. There is a continuing trend in the industry to move to femtosecond lasers for a number of reason that include; reduced/no post processing, reduced feature sizes, capability to process polymers or metals equally well (note polymers do process better using green wavelength even using femtosecond lasers), surface texturing for drug elution, and the big one which is increasing average powers and decreasing laser prices.

As of today there are still many stent and tube cutters supplied to contract manufactures that require flexibility rather than single application optimisation – in this instance I’m not sure I see the need for such a motion system. However, for a single point of use for say a neuro type stent or small diameter tube there may be some potential.

In summary I applaud Aerotech for the motion solution which is innovative and based on their ability to seamlessly integrate scan head and stage motion, for which there is definitely merit in other areas of micromachining, however at this point the jury is still out for stent processing. It would be great to see comparative data/ case study between the galvo system and say the Aerotech LT1 system for true cutting performance.

Geoff Shannon
Amada Miyachi America

INFLUENCE OF SCANNING STRATEGY ON ALLOY GENERATION

Konstantin Vetter et al.

The paper presents a very interesting approach for achieving new materials in small controllable quantities. The good accuracy of layer thickness in SLM and the control of laser energy in laser alloying are the key aspects ensuring successful outcome of this process. However, we should keep in mind that the effectiveness of mixing and homogeneity of the fusion zone in such a process is also dependent on the type of materials mixed together, i.e. relative difference in viscosity, surface tension, density etc. This may mean that for the same processing parameters some materials will be easier to mix and achieve fully homogenous fusion zone than others. Therefore the experiments should be extended into a wider range of materials to prove its viability. In addition the use of SLM deposited layers as the starting materials may lead to additional problems with control of the chemical composition of the alloys, especially in the case of volatile alloying element, which will vaporise during the SLM process. I think all these aspects related to the control of the material composition at each manufacturing stage, i.e. control of raw powder material, composition of SLM deposited layers and composition of the final product are vital. It is definitely interesting work, which has a lot of potential for further applications, well done.

Wojciech Suder
Cranfield University

DEDICATED SOFTWARE PLATFORM SIMULATES LASER MACHINING

Guillaume Cadot et al.

This useful article takes a very pragmatic approach to modelling of laser machining, by using the results from a well-defined series of experiments with a particular material and laser as inputs, rather than creating a highly complex model based on fundamental mechanisms. This approach should significantly reduce the amount of experimentation required for a new material and/or application, and hence accelerate the take-up of lasers in manufacturing. I look forward to seeing results from a wider range of materials.

Whilst this model has clear application to purely ablative processes, it is not clear from the article to what extent this can be extended to materials and processes where there is likely to be a significant molten layer and hence melt flow, or indeed other redeposited material.

Duncan Hand
Heriot-Watt University

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.

We need:

• Press releases
• Personnel & business news
• Technical articles
• Observations
• Anecdotes
• Case studies
• Interviews
• Application guides
• Tips and tricks

To submit content, send to cath@ailu.org.uk
The recent release of a new Star Wars movie reminds me of the US so-called “Star Wars” project involving high power laser development, officially known as the Strategic Defence Initiative (SDI) which gained momentum during the Reagan presidency. I once heard an anecdote about a demonstration of the laser power necessary to destroy something similar to a missile at a distance (I believe an oil drum full of flammable material was used for effect). As the physicists carefully explained, the power used was 10^6 W and a power of 10^12 Watts would be needed in the final laser to achieve the desired goal in space. One of the US politicians present allegedly commented that it was great that they were “half way” to achieving their goal – at which point rather than correct and disappoint the politician with the mathematical facts I believe the experts just smiled and remained silent (not wishing to jeopardise the funding stream by an injection of realism). If anyone can enlighten me with facts to back up this anecdote, I would love to know if it is actually true.

My own experience with decimal point problems relates to a couple of examples of digital displays which lack the clarity of the analogue dials they replaced. In the 1980s a visit to site was required to fix a TIG welding system that “wasn’t working right”. As a young and inexperienced electronics graduate, I was unsure of whether I had the skill to resolve the issue and spent much of the 3 hour drive to site thinking about what I might do if I couldn’t fix it. Arriving at the welding system in question, I was told that the “modulated ramp down” wasn’t working as it should be going “flash..flash..flash..flash…” and it was only going “flash”. The welding engineer even demonstrated a weld to show me. The identical system next door was “working fine”. I immediately looked at the settings and observed that the time in question was set to 200 milliseconds instead of 2000 milliseconds and displayed on a numeric LED display with a small red decimal point in the appropriate place. After adjusting the knob to read the correct number, I asked the welder to try again. He repeated the weld and declared “that’s how it should be”. To avoid further repeat visits I pointed out to him the importance of the decimal point and the zeros before and after it, which was probably the easiest, quickest and best service engineer result I have ever achieved.

On another occasion with a modern laser system, we were discussing with the customer the capabilities of his laser. He was totally satisfied that the laser could do what he bought it for (fine wire welding) but said it couldn’t do a strong and deep weld. When quizzing him about the settings used, he claimed to use always the same pulse width “15” – looking at the display I could see it was actually “1.5” and this explained the issue. Rather like buying a Ferrari and complaining about the performance when you don’t ever change out of first gear!

The moral of the above is always check your arithmetic, use common sense and look for the obvious fault first. In our modern digital world, I might also remind you that most things can be fixed by “switching it off and on again”...

Dave MacLellan
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AILU WORKSHOP

Presentations & Exhibition

LASERS IN BIOTECHNOLOGY (LiB '17)

15 JUNE 2017

Bibliothèque Marie-Curie, INSA, Lyon, France

AILU is running a workshop in Lyon, France to reach out to organisations in Europe with an interest in laser applications in Biotechnology. Lasers are used in surgical applications (eyesight correction, tattoo removal, cosmetic surgery etc.) as well as the more traditional manufacturing of medical devices or surgical tools. This is the first of a series of non-UK workshops.

www.ailu.org.uk/events

ADVANCED ENGINEERING 2017

1 & 2 November, NEC, Birmingham

Laser material processing will have a high profile for the first time with the introduction of a new Laser Manufacturing Hub of 160 square metres, hosted by AILU.

Contact the AILU office (info@ailu.org.uk) to find out about joining in with this initiative, space is filling up fast.

Also wanted: Presenters for the Open Forum sessions.

LASER PRECISION MICROFABRICATION (LPM) 2018

EDINBURGH UK

Save the Date: 25-29 June 2018

The LPM conference, organised by the Japanese Laser Processing Society (JLPS) has been held annually since 2000, but has never been held in the UK until now. In 2017 the event takes place in Toyama, Japan, but in 2018 the venue will be Heriot Watt University Conference Centre in Edinburgh. This event will be hosted by AILU and will represent a unique opportunity to UK visitors to attend this conference and exhibition on home territory.

Courtesy Fraunhofer ILT
# EVENTS: RECENT AND FUTURE

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