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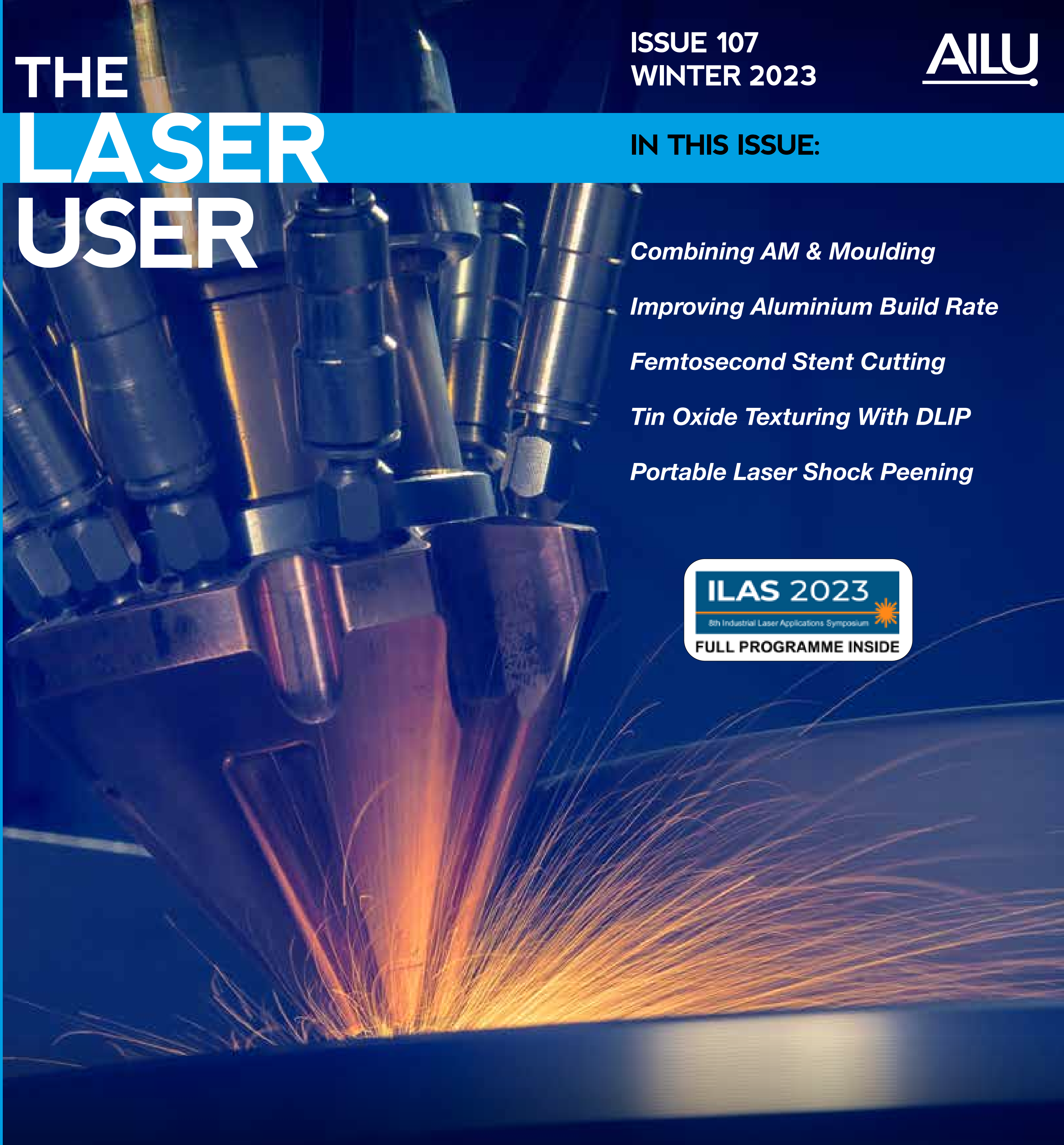
WINTER 2023

AILU

THE LASER USER



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ILAS 2023
8th Industrial Laser Applications Symposium
FULL PROGRAMME INSIDE

ADDITIVE MANUFACTURING:

HIGHER SPEEDS AND GREATER ADOPTION

THE LASER USER

Editor: Dave MacLellan
Sub-Editor: Catherine Rose

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The Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members. The views and opinions expressed in this magazine belong to the authors and do not necessarily reflect those of AILU.

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

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

Cover image: EHLA coating applied to an automotive brake disc.

Courtesy TWI Ltd

ADVERTISING ENQUIRIES

+44 (0) 1235 539595
cath@ailu.org.uk

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Association of Industrial Laser Users
Oxford House
100 Ock Street
Abingdon
Oxfordshire
OX14 5DH

+44 (0) 1235 539595
info@ailu.org.uk
www.ailu.org.uk

WELCOME TO NEW AILU MEMBERS

Direct Machining Control, Lithuania
Sarunas Vaskelis

Lantek Systems, UK
Adam Ball

Lumos Laser, Turkey
Seydi Yavas

Renishaw, UK
Ravi Aswathanarayanaswamy

Rolls Royce, UK
Clive Grafton-Reed

Trident Power Cleaning, UK
Mike Allpress

Welding Alloys, UK
Leonor Neto

AILU STEERING COMMITTEE 2022-23

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Vice President:	Mike Poulter (TRUMPF)
Exec. Director:	Dave MacLellan (Anode Marketing)

Elected until 2025

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Rachel McBain	(Laser Trader)
Jamie Costello	(Coherent)
Chris Waters	(Micrometric)

Elected until 2024

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Danijela Rostohar	(HiLASE)
Tian Long See	(MTC)
Sinan Bilgin	(SS Laser Solutions)

Elected until 2023

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Tom Chaffer	(TRUMPF)
Clive Grafton-Reed	(Rolls-Royce)

Co-opted until 2023

Derrick Jepson	(Aerotech)
Tony Jones	(Cyan Tec Systems)
Richard Carter	(Heriot-Watt University)

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

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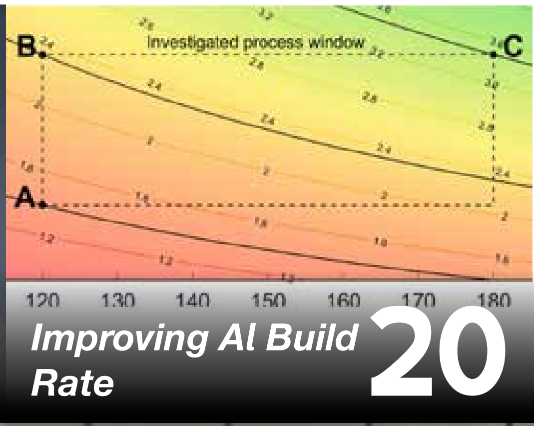
HIGHLIGHTS...



ASSOCIATION NEWS

FIRST WORD

As we are on the final countdown in the weeks before ILAS 2023, I want to encourage your to invite someone new to ILAS this year. There is simply no better place to top up your know-how of laser processing and the technologies that enable it. Putting on great events is one thing, but getting new people to attend them is more of a challenge and that is where you can help!

Over the past 5 months we have held 4 workshops, all in-person. This has helped people to renew connections and make new ones as well as sharing their know-how and new products. This is a fuller schedule than we have previously had in the run-up to ILAS, and has also enabled us to put together workshops on all the topics we had identified for 2022. Now we are pushing the reset button, so check out our draft workshop plans for 2023 (page 35) and see whether you would like to participate as a speaker, exhibitor or delegate.

An in-person Photonics West has just finished (sadly I couldn't be there this year) and another Laser World of Photonics is coming in June, so the international calendar is also very full.

Finally we have several new members since January – welcome on board! Hope to see as many of you as possible in 2023.

Dave MacLellan
dave@ailu.org.uk

PRESIDENT'S MESSAGE

This issue's President's Message has an AI co-author – I am starting to think that my job is under threat...

" Dear readers of the Association of Industrial Laser Users Magazine, it's an honor to have the opportunity to write a welcome message for such a prestigious publication. AILU plays a vital role in advancing the field of laser technology, and this magazine serves as a platform to share the latest developments and insights from both business and research organisations.

In this edition of the magazine, you'll find a wealth of interesting contributions from experts in the field. From case studies and technical articles to feature interviews and news from the industry, there is something for everyone. Whether you are an experienced laser user, a researcher, or simply someone with a passion for technology, you'll find a wealth of information to inspire and inform you.

We are living in a rapidly changing world, and the field of laser technology is no exception. With new developments and breakthroughs happening all the time, it's more important than ever to stay up-to-date with the latest trends and advancements. AILU's magazine provides an essential source of information and inspiration, and I encourage you to make the most of it.

In conclusion, I hope that you enjoy this edition of the magazine and that it helps you stay at the forefront of the laser industry. And remember, this message was written by ChatGPT, an AI language model developed by OpenAI.

Best regards, ChatGPT (and Adam Clare!)"

adam.clare@nottingham.ac.uk

RIC'S RAMBLINGS

I am writing this close to the day in January when everyone and everything is at a low ebb. The festive season has come and gone in a blink of an eye. The days are still shockingly short and the weather is just plain rubbish. Yes, we have just passed "blue Monday" which, I have always thought of as the first 12" single I purchased by New Order (for the younger readers of the Laser User, yes I am talking about actual vinyl - a thing you hold in your hand before placing on a turntable and resting a physical stylus upon it to play the music).

To compound my feelings of dejection and depression brought on by January I recently witnessed the UK Space launch "failure". There was so much excitement about the fact that a rocket was to be launched carrying satellites from UK soil for the first time ever (my LinkedIn pages were full of the pre-launch buzz). At last closing the circle to create a real end-to-end space ecosystem in the UK. We are excellent in the UK at designing, building, testing and putting instruments onto space hardware. Not so good it appears at launching them into space. But hey this was the first ever attempt to do this and, well at least half of it worked.

We launched the rocket carrying the satellites on a big aeroplane without a glitch, but then the rocket bit went wrong. So yet another reason to be depressed around "blue Monday". The reason I mention this is not however to be all doom and gloom - but to look at the positives that came from this so-called "failure". The bounce back, get up, dust yourself down and come back stronger messages and words of encouragement from all those involved and importantly all those watching from the side-lines was something impressive to witness. So often in the UK we get lambasted for failure, how refreshing it was to get the sense that its actually ok to fail, we will learn from this and make it better next time. I for one am convinced that the UK will launch satellites (be that from Cornwall, Scotland or elsewhere) and that our space industry will flourish because of it. So let us not look at failure in such negative terms, let us instead see what opportunities it might open up in future.

Having got through "blue Monday" I for one am now looking forward to what 2023 will bring. After all It's not long until ILAS 2023 (22/23 March), when we can all get together to exchange thoughts, ideas, opportunities and laughs. And guess what, I can even see the sun starting to peep through the clouds - now that's much better…

Ric Allott
ric.allott@stfc.ac.uk

OBITUARY
SILKE PFLÜGER

AILU was saddened to hear of the passing of Silke Pflüger, especially as she had been kind enough to deliver a plenary presentation at ILAS 2021. We are honoured to publish three personal tributes to Silke.

We mourn the loss of Dr. Silke Pflüger with a very heavy heart. Silke was a loyal, long-time and extremely committed friend and supporter of the Fraunhofer Institute for Laser Technology ILT. Raised in Germany, she most recently lived in the United States and worked in the field of laser technology throughout her career.

She has always been a real advocate for laser technology and contributed early in her days as a student at RWTH Aachen University and Fraunhofer ILT with her first scientific papers, contributing greatly to the building of the institute in the early days of applied laser technology in industry. Her expertise, her great openness and willingness to help, her captivating enthusiasm for laser technology and her impeccable sense of humour made her a valued colleague.

After receiving her doctorate in Aachen in 1994, Dr. Silke Pflüger moved to the US subsidiary of the Fraunhofer ILT in Ann Arbor (Michigan). In the course of her open-mindedness and curiosity for new things, she not only quickly found her feet in new teams, but also played a major role in shaping our profile of Fraunhofer ILT in the US. Her next step was joining a new technology startup where she demonstrated her entrepreneurial spirit. The company grew successfully and was the launching pad for her to a successful career in corporate management.

Her professional career covered many outstanding stations at different companies in the laser industry. During all these years, Dr. Silke Pflüger always kept in touch with the Fraunhofer ILT and was always available to the institute's management in an advisory capacity. She was one of the mainstays of the Fraunhofer ILT alumni network AKL Arbeitskreis Lasertechnik e.V.. In 2017, she was appointed to the Fraunhofer ILT Board of Trustees; in 2020, her term was extended for another three years. With her unbiased view of facts and constructive recommendations to the institute's senior management team, she contributed to the success of the Fraunhofer ILT. Despite her professional success, Dr. Silke Pflueger was always down to earth and approachable. She enjoyed an excellent reputation in the worldwide laser community and built bridges across continents.

As a mentor to newly diagnosed metastatic breast cancer patients, she worked tirelessly to support and encourage them, especially shortly after diagnosis, and to ensure that they received the best possible guidance and support in every aspect of dealing with this deadly disease.

Our deepest sympathies go out to the family, relatives, and friends of Dr. Silke Pflueger. We will miss her and cherish her memory.

Constantin Haefner, Fraunhofer Institute for Laser Technology ILT

It was an honour and privilege to have been fortunate enough to have met Silke at ICALEO in 1998, held at The Catamaran Hotel, San Diego. I had just listened to her present and was immediately drawn into her intense yet passionate drive for laser processing divinity!

I was convinced that she might be the brightest and smartest person I had ever heard speak in my life, and immediately sought out an introduction through the West Coast TRUMPF Rep. Col. Daniel F. Greby.

Fast forward to 2002 the fibre laser is just hitting the market and SPI needs space to start an application and sales lab and I'm fortunate enough to have space and the chance to have Silke in our building.

I dream of Silke nurturing us all into laser applications gods & goddesses but find out that Silke is what else? laser focused on dominating the market, and IPG!

She had little time for the office and her valuable time was spent on customers and applications for every industry. I learned from her that nothing rivals commitment, passion, and discipline.

I marveled at the way Silke and her husband Klaus embraced life and work and treated everyday as a gift. Despite Silke being able to steamroll through anyone mentally, physically, or intellectually, she had a giving heart, generous soul, and was a most gracious host (along with Klaus) as they opened their cabin every year after Photonics West to host our gaggle of Laser Professionals for skiing/snowboarding, debauchery, and even live music!

The loss of Silke to the global community is hard for us to comprehend but the gift she gave to all of us was this:

"Be the best human you can be!"

Neil S. Ball, Directed Light Inc.

I met Silke in 2016 when she invited me to be a speaker at ICALEO. I was immediately struck by her intelligence; her mind was simply much faster at interpreting and incorporating information than most, even those in her already very smart peer group. But even though Silke was definitely the smartest person in the room, she did not wield her power unkindly, but rather for good.

She was generous and cared fiercely about making the world better, in large ways and small. At that ICALEO, she took care to make me feel welcomed into the community even though she was quite busy making sure the meeting was running smoothly. I still remember her genuine laugh when she asked me if I had children, and I told her that I had a cat. "Me too!" she said, and I knew at that moment that we would definitely be friends.

After the meeting, we stayed in touch, eventually using Twitter as our main communication mode. I followed her journey and was always impressed with her insistence on speaking honestly and unambiguously about her illness, her experiences with our healthcare system, and human rights for all. As always, she was generous with her time, her effort, and her caring. She never gave up on the world and her belief that she could effect positive, meaningful change.

The last direct message she sent to me was a picture of us from that ICALEO in 2016, a reminder that relationships are the most important parts of our lives. Making connections with others really does change the world for the better.

Silke was a bright, unforgettable flame, and I feel fortunate to have shared in her light and warmth.

Nina Lanza, Los Alamos National Laboratory

AMPLITUDE ANNOUNCES ACQUISITION OF FASTLITE

Amplitude has announced the acquisition of Fastlite, a French high-technology company specialising in ultrafast pulse shaping, characterisation, and optical parametric amplifiers. Amplitude and Fastlite have long-established ties and have worked together to bring advanced ultrafast technology to the market.

Contact: Eric Mottay
eric.mottay@amplitude-laser.com
https://amplitude-laser.com/

STRONG SALES YEAR FOR YAMAZAKI MAZAK

The continued resilience of the UK's manufacturing base has delivered a strong sales year for Yamazaki Mazak in the UK. Despite challenging conditions, the company has reported strong sales in key markets and machine categories as UK manufacturers continued to invest in new technologies.

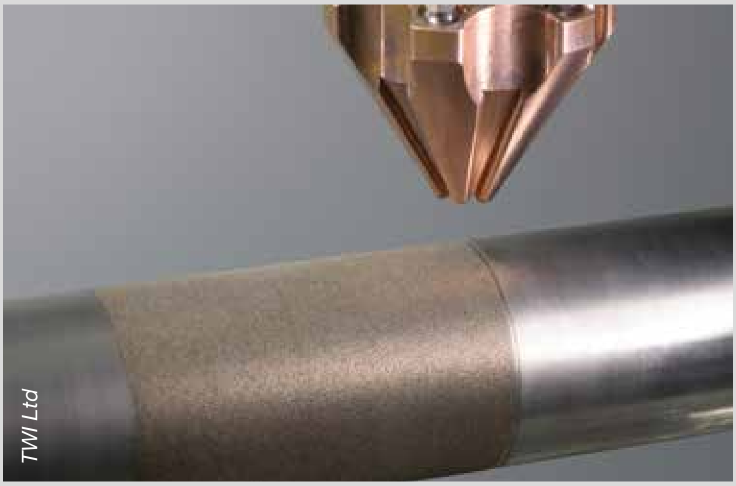
Contact: Ian White
iwhite@mazak.co.uk
www.mazakeu.co.uk

LUXINAR KICKS OFF 25TH ANNIVERSARY YEAR

Luxinar has started its 25th anniversary year by showcasing products from its ranges of ultrashort pulse and CO_2 laser sources at Photonics West. The LXR® series represents Luxinar's first range of ultrashort pulse laser sources, a patented technology that has revolutionised materials processing.

Contact: Yannick Galais
yannick.galais@luxinar.com
www.luxinar.com

LASER LINES & TWI PART OF NEW CENTRE OF EXCELLENCE FOR LASER COATING TECHNOLOGY



With over 20 years of history in laser metal deposition, TWI has recently invested in developing one of the newest coating technologies, Extreme High-speed Laser Application (EHLA), which is a step change from laser cladding.

TWI worked with Oxfordshire-based laser specialist Laser Lines, manufacturer Laserline GmbH in Germany, and Hornet Laser Cladding in Holland, along with Fraunhofer ILT, the process inventors, to establish a UK Centre of Excellence for this new technology. Laser Lines provides the UK with systems and support of Laserline GmbH lasers.

Josh Barras, UKRI Future Leader Fellow at TWI, says: "The EHLA process was invented as a hard chrome plating replacement technology, which traditionally is a heavily used coating technique that is under a lot of regulation issues currently, due to the chemicals being used and recent and future restrictions related to sustainability and net-zero."

TWI's approach is to be technology-agnostic and work on a solution that will offer the best results for the benefit of its industrial members. As part of the programme development, TWI purchased a Laserline 7000-40 LDF.

Contact: Jeryl Adcock
JerylA@laserlines.co.uk
www.laserlines.co.uk

GRANT AWARDED TO ORC, SOUTHAMPTON

The Optoelectronics Research Centre (ORC) at the University of Southampton is pleased to announce that its "Smart Fibre Optics High-Power Photonics" (HiPPo) programme grant proposal has been successfully funded by EPSRC. The HiPPo programme is focused on understanding how to control the properties of fibre lasers, to go beyond the "fixed" fibre lasers that are currently used in manufacturing and towards "smart" fibre lasers that are automatically reconfigured and optimised in real-time.

Contact: Ben Mills
bm602@orc.soton.ac.uk
www.orc.soton.ac.uk

ES PRECISION LASER MARKS INSTRUMENTS FOR DENTAL PRACTICE

ES Precision has helped an Oxfordshire dental practice to keep track of dental tools without the need for label application or hard-to-read serial numbers.

Deddington Dental is a 4-surgery dental practice with around 40 fast and slow dental handpieces that are used by 7 dentists and looked after by 8 nurses. Each dental handpiece costs £400-700 so it is important to keep track and account for each one.

Each surgery has its own allocation of handpieces, and they are taken to a different decontamination room and processed several times each day.

Akhil Gupta, Principle Dentist, explains: "Previously, we relied on using the tiny serial numbers marked on the handpieces or using a coloured tape on each one to identify which surgery they belonged to. The method of using the serial number was very time consuming and hard to read. The tapes would regularly come off when the handpieces were autoclaved."

The handpieces are made out of titanium or stainless steel and some are coated by physical vapour deposition (PVD), so Deddington Dental needed a permanent marking solution that would be compatible with each of these materials and also their regular cleaning processes.

Dr Gupta continues: "After researching, we decided on laser marking with a local company, ES Precision. We were able to mark each handpiece and these marks were clear, large enough and were cost-effective to do. Now, our nurses can easily identify each handpiece and we can account for each one at the beginning and end of the day as part of our daily checklists. The feedback from my nurses has been that the process saves a lot of time and looks a lot neater than using a coloured tape."

Contact: Andrew May
a.may@esprecision.co.uk
www.esprecision.co.uk

NUKON LASERS AND UNISON HELP EQUIPMENT MAKER REACH NEW HEIGHTS

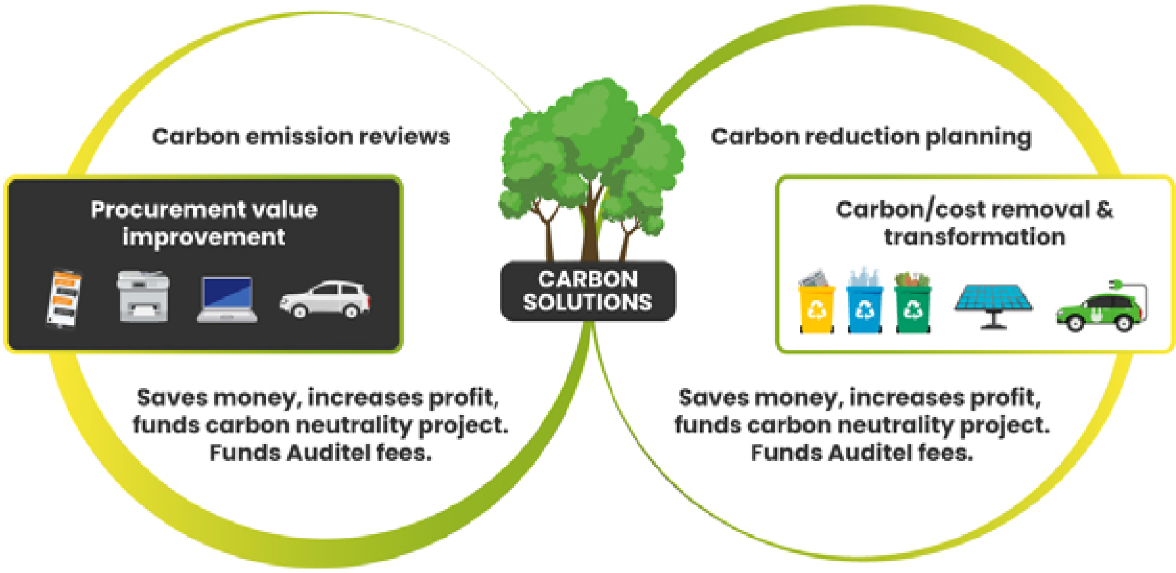
Redditch-based access equipment maker, Redhill Manufacturing, has purchased two fibre laser cutting machines from Nukon Lasers UK and two British-built all-electric tube bending machines from Nukon Lasers' sister company, Unison.

The new machines will be used by Redhill to meet increased demand for its products, with one of the tube benders replacing a machine that was lost in a factory fire in May 2022.

The first of the new fibre lasers, a Nukon ECO 315 4kW flat sheet metal machine, was installed at Redhill's newly acquired facility in December 2022. The second laser, a Nukon NKT-125 2kW 3D tube cutting model, and the two Unison tube bending machines will be installed later in 2023. Combined, the value of the four machines is in excess of £1 million.

Contact: Steve Haddrell
sales@nukonlasers.co.uk
www.nukonlasers.co.uk

GOING GREEN IN 2023



Businesses play a critical role in accelerating the net zero transition. However, the current economic climate has meant that organisations are battling to drive growth and profitability whilst investing in low carbon emitting technologies to reduce carbon footprint.

While implementing an Environmental, Social and Governance (ESG) strategy can help set businesses on the right path, achieving a recognised specification for carbon neutrality helps ensure the journey is simplified and the impact on their business is greater.

PAS 2060 certification

The British Standards Institution (BSI) PAS 2060 certification is the only internationally recognised specification for carbon neutrality. Following the PAS2060 framework provides an organisation with official documentation that attests to their carbon neutrality claims, increasing credibility and customer confidence.

There are numerous other benefits to certification:

- Brand transparency
- Enhance sustainability credentials
- Demonstrate leadership in combatting climate change
- Gain a competitive edge by offering greener services and products
- Improve business efficiency

The are four simple steps required to achieve carbon neutrality and become internationally certified:

1. Define and measure

Measuring the carbon footprint of the product, activity or organisation. It should include all scope 1 (direct) and 2 (indirect) emissions, in addition to any scope 3 (indirect third-party) emissions that contribute more than 1% of the overall carbon footprint.

2. Reduce

Developing and implementing a carbon footprint management plan will ensure that organisations reduce their carbon footprint, as well as showing a public commitment to decarbonisation. The plan should incorporate a timescale, specific targets for reductions, the means to achieving reductions and how residual emissions will be offset.

3. Offset

Purchasing high quality carbon credits to offset the total amount of residual carbon. The credits must meet specific criteria set out within the standard.

4. Document and validate

Organisations will receive official documentation declaring that the standards have been met and verifying their carbon neutral commitment. This will involve self-validation, validation from other parties and independent third-party validation.

Carbon solutions

To simplify and assist with the certification process and journey to net zero, Control Energy Costs, working with their carbon solutions specialist partner, helps businesses become certified carbon neutral within 12 months, without costing the earth.

Together, they can guide organisations through each part of the four step process required to achieve the international certification.

With the carbon solutions and energy procurement services working together, organisations can reduce both their carbon emissions and costs at the same time. The primary benefit is that there is no direct cost to the business – the fee is based on actual gains, not projections. For many clients, the process is self-funding and can even be profitable.

Contact: Liam Conway
liam.conway@cec.uk.com
https://cec.uk.com/

ILAS 2023

8th Industrial Laser Applications Symposium

22-23 MARCH 2023

www.ilas2023.co.uk

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

Time: 08:00, 08:15, 08:30, 08:45, 09:00, 09:15, 09:30, 09:45, 10:00, 10:15, 10:30, 10:45, 11:00, 11:15, 11:30, 11:45, 12:00, 12:15, 12:30, 12:45, 13:00, 13:15, 13:30, 13:45, 14:00, 14:15, 14:30, 14:45, 15:00, 15:15, 15:30, 15:45, 16:00, 16:15, 16:30

WEDNESDAY 22 MARCH DAY 1

Room 1	Room 2	Room 3
Registration & refreshments		
OPENING of ILAS 2023		
Plenary 1		
Plenary 2		
Refreshment break		
Welding	Additive Manufacturing 1 (DED)	Beam Delivery & Shaping
Lunch		
Cleaning	Additive Manufacturing 2 (LPBF)	Surface Engineering
Refreshment break		
Marking & Ablation	Systems & Automation	Drilling

18:30-19:15	Networking Drinks Reception
19:15	Symposium Dinner

THURSDAY 23 MARCH DAY 2

Room 1	Room 2	Room 3
Registration & refreshments		
Surface Engineering/ Texturing 1	Sources	Welding 2
Refreshment break		
AI & Machine Learning	Microfabrication	Welding for e-Mobility
Lunch		
Cutting	Additive Manufacturing 3	Surface Engineering/ Texturing 2
Refreshment break		
Plenary 3		
Plenary 4		

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

WEDNESDAY 22ND MARCH 2023

09:15-09:45 PLENARY 1: Emerging new laser infrastructures in high power lasers and their applications
Hernandez-Gomez, Christina (STFC)

09:45-10:15 PLENARY 2: Recent topics of laser applications in Japan and high-quality Cu/Al laser welding
Okamoto, Yasuhiro (Okayama University, Japan)

WELDING 1 10:45-12:15

Meltpool dynamics and feedstock melting in laser welding
Suder, Wojciech (Cranfield University)

Laser welding with beam wobbling and filler wire of 5083 Al automobile bumper using prototype Tau robot
Sokolov, Mikhail (TWI)

Enabling E-Mobility - With laser welding and sophisticated sensor technology to guaranteed quality
Kogel-Hollacher, Markus (Precitec)

Wobble laser welding of Aluminium to Copper for electric vehicle (EV) battery manufacturing
Sadeghian, Amirhossein (Coventry University)

Challenges and Opportunities in Laser Welding of Additive Manufactured Materials for E-Mobility applications
Sun, Tianzhu (University of Warwick)

ADDITIVE MANUFACTURING (DED) 10:45-12:15

ABA cladding – a new cladding strategy to improve productivity in laser cladding/DED
Koti, Daniel (University of Nottingham)

The Optimisation of Ni Superalloy Coatings Using Extreme High-Speed Laser Application Technology (EHLA)
Satterlee, David (Sheffield Hallam University/TWI)

New cladding applications for diode lasers with higher power, higher speed and new wavelengths
Eltze, Andre (Laserline)

Advances in hybrid manufacturing which enables greater flexibility and possibility
Solomon, Peter-Jon (Hybrid Manufacturing Technologies)

Metal cored wires and their potential to attain complex chemistries in additive manufactured components
Cordero, Mario (Welding Alloys)

BEAM DELIVERY & SHAPING 10:45-12:15

Innovative Spatial Beam Shaping for Gas-tight Welding of Aluminum and Laser Welding of Metal Ceramic Substrates in Power Electronics at 515 nm Wavelength
Möller, Mauritz (TRUMPF)

Why are ultrafast lasers ultrafast in damaging optics?
Ceizaris, Lukas (Optoman)

Beam-Shaping with Multi-Plane Light Conversion to improve laser micro-processing
Pallier, Gwenn (Cailabs)

3D Laser Beam Shaping for Manufacturing within Volumes
Carter, Richard (Heriot-Watt University)

CLEANING 13:30-14:45

Laser de-coating in cutting tool reuse and recycling for circular economy and environmental impact reduction
Ouyang, Jinglei (University of Manchester)

Reduced Hazard Laser Cleaning using 'Retina Safe' Wavelengths
Murphy, Tara (Woodrow Scientific)

Automating the Laser Cleaning Process
Jones, Tony (Cyan Tec)

High speed large scale selective coating removal by high power nanosecond laser with interacting multi axis system
Gabzdyl, Jack (TRUMPF Lasers)

ADDITIVE MANUFACTURING - LPBF 13:30-14:45

From high-speed imaging to in-layer process planning for laser powder bed fusion
Moore, Andrew (Heriot-Watt University)

Twin activity in 316L fine microstructures generated by laser powder bed fusion: opportunities for energy absorption applications
Della Crociata, Diego (University of Nottingham)

Diode Area Melting (DAM)
Alayil Veeti, Sarath (University of Sheffield)

Processing a wide range of Ti6Al4V powders using a 500W laser machine
Aswathanarayanaswamy, Ravi (Renishaw)

SURFACE ENGINEERING (LSP) 13:30-14:45

New Frontiers in Laser Shock Peening
Shukla, Pratik (MTC)

Study on surface enhancement of D2 steel by conventional shot peening and laser shock peening
Dhakshinamoorthy, Praveena (SRM Valliammai Engineering College)

The Application of Laser Shock Peening for Improvement of Stress Corrosion Cracking Behavior in Additively Manufactured Steel
Over, Veronica (Colombia State University)

MARKING & ABLATION 15:15-16:30

Manufacture and testing of a laser ablated emitter intended for use as a propulsion system for small satellites
Maharaj, Sahil (University of Manchester)

High-efficiency metal microprocessing with femtosecond fiber laser
Bogusz, Stępak (Fluence Technology)

SYSTEMS & AUTOMATION 15:15-16:30

Innovative and software-embedded process control tools for laser systems
Mayerhofer, Roland (Coherent)

Challenges for positioner design when using liquids in the laser processing zone
Jolliffe, Cliff (PI)

Automated Robotic Assembly of Laser Systems
Carter, Richard (Heriot-Watt University)

Technological Advances in High Dynamic Laser Processing to Improve process Throughput and Increase Part Quality
Germann, Bryan (Aerotech Inc)

DRILLING 15:15-16:30

Low carbon emission simultaneous laser and mechanical hybrid drilling of carbon fibre reinforced polymer composite
Zhu, Menghui (University of Manchester)

Investigation into the laser micro-hole drilling of 1 mm thick C263 sheet material
Kerwin, Annie (MTC)

Millisecond Fibre Laser Drilling of Alumina-Alumina Ceramic Matrix Composites
Marsh, Nathaniel (Heriot-Watt University)

Precession laser machining of micro-holes on Nickel super alloy
Nasrollahi, Vahid (University of Birmingham)

THURSDAY 23RD MARCH 2023

SURFACE ENGINEERING/TEXTURING 09:00-10:15

Surface treatment of reinforced carbon fibre with woven reinforcement using nanosecond pulsed fibre laser
Al-Mahdy, Ahmed (Liverpool John Moores University)

Laser surface engineering for improved osseointegration
Mirhosseini, Nazanin (University of Manchester)

USP laser texturing: from surfaces to products
Mincuzzi, Girolamo (ALPhaNOV)

Use cases of productive multi-beam micro/nanostructuring technologies – from glass functionalization towards battery enhancement and friction reduction surfaces
Hauschwitz, Petr (HiLASE)

SOURCES 09:00-10:15

Large area processing with kilowatt femtosecond lasers
Mottay, Eric (Amplitude)

Material Processing with Dual Mode GHz Ultrafast Laser System
Yavas, Seydi (Lumos Laser)

High Power Femtosecond Laser Sources Operating at 1030nm, 515nm and 343nm for Industrial Applications
Fulford, Ben (Luxinar)

Versatile GHz burst-mode operation in high-power femtosecond laser for industrial applications
Andriukaitis, Deividas (Ekspla)

WELDING 09:00-10:15

Investigating stresses during laser welding of dissimilar materials: a thermomechanical modelling approach
Dondieu, Stephen (Heriot-Watt University)

Laser Beam Welding of different materials improved thanks to tailored beam *shaping with Multi-Plane Light Conversion*
Grosclaude, David (Cailabs)

Where do we stand with laser welding of steel-to-aluminium? Needs, challenges and opportunities
Baghbani Barenji, Ali (University of Warwick)

Applying optical coherence tomography for weld depth monitoring in laser welding – a user perspective
Capar, Necdet (TWI)

In-situ strain field investigations of solidification cracking susceptibility during laser welding of 6xxx series aluminium alloys
Pamarthi, Venkat Vivek (University of Warwick)

AI & MACHINE LEARNING 10:45-12:00

Low cost, in-process, image-based weld imperfection detection
Allen, Chris (TWI)

Industry 4.0 based framework for real-time prediction of output power of multi-emitter laser modules during the assembly process
Markatos, Nikolaos (Brunel University)

Self-Directed Femtosecond Laser Machining of Microscale Patterns using Deep Learning
Mills, Ben (University of Southampton)

Importance of automating advanced laser process development using metrology/database technologies
Tuohy, Simon (Oxford Lasers)

MICROFABRICATION 10:45-12:15

Improved EV Battery Anode and Cathode Processing with USP Lasers
Leopold, Philippe (Lumentum Technology)

Industrial ultrashort pulsed laser welding of copper and titanium to quartz and glass components for optical applications
Dzipalski, Adrian (Heriot-Watt University)

Laser-induced forward transfer of high viscosity graphene for flexible electronics applications
Dimly, Dawood (University of Birmingham)

Pulse burst generation for dynamic Picosecond laser- materials processing
Perrie, Walter (University of Liverpool)

Structured optical fields for short and ultrashort pulse lasers: principles and example applications
Allegre, Olivier (University of Manchester)

WELDING FOR E-MOBILITY 10:45-12:15

SONI-LASER - Ultrasonic assisted laser welding for high volume assembly of automotive battery packs
Carr, Phil (Carrs Welding)

Laser wobble welding for e-mobility applications
Rajamudili, Kuladeep (Cranfield Uni)

Dynamic Beam Lasers Offer New Parameters for Laser Welding in Automotive Applications
Nissenbaum, Asaf (Civan)

Modelling of Laser Joints for Understanding Joint Strength in Electric Vehicle Battery Interconnects
Kumar, Nikhil (University of Warwick)

Evaluation of spatially oscillated single mode infrared laser beam welding to competing approaches, for electric vehicle battery module joints
Allen, Chris (TWI)

Challenges and Opportunities for Adhesive Bonded Joints Reinforced by Laser Beam Stitches in Automotive Body Construction and E-Mobility Parts
Al Botros, Lara (University of Warwick)

CUTTING 13:15-14:30

Performance Enhancements in Laser Cutting Sheet Metal with "Light Tunnel Generators"
Kidd, Steve (PowerPhotonic)

High Power Water Jet Guided Laser Cutting of Carbon Fibre Reinforced Polymer
Chingwena,Kuda (MTC)

Laser Based Machining (Cutting, Drilling and Blind Machining) of Ceramic Matrix Composites
Marimuthu, Sundar (MTC)

How nanosecond fiber laser pulse characteristics affect battery foil cutting
Wright, Thomas (TRUMPF Lasers, University of Bath)

ADDITIVE MANUFACTURING 13:15-14:30

Effect of post heat treatment on the microstructure and mechanical properties of LPBF Nickel Superalloy 718
Aswathanarayanaswamy, Ravi (Renishaw)

Control of Microstructure through Coordinated Dual-Beam Laser Scanning
Perkins, Kyle (Heriot-Watt University)

Laser and wire directed energy deposition of net-shape sub-millimetre features
Wang, Xichen (Cranfield University)

Next generation melt pool control via laser beam shaping
Mark Keating (Flow Science)

SURFACE ENGINEERING/TEXTURING 13:15-14:30

A comparison of the tribological performance of textured cylinder liner segments modified by Direct Laser Writing and Direct Laser Interference Patterning processes
Butler-Smith, Paul (MTC)

Laser Surface Texturing of Stainless Steels for Biomedical Applications
Dong, Jialin (University of Loughborough)

Femtosecond laser engraving, microstructuring and texturing applications
Garcia, Raul (Microrelleus)

Laser-based interdiffusion of electroplated nickel-titanium layers for shape memory applications
Muniraj, Logaheswari (Heriot-Watt University)

15:00-15:30 Plenary 3: Unlocking the potential in laser powder bed fusion additive manufacturing
Aboulkhair, Nesma (Technology Innovation Institute, UAE)

15:30-16:00 Plenary 4: Large area functionalisation of surfaces using Direct Laser Interference Patterning, new approaches and perspectives
Lasagni, Andres (Technical University of Dresden, Germany)


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THE NATIONAL ROBOTARIUM: A SYNERGY OF RESEARCH AND ENGINEERING

The recently opened National Robotarium is a new UK centre for Robotics and Artificial Intelligence research based at the Heriot-Watt University Edinburgh campus. This research focuses on three key areas: Robotics and Autonomous Systems, Human and Robot Interaction and High-Precision Manufacturing.

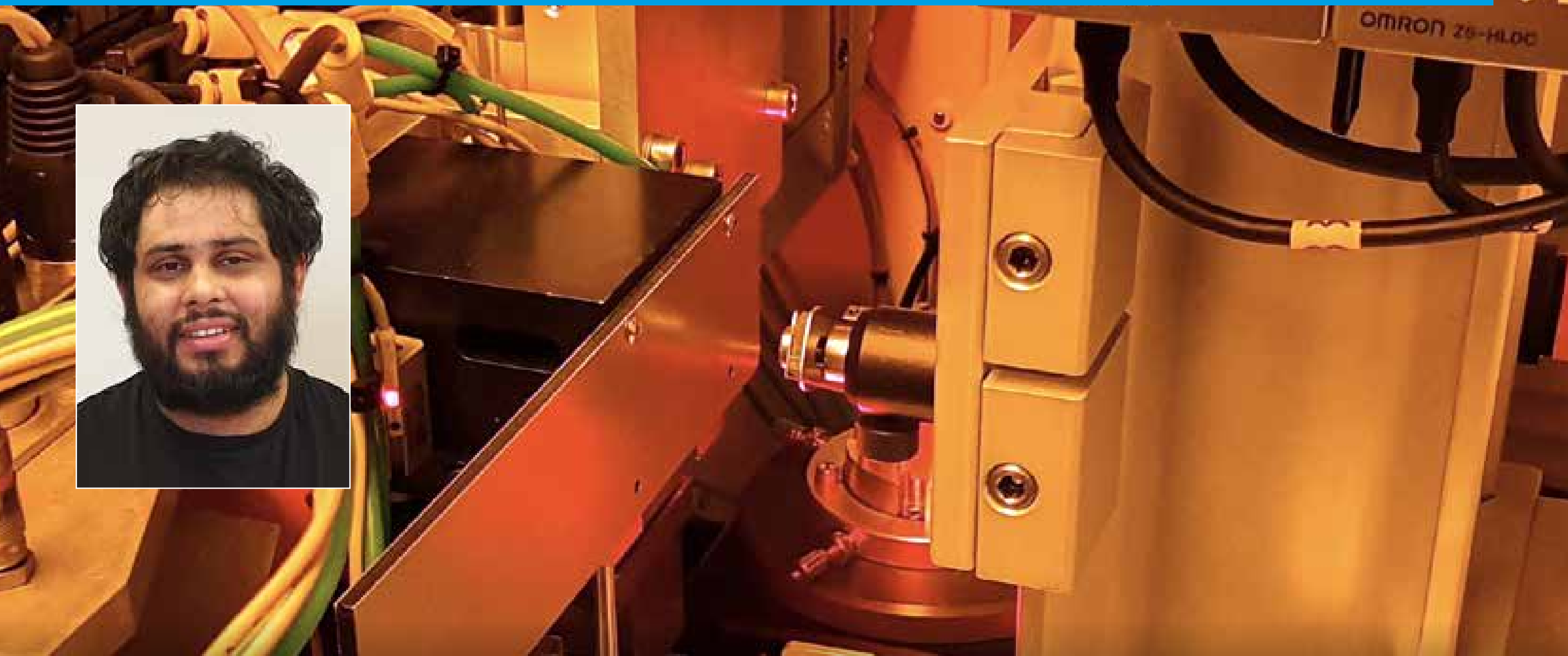
The National Robotarium held its Staff Open Day in December 2022. Staff members from across the University were shown around the new facilities, including the Precision Laser Application (PLA) laboratories. The PLA laboratories are being used for various research projects. These include using ultrafast lasers to weld dissimilar materials, improve surgical procedures, as well as investigations into using robots to aid in the assembly of laser systems.

In principle, robotic systems are ideally suited for performing the sensitive, repetitive and time-consuming alignment processes that currently require well-trained staff. However, due to the initial instrumentation costs involved and the collaborative technical expertise required from both photonic and robotic disciplines, this has not yet been realised. To capitalise upon this potential, optical diagnostics will be combined with human behaviour analysis and machine learning techniques to inform the robotic systems.

The human behaviour analysis will enable the robotic arm to replicate the fidelity of a human user, as the behavioural studies performed on human experts will allow the researchers to interpret how these experts navigate the alignment spaces of increasingly complex optical systems (see image below). These findings will be implemented into the machine learning techniques, enabling the robotic systems to effectively be "taught" by the experts.

The industrial collaborators on the project include Gooch & Housego, Leonardo, Luxinar and Renishaw.

Contact: Donald Risbridger
Donald.Risbridger@hw.ac.uk
https://thenationalrobotarium.com/



INNOVATIVE ANTENNAS MADE BY LASER PROCESSING

AN INTERVIEW WITH SIMON LEISTEN
MANUFACTURING TECHNOLOGY ENGINEER, HELIX GEOSPACE

Q. Can you tell us a bit about Helix Geospace?

Helix Technologies was founded in 2017 by my father Oliver Leisten to commercialise his research in the field of dielectric-loaded multi-filar antennas. Since the foundation of the company, the scaling up process has led to a rapid growth in staff numbers and an exciting product portfolio under the Helix Geospace brand. The business is currently based on the Harwell Campus near Oxford, but plans to relocate to larger premises are under consideration.

Primary markets include autonomous vehicles, satellite communications, defence and aerospace as well as critical national infrastructure. An example of the technology in action is in the navigation of autonomous vehicles (either commercial or military) where the positional accuracy delivered by the system enables a resolution and accuracy of better than 10 cm – essential for safe, collision-free future traffic applications.

The heart of the antenna is a ceramic core (resilient and rugged enough for defence and aerospace applications) that is coated with an etched multi-helix copper track which must be extremely accurately dimensioned. Advanced material science is fundamental to the performance of the high dielectric materials used in our patented DielectriX™ technology. The antenna is smaller than competing technologies – important where compact form factor is critical.

Q. How is your business growing in 2023?

Growth is very rapid as we seek to increase production and respond to the demands of growing markets. Emphasis on improving yield and throughput to enable scaling up from producing 100s of antennas per week to 1,000s per week. We expect a four-fold growth in the business this year, which will require our staff to almost double to meet our targets. Our in-house developed laser machine will be critical to achieving this goal with much improved cycle time using a combination of multi axes motion and precision XY galvo-scanning.

> *"The ability to accurately pinpoint location is enhanced by our antennas"*

Interesting markets for us include the rapid adoption of drones or UAVs (Unmanned Autonomous Vehicles). These vehicles are growing exponentially as new applications in commercial and military markets open up, and the ability to accurately pinpoint location in space and time is enhanced by our antennas.

Satellite communication in remote areas is another growing market and our antennas are compatible with the second generation Iridium network which is used for handheld satellite phones – taking away the reliance on land-based cellular networks and avoiding the need to provide local towers in sparsely populated territory.

Q. How are lasers used in your business?

The process of manufacturing our helical antennas requires precisely etched copper tracks, accurate to a few microns in width. Compensation for the inconsistency of diameter and position of the ceramic during manufacture is made using our proprietary software and the laser is used to expose the etch resistant coating which defines the exact geometry of the copper helix. The laser power is very low as it is not used to machine the copper, only to expose the etch resist.

We are currently using a first generation laser machine and building a second in-house designed system to enhance the process flexibility and cycle time. We are anticipating the use of laser marking too, where we can permanently mark a 2D matrix onto the gold plating with a UV laser. This avoids the use of a sticky label which takes up more space on the product and is a more labour intensive to apply. We are keeping a watch on additive technology and laser micromachining to see if either of them is going to improve our manufacturing process.

Q. What are the biggest challenges at the moment?

As well as ramping up our manufacturing very rapidly, we are looking to hire a lot of staff. During the next months we are transforming our business from VC-funded and grant-funded research and development to full-scale production as a business that can be self-sustaining with a high return on investment. Our laser manufacturing challenge is to convert our breadboard system into a fully-developed production tool capable of high throughput and high yield.

Q. Tell us how you discovered AILU?

Having a requirement to get up-to-speed with the industrial laser supply chain, we very quickly discovered the Products and Services Directory on the AILU website which enabled us to find laser source suppliers, beam delivery and motion system experts and consultants in laser safety and machinery design – as well as subcontractors who could help us develop our process and supply parts.

By the time we visited the AILU stand at the MACH show in Birmingham in April 2022, we knew that membership would be valuable to assist our development of the next generation of manufacturing equipment. We signed up as members very shortly afterwards.

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

Being well-connected to the industrial laser community has been essential for us in selecting the suppliers to use in our production. Attending AILU events is time well spent and during the workshop on laser sources and beam delivery in October last year, I was able

> *"We knew that AILU membership would be valuable"*

to have conversations with people from nearly all the companies who were supplying us, one of them a German supplier that I wouldn't have been able to meet easily otherwise. We have also used AILU to recommend suppliers for software.

Contact: Simon Leisten
simon.leisten@helixgeospace.com
https://helixgeospace.com/

MIDTHERM REAPS BENEFITS OF £1.2M MACHINE INVESTMENT

Midtherm Laser, which employs 45 people at its factory in Dudley, has increased its capacity and speed of processing thanks to the installation of a new Bystronic Bystar Fiber 12 kW laser with part automation.

One of the largest purchases in its 23-year history introduces the next level of power in fibre laser cutting and will help the company deliver high cutting dynamics and thin-to-thick cutting capabilities to a customer base that spans aerospace, automotive and decorative work to food processing, agricultural and conveyors.

It has also made a massive difference to the firm's environmental performance, with the Bystronic model replacing two older CO_2 machines and is already delivering a 50% energy saving – the equivalent of powering 2100 average homes every month.

"Our expertise in laser cutting and metal forming is respected throughout our sector and has led to us increasing sales by a further 6% last year, a great achievement considering the volatility of the market," explained Mark Hannon, Director of Midtherm Laser.

"The knowledge of our experienced people is one of our greatest strengths and we like to complement this with a sustained investment programme that incorporates the latest technology into our production processes."

He went on to add: "The 12 kW Bystar Fiber is a class-leading machine that can cut from 0.5 mm to 30 mm in mild steel, aluminium, and a host of other materials. It gives us more capacity to target new opportunities and, importantly, means three-quarters of our machines are now fibre technology instead of gas.

"With this in mind, and when you consider we have also invested in LED lighting, sensor switches and electric vehicles and charging for our staff on the road, it's not difficult to see how we have managed to cut our energy usage in half since 2018."

Today, Midtherm Laser works with more than 500 companies across 20 different sectors, cutting or forming various sheet metals from 0.5mm to 30mm to a +/- 0.25mm tolerance.

It is also the only sub-contract laser provider that can offer the cutting of non-ferrous materials without the risk of cross-contamination for industries, including food processing and chemical manufacturing.

Richard Andrews, Director at Midtherm Laser, concluded: "There has been a lot of investment recently, with the new laser following the installation of automated warehousing and the rebrand to form the Midtherm Group.

"Embracing new technology is a must for our business, but the company still thrives on the same values my father started it on in 1968, which are quality, service and technical knowledge."

Contact: Mark Hannon
mark@midthermlaser.co.uk
www.midthermlaser.co.uk

FIMARK CELEBRATES 25 YEARS

This year Fimark celebrates 25 years in the laser subcontract industry. Starting with one laser in 1997, Fimark now has 7 lasers including two high-end 5-axis machines.



Contact: Charles Dean
info@fimark.com
www.fimark.co.uk

YORKSHIRE LASER'S TEAM CONTINUES TO GROW

Normanton-based Yorkshire Laser & Fabrication Ltd has welcomed two new members of staff to its team. Their skills and experience will contribute to the future development of the business.

Contact: Matt Orford
matt@yorkshirelaser.co.uk
www.yorkshirelaser.co.uk

EVENT REVIEW

ANNUAL JOB SHOP BUSINESS MEETING

24 NOVEMBER 2022

Our annual meeting took place near the end of November at the National Metalforming Centre, West Bromwich. The focus of the meeting was to present cost saving opportunities for businesses and to introduce handheld welding and cleaning systems, giving members the opportunity to find out more about the new technology.

Talks about steel supply from UK Steel, the best policy when reviewing energy costs (CEC) and the opportunities presented by Degree Level Apprenticeships (University of Nottingham) were followed by a coffee break and the first opportunity to view the exhibited lasers.

Next was a presentation about the benefits of R&D Tax Credits and then an insight into the current status of commercial solar power, interestingly in the current market the typical payback is under 5 years.There was significant interest from delegates about adopting solar PV.

Finally before lunch there were presentations on both laser welding and laser cleaning, setting out the advantages, limitations and important safety issues.

After lunch came the "what's new" session and the overall discussion forum. If you were unable to attend the meeting but would like to know more about the topics covered, please get in touch with AILU, and look out for details of our 2023 event.

BEST OF BOTH WORLDS: A FRAMEWORK FOR COMBINING AM AND IM

NAMEER SYED, NICOLAS DILL & ALISA KAMMER

Additive Manufacturing (AM) and Injection Moulding (IM) are often portrayed as two competing plastic processing technologies.

Injection Moulding is a mature established technology, developed over nearly a century, that offers high quality and repeatability in mass production for various applications – batches of up to 10 million parts with a wide range of materials are realistic expectations.

Conversely, Additive Manufacturing enables today's users to manufacture mass-customised parts, complex geometries, and small batch sizes of up to 200,000 parts economically with a fully digital value chain.

Advanced Manufacturing

The reality of achieving truly advanced manufacturing requires the combination of both technologies in a flexible way across the manufacturing lifecycle. How this is achieved is in part a function of the technical and economic requirements of any given application. It is also important to remember that advanced manufacturing should not be viewed as a catch-all, and different combinations of production technologies will be relevant at different stages of the production lifecycle.

The approach described in this article counters the perceived conflict between AM and IM, and is something that we at EOS' consulting division, Additive Minds, have worked on closely to conceptualise with KraussMaffei, a leading manufacturer of injection moulding machines. Together, we have created a framework to help companies assess the current and future challenges they may face with different aspects of plastics manufacturing, and determine how best to apply and integrate the two process technologies.

The framework will help decision makers choose a suitable plastic processing technology depending on criteria across three categories: technical, economic, and the readiness of their organisation for advanced manufacturing. The output of the framework is a series of graphs, showing which of the manufacturing scenarios would be appropriate.

Using the decision-making framework

Finding the most suitable manufacturing technology for an application can be challenging, particularly when trying to work out whether to focus on conventional manufacturing such as Injection Moulding or newer technologies such as industrial Additive Manufacturing.

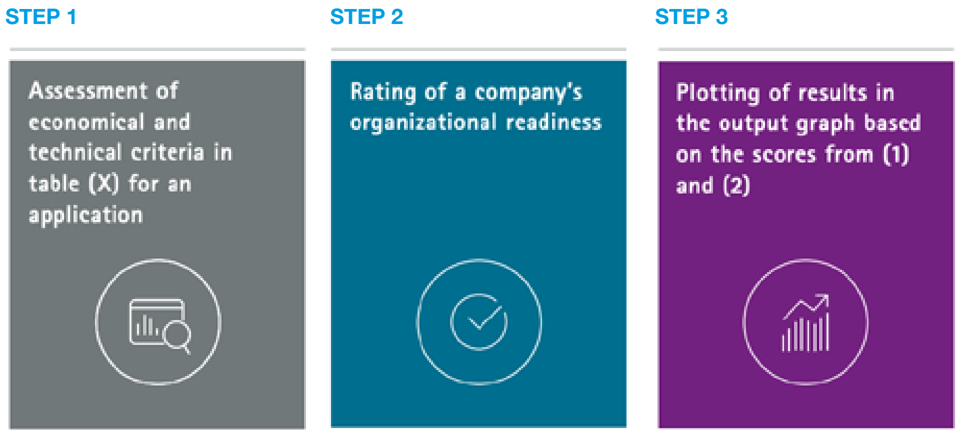


Figure 1: Three steps of the framework

Table 1: Framework senarios

Scenario 1	Applying AM for prototyping and switching to IM when the ramp-up phase starts
Scenario 2	AM and IM are both technically suitable for ramp-up and declining phases. Economic criteria determine at which batch size to switch from AM to IM
Scenario 3	A recommendation for a completed AM solution based on the technological and economic criteria provided
Scenario 4	A recommendation for a completed IM solution based on the technological and economic criteria provided.

The decision-making framework that has been developed is a simple three-step process that will help select the most suitable manufacturing technology for each application (see Figure 1). By completing an assessment for a given application and lifecycle stage, a set of graphs is produced, which suggest which of four manufacturing scenario to consider. The scenarios are outlined in Table 1.

Step 1 Assessment of economic and technical criteria

The first step is to assess an application from an economic and technical perspective, by completing an assessment table. Each economic and technical characteristic has a score, which influences the recommendations of the framework, based on their significance.

Economic factors include the size of the series, time to manufacture, whether the product is highly customisable and the lifecycle stage of the product. Technical properties include the part size, surface quality and tolerances required, as well as regulatory requirements and material availability.

Four of the characteristics in the table are are defined as “star characteristics”. Where these characteristics apply it would push the scenario to be either a complete AM or IM solution.

An example of such a scenario is an application with a series size greater than 500 k/annum. In that case, the costs of tooling and productivity in IM will outweigh any AM solution in the market. On the other hand, if the application requires mass customisation, then an AM scenario will outweigh the costs of producing multiple tools for customised applications; hence the application will shift to an AM only production scenario.

Step 2 Rating of a company's organisational readiness

The final section of the assessment table considers organisational readiness. Ultimately, this is the most important aspect of the framework, as it defines a company's ability to evaluate and switch between technologies.

This is important because there would be little point in proposing a combination of technologies that an organisation cannot realistically apply to a given application. To this end, characteristics such as the level of IM knowledge (in-house), the risks of swapping between technologies, and openness to new technology, will influence the scenario proposed by the framework for the same economic and technical criteria. The results from this section of the assessment will place an organisation at one of the following levels (see Figure 2):

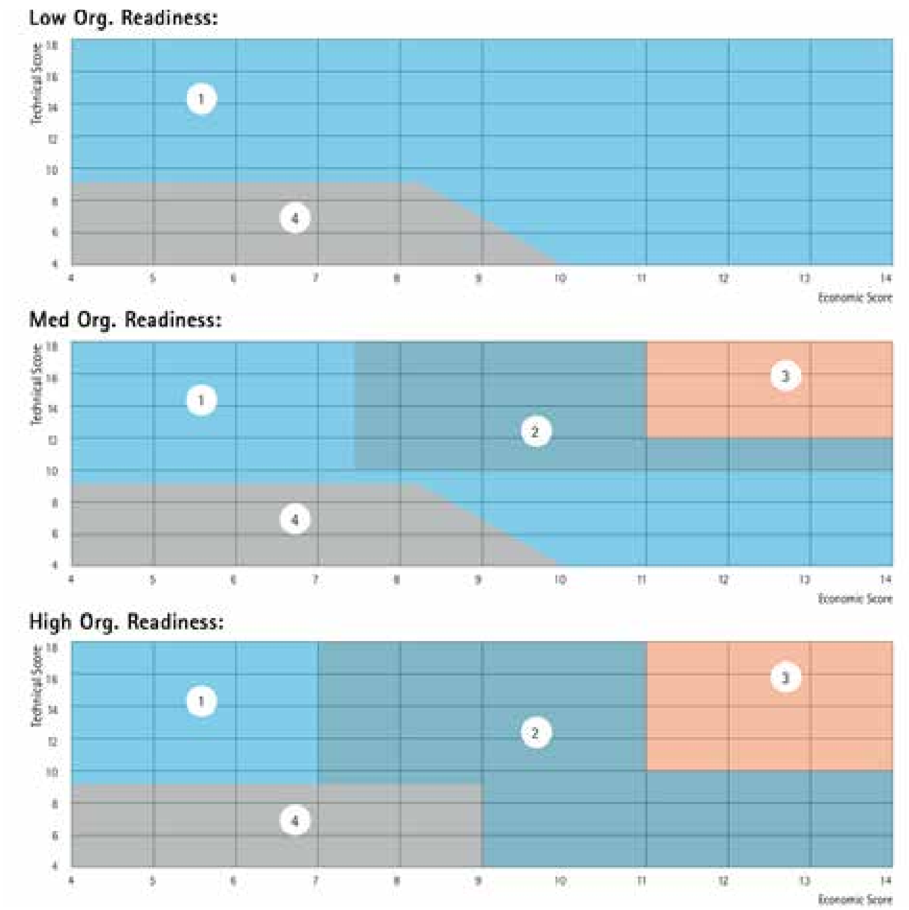
- **Low** – The organisation specialises in IM or AM. It has established manufacturing capacities and experience in running the production line.
- **Medium** – The organisation specialises in IM or AM. Furthermore, it has the knowledge to apply the other technology on a beginner to moderate level. Decisions can be made in favour of one of the two technologies on the basis of a simple break-even analysis.
- **High** – The organisation specialises in both technologies, and can switch between conventional and modern plastic processing technology seamlessly. It has the necessary knowledge of all materials, in-depth expertise in the processes of both manufacturing technologies and an understanding of available manufacturing output.

Step 3 Analysing the results

Once completed, the framework provides three graphs based on the level of organisational readiness (see Figure 3).

On each of the graphs, the application is plotted based on the economic and technical score. The economic score is plotted on the X-axis, and the technical analysis on the Y-axis. The point drawn on the chart is located in one of the four coloured fields. Depending on which field the point is in, that indicates the recommended manufacturing method, which could be IM, AM or a combination of the two.

By reviewing the different graphs, the impact of



1. The use of AM for rapid design iterations and preparation for IM mass production is probable
2. Cost- and time-efficient transition between both technologies is probable
3. The expansion of AM and the exploitation of the potential of the virtual value chain is probable
4. Automated IM mass production is probable

Figure 2: Result diagrams illustrating levels of organisational readiness.

organisational readiness can be seen, and highlights how important it is to be honest about the stage at which a manufacturer is on its journey to advanced manufacturing. The final recommendations provide a point of discussion with all stakeholders across the manufacturing process.

AM and IM are complementary manufacturing technologies

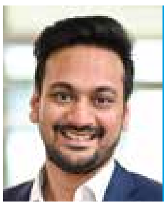
Today, AM and IM production technologies are a key part of the vision for advanced manufacturing. A seamless change between conventional and digital manufacturing technologies depends on the part properties, economic aspects, lifecycle stage and overarching organisational readiness.

By using the step-by-step framework outlined in this article, manufacturers can ease the path of transitioning to advanced manufacturing techniques that combine manufacturing processes. The framework provides manufacturers with a tool to ask the right questions and decide whether to use Injection Molding or Additive Manufacturing.

This article is a summary of the EOS Whitepaper "The best of both worlds: Combining AM and IM" in which detailed explanations of how to use the framework are given, along with worked examples. Download the Whitepaper here: https://www.eos.info/best-of-both-worlds

Nameer Syed & Nicolas Dill are Strategy Consultants at Additive Minds, EOS. Alisa Kammer Is product manager Additive Manufacturing at KraussMaffei

Contact: Nameer Syed
syed.nameer@eos.info
www.eos.info



Nameer Syed is a Strategy Consultant at Additive Minds, EOS. He focuses on enabling customers along the AM adoption journey.

SEE OBSERVATIONS P28

INCREASING THE BUILD RATE OF HIGH-STRENGTH ALUMINIUM ALLOYS

GIUSEPPE DEL GUERCIO & MARCO SIMONELLI

Aluminium (Al) alloys of the 2xxx series are important engineering materials for the aerospace and automotive sectors, having a balance of moderate to high strength and good corrosion resistance. However, the production of structural aluminium components by Additive Manufacturing (AM) and specifically laser powder bed fusion (PBF-LB/M) has yet to achieve its transformative potential for digitalised manufacturing. A major remaining technical challenge is to eliminate the formation of defects such as pores and cracks during processing as these are detrimental to part properties [1].

Currently two main approaches are adopted to mitigate the formation of hot cracks in Al-alloys processed by PBF-LB/M. The most common method is represented by grain inoculation, a well-consolidated technique in casting, in which the addition of selected compounds to the base material promotes the presence of a refined microstructure thought to be advantageous to mitigate hot crack formation [2]. The other method is the use of specific processing regimes (pre-heated substrates [2-3] and/or regimes characterised by low laser scan speed [4-5]) which are thought to reduce the cooling rates during solidification of the melt pool and in turn its sensitivity to cracking.

There remains a need to understand how cracking during PBF-LB/M can be suppressed whilst optimising build rates. This is main objective of the study outlined in this article.

Table 1: List of process parameters investigated in this work.

Parameters	Values
Power P [W]	***200, 220, 240, 260, 280, 300***
Layer thickness Δz [µm]	***30, 35, 40, 45, 50***
Hatch distance h_d [µm]	***120, 130, 140, 150, 160, 170, 180***

Materials and methods

AA2024 powder was procured from TLS Technik AG GmbH. More information on the feedstock can be found in [5-6]. Cubic samples of 10 mm edge were produced using a Renishaw AM400 featuring a 400W ytterbium fibre laser and a Reduced Build Volume (RBV) set up. During processing, the build chamber was held under an Ar atmosphere to minimise oxidation with an oxygen content below 400 ppm. A meander scan strategy, where the direction of laser tracks was rotated by 67° at each layer, was adopted. The laser scan speed v was fixed at 0.107 m/s (point distance of 15 µm, exposure time of 120 µs and an inter-pulse delay of 20 µs), as this proved effective to fabricate crack-free parts. The remained of the parameters that were investigated are given in Table 1.

In order to minimise lack-of-fusion defects we have adopted a melt pool geometrical model as described by Tang *et al*. [7]. Details on the modelling methodology (including measurement on powder absorptivity A) can be found in [3]. The build rate *V* was calculated using the model:

$$\dot{V} = \Delta z \cdot h_d \cdot v$$

where Δz is layer thickness (µm), h_d is hatch distance (µm), and v is laser scan speed (m/s).

Results

Figure 1(a) shows the relationship between the predicted melt pool size and the nominal values of layer thickness and hatch distance. Graphically, the various processing regimes are represented by distinct points in Figure 1(a), where points situated within the area of the graph shaded in green are considered adequate regimes against the formation of lack-of-fusion defects. Figure 1(b-g) depicts optical micrographs of the typical microstructure of samples produced with 260 W but different hatch distance (h_d) and ayer thickness (Δz). It can be observed that these specimens are characterised by the absence of lack-of-fusion pores with the occasional presence of minimal gas porosity. Even more importantly, the absence of both delamination and hot cracks is observed resulting in near-full dense parts.

The graph in Figure 1(a) shows that the specimen depicted in Figure 1(b) is extremely conservative and that the fusion zone created by newly deposited layers extend significantly in the prior layers as well as a large overlap between adjacent melt tracks exists. As all process parameters except layer thickness are kept

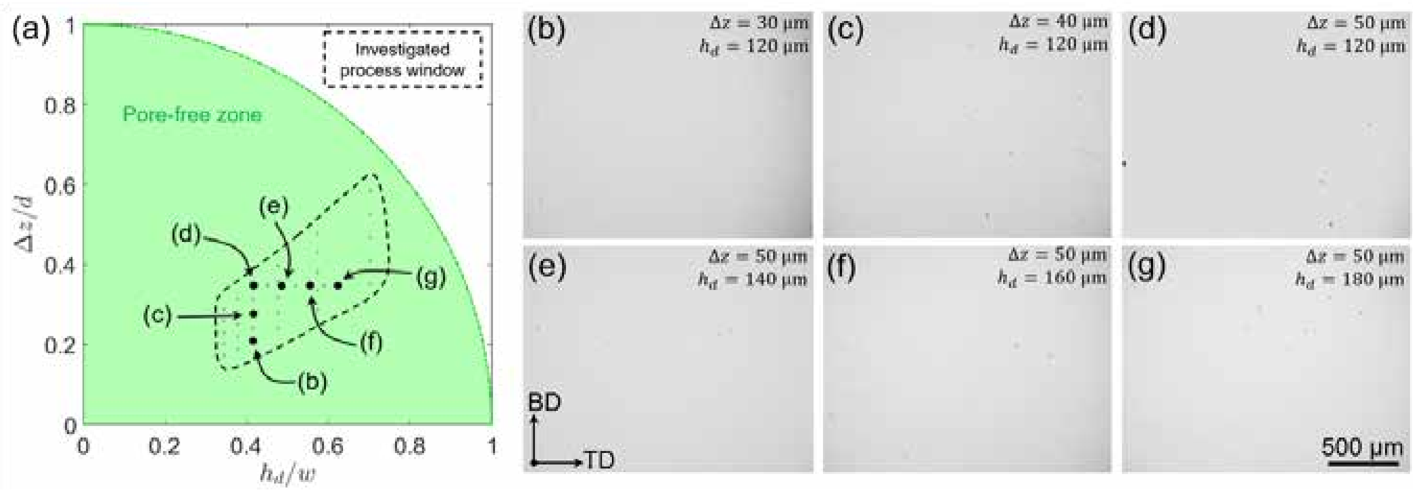


Figure 1: (a) graphical results of the processing regimes predicted to be characterised by the absence of lack-of-fusion defects. (b-g) optical micrographs of specific samples all printed with the same power (260 W) and a progressive increment of (b-d) layer thickness and (d-g) hatch distance.

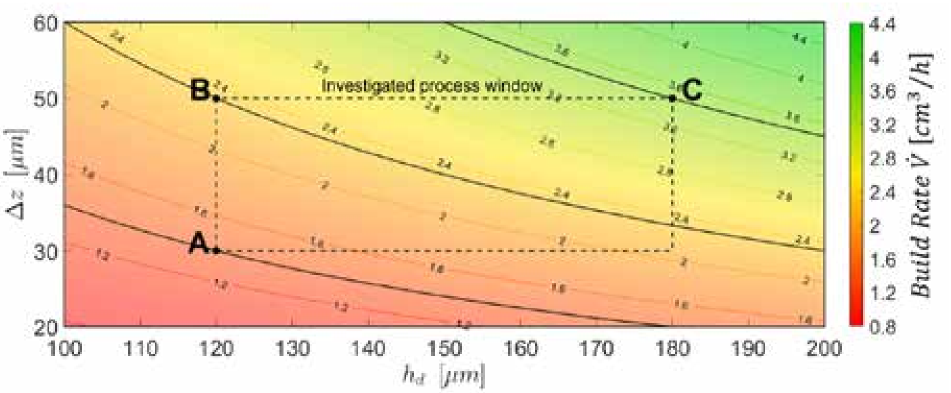


Figure 2: contour plot of the build rate as a function of hatch distance and layer thickness. The dashed box represents the experimentally tested processing window. Three regimes (A, B and C) are taken into account for further investigations.

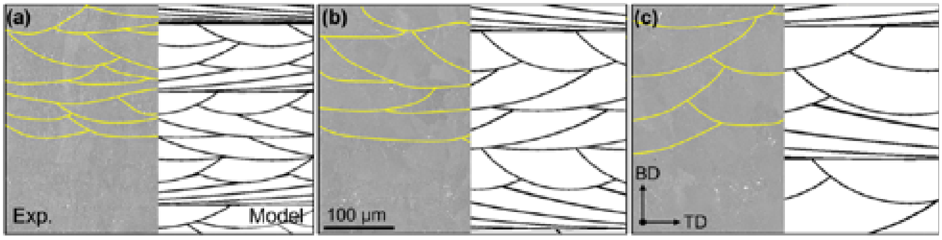


Figure 3: comparison of the melt pool overlap experimentally observed (BSE micrographs on the left, fusion boundaries in yellow) and computationally predicted (right, fusion boundaries in black) adopting the Rosenthal solution. (a), (b) ad (c) depict samples A, B and C, respectively.

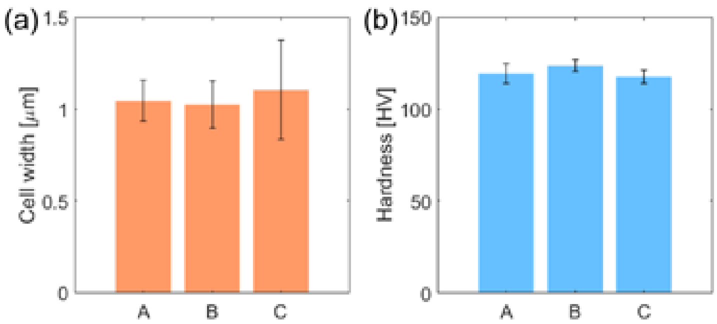


Figure 4: (a) average solidification cell widths and (b) hardness measured for the considered specimens.

constant, it is assumed that the increase in layer thickness (from (b) to (c)) will cause a reduction in layer overlap along the build direction. Similarly, the increase in hatch distance (from (d) to (g)) will cause a reduction in transverse melt pool overlap. Nevertheless, as predicted and experimentally observed in Figure 1, these regimes result to be within an acceptable processing map paired with near-full dense defects-free parts.

Figure 2 is a contour plot that shows how build rate varies with respect to layer thickness and hatch spacing. It can be observed that, within the process parameters range here investigated, to achieve maximum build rate both the layer thickness and the hatch spacing need to be increased. It can also be noticed that the contour lines have a relatively low gradient with respect to the h_d, that is build rate is predominantly influence by Δ*z*.

We therefore compare in detail three build regimes within the range of parameters investigated to establish a pathway to fabricate good quality AA2024 parts. These regimes are labelled in Figure 2 and correspond to Figure 1(b) (point A), 1(d) (point B) and 1(g) (point C). Point A, considered as reference specimen, represents the sample fabricated with a layer thickness of 30 μm which is the default Δ*z* used to process "difficult-to-weld" materials. This is then compared to point B, a material produced by increasing the layer thickness to 50 μm, leading to an increase in build rate of approximately 50%. Finally, we investigate an additional point in the processing map (point C), where the hatch spacing is increased from 120 to 180 μm to achieve a further 50% increment in build rate.

Figure 3(a-c) depicts a comparison of the experimental (left half) and predicted (right half) melt pool traces of samples A, B and C, respectively. This can be used to tune process parameters such as laser power and hatch distance. The underlying Al-FCC grain structure also appears to be affected by the processing regime. It is observed that point A is characterised by grain predominantly elongated towards the build direction (Figure 3(a)). This appears less obvious in the point B and then C where stray grain morphologies also develop (Figure 3(c)).

The characteristic solidification cell size and values of hardness measured for the considered samples are reported in Figure 4. It can be observed that the hardness of the specimens is not significantly different.

Conclusions

This research investigates the consolidation behaviour of a high-strength aluminium alloy (AA2024) in processing regimes characterised by high build rates. The build rate of AA2024 can be increased by 50% when layer thickness is increased from 30 μm (default value) to 50 μm. The build rate can be further increased by using larger hatch spacings, although this parameter has a second-order influence of the productivity. The proposed approach can be uptaken in standard machines and it does not rely on any high-cost adaptations. Therefore, it represents a practical solution to improve the build rate of aluminium alloys in industrial settings.

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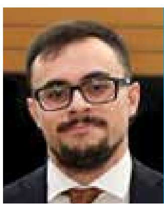
Contact: Giuseppe Del Guercio
Giuseppe.Delguercio@nottingham.ac.uk
www.nottingham.ac.uk



Giuseppe Del Guercio is a PhD student at the University of Nottingham. He aims to improve the processability and properties of high-strength Al alloys.

SEE OBSERVATIONS P28

MANUFACTURING MEDICAL DEVICES USING FEMTOSECOND LASERS

BOGUSZ STĘPAK ET AL.*

A recent report from the World Health Organisation (WHO) identified that heart disease is the leading cause of death globally and that the rate of heart disease cases is rapidly increasing [1]. In order to treat heart disease one of the most common surgical procedures is to implant a small device, called a vascular stent, to maintain blood flow. Stents are also used in other parts of the body to expand constricted vessels. Other locations include the biliary, urinary and gastro-intestinal tracts, as well as the tracheal-bronchial tree.

Stents have evolved significantly in the past two decades and many of them are manufactured by laser cutting and laser welding. In this article we investigate the different types of materials used in stents and how a single laser source can be used to machine all of the necessary materials.

The stent – miniature device saving lives

Since the advent of the vascular stent, heart disease has been successfully treated with minimally invasive surgery. According to reports, more than 965,000 angioplasties are performed each year in the USA alone, in this procedure a balloon is used to inflate the blood vessel – often this is accompanied by the insertion of a stent, in which case the procedure is known as Percutaneous Coronary Intervention (PCI).

The market is divided into vascular and non-vascular stents, with vascular stents being by far the majority. Stents may be coronary or peripheral and there are some other non-stent implants like vena cava filters which are similar in terms of manufacturing requirements.

Materials for stents

As stents are implanted in the body, there are a variety of requirements that must be met. Firstly, it is essential that they are made from a bio-compatible material which will not cause a reaction with tissue and blood. Secondly, stents are implanted for long periods of time and thus they must be resilient and durable. Finally, stents require high precision processing so that they are fit for purpose and do not accumulate debris.

Traditionally, metals have been used with the most common being stainless steel, nitinol (a nickel titanium alloy with shape memory) or cobalt chrome alloys. These materials have high wear resistance, high impact strength, ductility and the capacity to absorb force well. To ensure that there is no restenosis (repeated narrowing of the artery), sometimes drug-eluting stents slowly emit drugs, preventing swelling of the tissues and restriction of the blood flow.

Another technique to ensure long term efficacy is to use a stent which has suitable mechanical properties but gradually dissolves in the artery – these are known as bioabsorbable (or bioresorbable) stents. Typically, these are either made from magnesium alloys that 95% dissolve harmlessly in situ, or alternatively they are made from polymers like Polylactic Acid (PLA) and similar materials. The laser cutting of metals and polymers with a single laser source is challenging as typically they have different laser material interactions depending on wavelength, power and pulse duration.

Laser manufacturing of stents

Over the years, many methods of manufacturing stents have been developed, such as braiding (sometimes joined with laser welds), micro-injection molding, 3D printing or laser cutting, but only the latter meets the demands of high precision in both polymer and metal structures.

One source for all materials

When manufacturing stents by laser cutting, the highest demands on geometrical repeatability, rapid throughput and minimum post-processing are all significant. Given the different types of materials used (both metallic and plastic) there are distinct advantages in having one source which can cut multiple materials, consequently minimising the cost of production machinery.

One of the main advantages of laser cutting with ultrashort pulses (less than 1 picosecond) is that there is virtually no heat input which avoids the heat affected zone (HAZ) also the melting of heat-sensitive polymers. The interaction time of a femtosecond pulse is much shorter than the thermal diffusion time, which results in cold ablation cutting rather than thermal cutting – a much cleaner and more precise solution for all materials.

Femtosecond lasers with a combination of short pulse, high energy peak and customisable repetition rate (e.g. the Jasper X0 from Fluence) make this application successful. Recent testing in the Fluence Ultrafast Laser Application Laboratory (ULAL) has investigated many applications, including one of the most challenging, the fabrication of stents made of thermally sensitive biodegradable PLA.

Two methods of material processing using ultrafast lasers are dicing and laser ablation. Each has their own benefits, and ultrafast lasers provide capability to both methods, which are explained in the following sections of this article.

Dicing method

When cutting materials like PLA, it is possible to use a “dice and break” technique. The results shown by Fluence Technology show extremely high cutting speeds, up to 1 m/s, with high quality when using this advanced and novel processing technique in the PLA material. As shown in Figure 1, the material is diced with a very fine row of holes (between 1 and 2 microns in diameter) which can then be mechanically broken to give a very smooth edge without melting and “striations”. This effectively limits the HAZ of the material to a negligible level in terms of the chemical changes in the material.

Figure 2 shows the edge quality of laser cut PLA sheet close up. The lack of melting at the edge allows the possibility of leaving a small

Figure 1: PLA dicing through internal modifications before fracture.

Figure 2: PLA sheet after dicing and fracture showing the smooth cut edge.

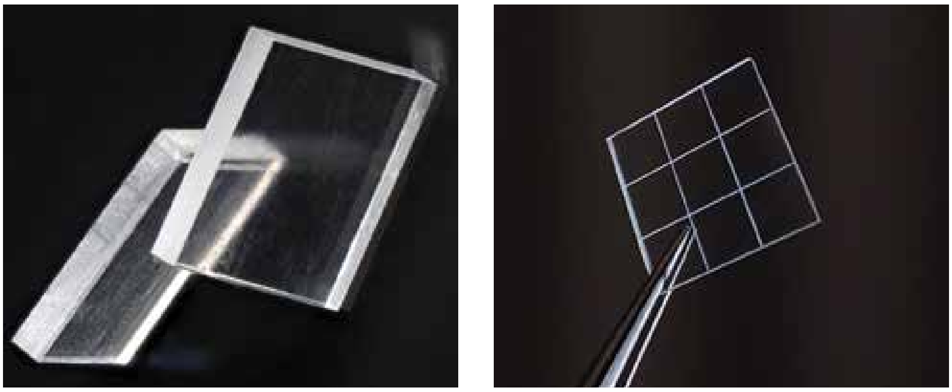


Figure 3: Cut elements from PLA sheet, using femtosecond pulses and precise optics. Dicing-like process of PLA with non-ablative approach based on the weakening the material along ultrathin line <1 μm. No material loss occurs and the process is the most inert to the material. The size of the squares is 2 x 2 mm.

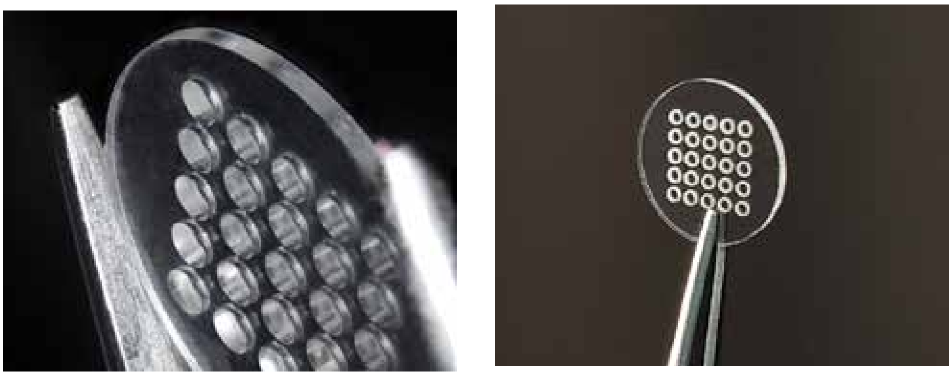


Figure 4: An example shape cut from biodegradable polymer using ultrashort pulses. The diameter of the holes is 500 μm.

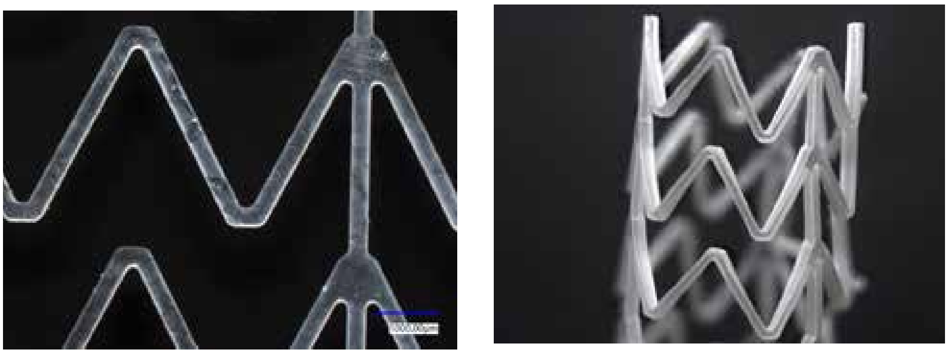


Figure 5: PLA stents processing result of ablation cutting with a femtosecond laser Jasper X0.

amount of material between adjacent cut outs. In the application of stent cutting, it is the small "struts" between the cut-out material that form the scaffold on which the product relies for successful expansion inside the artery.

Recently a technique of non-ablative, modification-based separation of the material was adopted for bioresorbable polymer cutting. With ultrashort pulse duration, which is <250 fs, and using beam shaping, it was possible to cut PLA with negligible kerf (< 1 μm) and no taper, which is typically an issue with ablation cutting, as well as no HAZ. Moreover, speeds up to 1 m/s can be achieved with no material loss and round shape fabrication capability (Figure 3 & 4).

This kind of cutting based on laser modification (dicing) and followed by a mechanical separating force leaves the material untouched, which ensures biocompatibility. By combining the advantages of ultrashort pulses with innovative beam shaping, the laser-matter interaction is strongly localised along a very narrow (~1 μm) filament.

Laser ablation method

More commonly in laser cutting, the approach is to cut using material removal (ablation). For comparison to the non-ablative method, ULAL manufactured the polylactide structures also via ablation cutting.

Very strong and localised absorption in the UV spectral range combined with multiphoton ionisation provides the highest precision, reduced HAZ but also high throughput when it comes to free shape polymer cutting. An important factor is also that post-processing after laser cutting is minimal. Precisely finished, smooth edges of these stent struts are safe for the body, reducing risk of injury to the vessel tissues (Figure 5).

This technique is also applicable to metal stents which currently form the vast majority of the total market. Ultrafast lasers are used in metal stent manufacturing where the reduction in burr and HAZ makes a suitable surface for the stent struts which will no longer need deburring (an issue commonly found with nitinol when cut using longer pulse lasers). The minimal impact on the surrounding material is also advantageous for metals as the physical properties remain substantially unchanged. Research developed by Fluence Technology shows that smart machining using femtoseconds does not affect the corrosion resistance of the steel.

Ultrafast lasers not only yield the best results for micro-cutting but also for surface patterning as ultrashort pulses do not damage the material. Surface modification improves the implant integration within the body and may serve several additional functions like antibacterial action or enhancement of the desired cell proliferation.

Conclusion

Vascular and non-vascular stents enable serious medical conditions to be treated with minimal invasive surgery, and are made from durable bio-compatible materials requiring precise laser machining to manufacture. Ultrafast pulsed lasers utilise precise bursts of light to cut stents smoothly and to extremely high tolerances, and they improve implant integration via laser surface patterning. Femtosecond lasers are used to manufacture metal stents and are the only practical solution for polymer stents. Femtosecond lasers enable high throughput and maximum flexibility, making them the preferred tool for stent manufacturers regardless of material.

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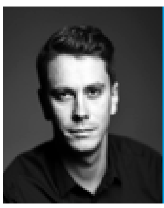
*** Bogusz Stępak, Katarzyna Kowalska, Dariusz Świerad, Yuriy Stepanenko, Michał Nejbauer - Fluence Technology, Poland**

Contact: Bogusz Stępak
info@fluence.pl
https://fluence.technology/



Bogusz Stępak joined Fluence in 2019 and established the Ultrafast Laser Application Laboratory. He is R&D Director of Laser Microprocessing at Fluence.

SEE OBSERVATIONS P28

SURFACE TEXTURING

IMPROVING THE SPREAD OF LIGHT IN TIN OXIDE THIN FILMS USING DLIP

HERMAN HEFFNER ET AL.*

Surface texturing of transparent conductive oxides (TCOs) is of special interest for optoelectronic devices. This article presents the impact of infrared (IR) sub-picosecond Direct Laser Interference Patterning (DLIP) on the surface morphology, optical and electrical properties of Fluorine-doped Tin Oxide (FTO). The topography characterisation revealed periodic line-like microstructures with an average height between 15 and 600 nm, depending on the applied laser fluence. The presence of Laser-Induced Periodic Surface Structures (LIPSS) in the same direction of the laser structuring was also observed. An increment in the incident spread of light up to 700% was obtained in the visible-Near-Infrared Radiation spectrum as an outcome of the interaction of the periodic micro- and nanostructures with white light. Our results indicate that DLIP is a powerful tool for future application in structuring electrodes for highly efficient optoelectronic devices and sensors.

Introduction

Transparent conducting oxides (TCOs) have garnered much of the attention of the scientific community in recent decades due to their ability to function both as an optical window allowing light to enter, as well as a top electrode for high-efficiency optoelectronic devices, such as thin film (CIGS/CdTe) [1] and dye-sensitised solar cells (DSSCs) [2]. To meet this high-performance quota, work has been done to improve their optical and electrical properties. In particular, fluorine-doped tin oxide (F-SnO_2; FTO) is the electrode of excellence in DSSC cells due to its low cost, thermal resistance and electronic compatibility. To approach the maximum theoretical efficiency of solar cells [3], different strategies involving surface modification strategies of FTO thin films have been studied. In this direction, previous works have sought to enhance the optical path by scattering the incident light (T_{diff}) [4].

Experimental details

FTO films (~550 nm thick) glass substrates (XOP Física, Spain) were textured by the DLIP technique. A DLIP workstation (developed by Fraunhofer IWS and TU Dresden, Germany) equipped with a sub-picosecond solid-state laser (LXR 100-1030, Luxinar GmbH, Germany) with a maximum average output power of 100 W at a pulse frequency of 1 MHz was used to structure the FTO substrates. The laser operated at a wavelength λ_L=1030 nm with a pulse duration of τ_L=900±100 fs and a repetition rate of f_L=100 kHz. The DLIP optical module consists of a telescope system that acts as a beam expander, and a diffractive optical element (DOE) that divides the main laser beam into two sub-beams which are then parallelised using a prism and focused on the substrate by a convergent lens.

Results

In order to quantify the topographical effects that laser ablation induced on FTO thin films, the surface topography of DLIP-treated FTO thin films using Atomic Force Microscopy (AFM) is shown in Figure 1(a-b) for the highest and lowest applied laser fluence. For a fluence level of F=0.73 J/cm^2, line-like structures with a spatial period of 6.0 µm and an average structure height of ~600 nm could be observed. The quality of these structures is reflected in the high regularity of the profile. For the lowest value of laser fluence, significant lower heights were reached (Figure 1b) with an average value of ~15 nm. Since the used laser parameters are close to the ablation thereshold, a lower homogeneity for the structures was obtained.

Further characterisation of the produced topographical elements was performed using Scanning Electron Microscopy (SEM) analysis. For instance, Figure 2 shows an SEM image for a treated sample at a laser fluence of F=0.73 J/cm^2. The formation of Laser-Induced Periodic

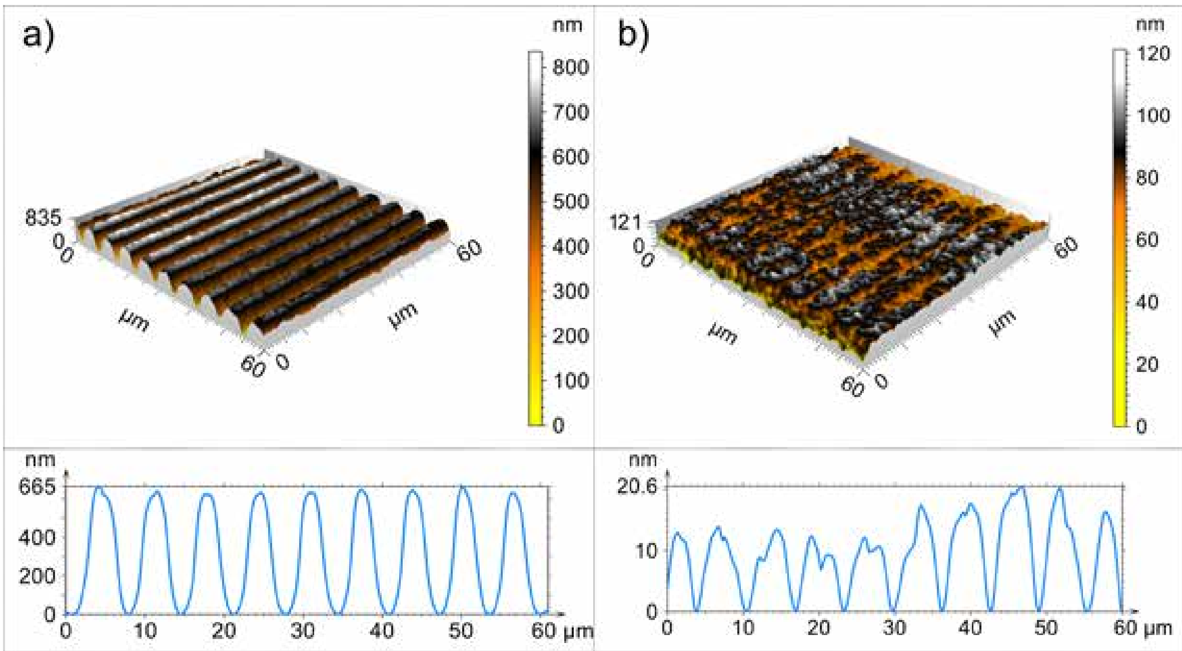


Figure 1: Structured FTO AFM images along with the average height profiles for fluence levels: a) F=0.73 J/cm² and b) F=0.42 J/cm²).

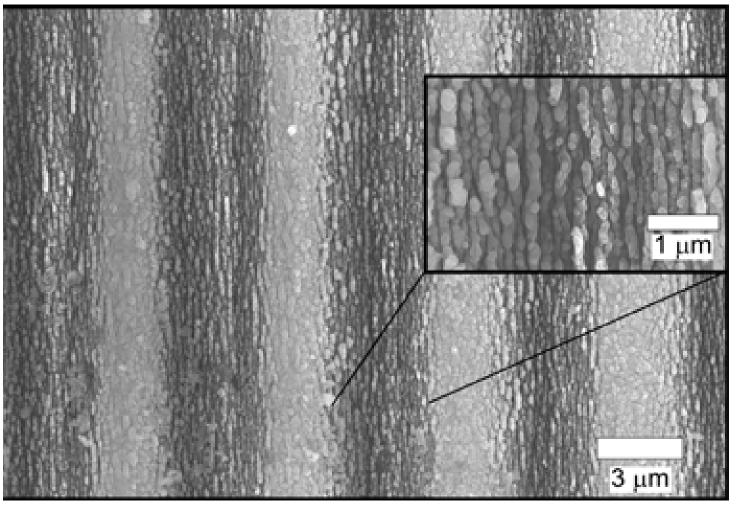


Figure 2: SEM image of structured FTO sample using laser fluence of F=0.73 J/cm² along with a zoomed view of the generated LIPSS.

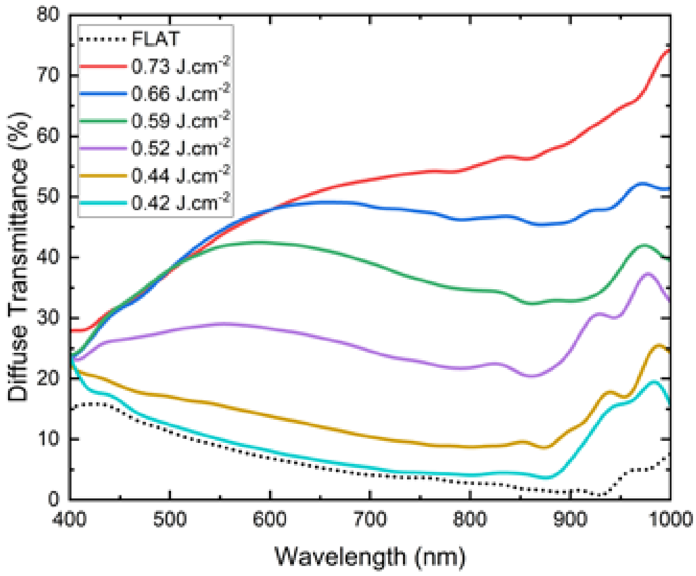


Figure 3: Diffuse transmittance of structured FTO films for selected fluence values (continuous lines). The dotted line indicates the value for untreated FTO.

Surface Structures (LIPSS) can be observed in the valleys of the texture which is in accordance with the maxima positions of the interference pattern. The spatial period of the produced LIPSS was estimated to be 200 ±40 nm.

After that, the changes in the optical properties of the laser treated samples was evaluated by measuring the diffuse transmittance in the wavelength range from 400 to 1000 nm as illustrated in Figure 3. The measured diffused transmission (T_{diff}) improves remarkably after the DLIP treatment, particularly, for the film treated with a laser fluence of F=0.73 J/cm²), exceeding 50% (absolute) in the 600–1000 nm range. This outstanding outcome can be recognised in Figure 4 where a photograph of a laser-treated FTO with the highest laser fluence is shown and the spread of light's reflection into the different frequencies of the visible spectrum can be recognised. This outcome might improve the photon-harvesting capabilities in optoelectronic devices in the vis-NIR spectrum or enhance the light out-coupling for light-emitting diodes [5].

Conclusions

The surface modification as well as the enhancement in the spread of incoming light that laser texturisation using DLIP induced in FTO thin films was analysed. As the laser fluence underwent from 0.42 J/cm² to 0.73 J/cm², the FTO film progressed from a slight surface modification to the development of well-defined line-like microstructures along with the formation of LIPSS. In addition, a remarkable enhancement in the absolute spread of light, particularly, in the 600–1000 nm spectral range an increase by up to 50% was achieved as a consequence of the diffraction of incoming light into several diffraction orders by the periodic texture.

The improvement of the scattering of light can benefit optoelectronic devices by increasing the absorbance in the active layer, particularly for those devices based on photoactive materials with an optical bandgap in the NIR spectrum. In addition, the increase in the effective surface area by the formation of micro- and nanostructures might be also beneficial for a more effective charge transfer between the electrode and electrolyte in the DSSCs.

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*** Herman Heffner, Marcos Soldera, Frederic Schell, Marielle Deconinck, Yana Vaynzof, Lucinda Mulko, Andrés Fabián Lasagni**

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Contact: Herman Heffner
herman.heffner@tu-dresden.de
https://tu-dresden.de/ing/maschinenwesen/if/lmo

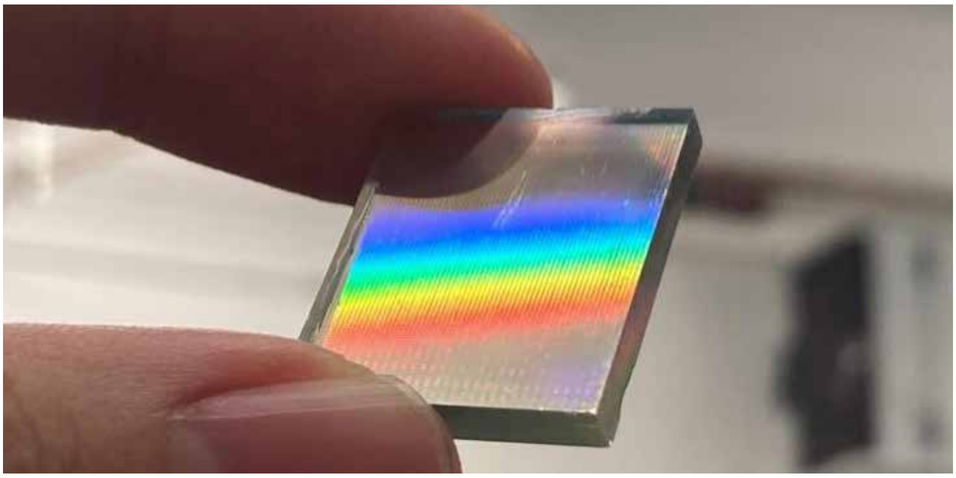


Figure 4: Photograph of laser-processed FTO thin film with a laser fluence of F=0.73 J/cm².

Herman Heffner is an associate researcher of the Chair for Laser-based Manufacturing (LBF) at Technische Universität Dresden.

SEE OBSERVATIONS P28

SURFACE ENGINEERING

NEXT-GENERATION LASER SHOCK PEENING: A COMPACT LSP SYSTEM

PRATIK SHUKLA

Laser Shock Peening (LSP) is an advanced surface treatment process that can tackle many industrial problems related to fatigue, corrosion damage, wear, microstructural defects and tensile residual stresses. The process has been around for up to 5 decades, but its full deployment for wide a range of industrial applications is still scarce. One of the primary reasons for this is due to the high implementation cost, including the cost of a high energy laser source; its cooling requirement; the cost of suitable beam delivery; motion system; ample space and utility requirements; laser safety enclosures; as well as significant integration and know-how to put the process/system together. This discourages many potential end-users who might otherwise benefit from implementing the technology.

Development of a new portable system

A viable industry solution has been developed to address these issues utilising the author's experience of implementing high intensity laser peening in academic/research institutions for the past nine years. This development offers a step-change by introducing the next-generation laser shock peening that is not just cost effective but, flexible, easy to use, and integrated as a turn-key solution. This helps to take laser peening out of the labs and onto the factory floors – helping the industry uptake of this technology. The system is being commercialised via a start-up company, Bright-Beams Laser Technology Ltd.

Portable LSP has been reported in the past, but to the author's knowledge, this is the first genuinely compact system developed with a dimensional foot-print of 750 mm x 750 mm and can be operated free-standing on four wheels, or placed on a table or a bench-top.

The system is also energy-efficient, offering low wall-plug efficiency and cost per Watt. The system can be deployed to undertake a wide range of additional processes, namely; laser hardening; laser blast cleaning, laser rust removal and bond inspection. The system comprises of features including both green and infra-red wavelengths that are desirable for laser peening a wide range of materials/parts. Some of these features are also subject to a recently filed patent (GB2215953.7).

The user is able to manoeuvre the system from one place to another with minimal effort and avoid the requirement of expensive utility. There is no need to build enclosures for laser safety, as the system is fully enclosed. The laser peening treatment can also be conducted on both flat-sheet parts for academic use, and circular and curved parts suitable for industrial purposes, particularly small-scale miniature parts, as built with additive and conventional processes. Various confinement mediums can also be made available with the end-user having the option to develop their own confinement methodologies within the system for their own process development.

System validation

Bright-Beams has been working with several academic partners to test and validate the system, namely; the University of Malta, Loughborough University, Brunel Innovations Centre, and TNO (Netherlands).. Some of the materials tested after LSP were; an additively manufactured Inconel 718, commercially available copper, aluminium, stainless steel, austempered ductile iron (ADI), and advanced ceramics.

A low energy Nd:YAG laser was deployed within the system for the LSP application, emitting laser energies ranging around 240 mJ to 500 mJ per pulse. The spot size of the beam was 1 mm with a wavelength of 1064 nm and 532 nm. The laser emitted a beam quality factor (M^2) of 1.6 at 1064 nm and 1.4 at 532 nm, delivering a flat-top beam profile after characterisation. Laser shock peening without coating (LSPwC) was conducted with a polymer confinement layer for the trials reported in this article. The energy loss through the polymer confinement layer was an average of 8% for 1064 nm and 21% for 532 nm wavelengths. The pulse overlap was 20% and was delivered in a zig-zag pattern over the surface of the specimens.

An average surface hardness from 10 indentations was measured on each surface for both the treated and untreated metals. Residual stress was also measured for the AM Inconel 718 using the X-Ray diffraction technique (curtesy of Dr. Prabhakaran Subramanian, University of Malta) and is presented in Figure 1. The untreated specimen demonstrated -51.4 MPa of compressive stress, whilst, both the laser shock peened substrates with 532 nm (green) and 1064 nm (near-infra-red) wavelengths showed higher compressive stresses of -312 MPa and -455 MPa respectively. The hardness of the specimen can be found in Table 1 showing 10% increase on the top surface layer. Published literature [1] on LSP AM Inconel 718, made with the direct metal laser sintering (DMLS) process, showed that macro-hardness increased to 13%, on the surface. The compressive residual stress of -398.7 MPa was reported on the surface after LSPwC with 350 mJ, 0.8 mm spot size, 50% overlap, 10 ns pulse duration and 10 Hz repetition rate, using PVC confinement layer. A 4-fold increase in residual compressive stress was observed, whilst, in comparison to the maximum 9-fold increase in the results found in this work using lower laser intensity. Another study on an additively manufactured specimen of Inconel 718, showed Vickers micro-hardness of 360HV, and compressive residual stress of up to -307.9 MPa after LSP [2]. The laser power applied was 170 mW with 7 shots [2]. The results herein only delivered one pass (layer), thus, applying more passes is likely to render deeper and higher magnitude of residual compressive stress.

Table 1 shows surface hardness of some of the metals trialled in this work, using low energy LSPwC. Previous literature on aluminium alloy 5083 [3], reported a 19% increase in surface hardness when pulse energy was 1.3 J with 20 ns pulse duration and laser power density of 2.2 GW/cm^2. This was significantly higher compared to the laser power densities applied herein. LSPwC of copper, at laser energy densities of 5.3 and 10.6 GW/cm^2 enhanced the surface hardness from 55 HV to 110 HV and 120 HV for the laser shock peened copper at 5.3 GW/cm^2 and 10.6 GW/cm^2, respectively [4]. This was again significantly higher than the energies applied in this work. Thus, it goes to

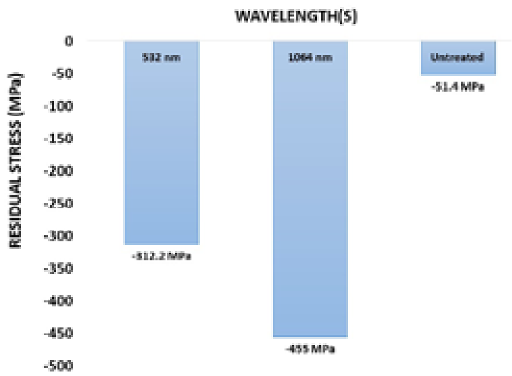


Figure 1: X-Ray diffraction measured residual stresses for both the untreated and laser shock peened Inconel 718 using the Bright-Beams compact LSP system.

Table 1: Average surface hardness of various metals tested from initial feasibility trials along with process parameter applied.

Material	Hardness (HV)		STVD		% change after low energy LSPwC	Laser Peening Parameters
	Untreated	LSP	Untreated	LSP		
Copper	82	89	2.38	2.29	9.5%	250mJ per pulse, 1 layer, 1mm spot, 20% overlap @ 532nm, 10ns, 10Hz, polymer confinement
Aluminium	35	40	0.98	1.66	13%	480mJ per pulse, 1 layer, 20% overlap @ 1064nm, 10ns, 10Hz, polymer confinement
Austempered Ductile Iron (ADI)	274	345	6.85	10.35	23%	475mJ per pulse, 1 layer, 1mm spot size, 20% overlap @ 1064nm, 10ns, 10Hz, polymer confinement
Inconel 178 Additive Manufactured (see Figure 1)	449	496	21.67	8.32	10%	470mJ per pulse, 1 layer, 1mm spot size, 20% overlap @ 1064nm, 10ns, 10Hz, polymer confinement

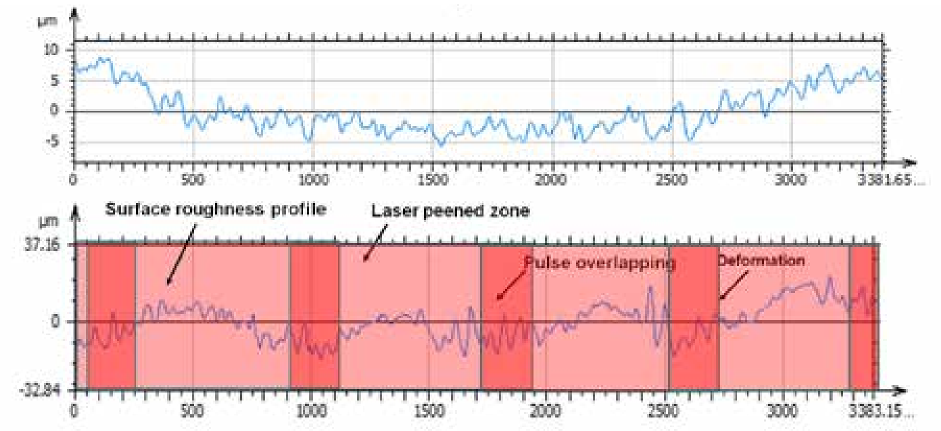


Figure 2: Surface roughness 2-D profiles of untreated (as-built) surface in (a) and (b), the laser shock peened surface of additively built Inconel 718.

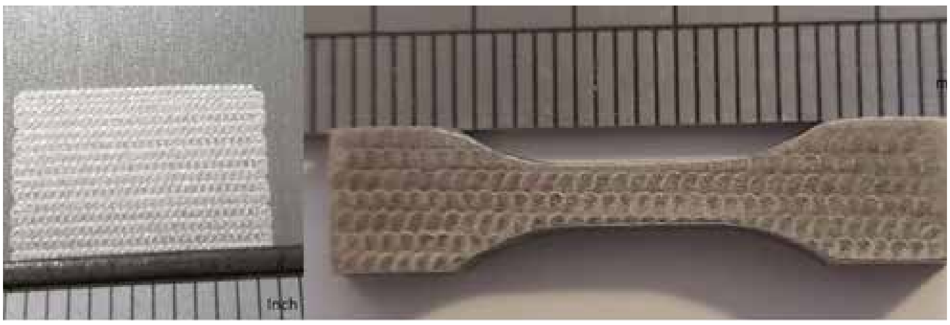


Figure 3: Examples of a laser shock peened surface of aluminium in (a) and Inconel 718 Additive manufactured specimen in (b), using the compact Bright-Beams LSP system.

show that with further optimisation of the parameters using the Bright-Beam system, especially, using the 532 nm wavelength, offering increased likelihood of higher absorption into the copper, would create further improvement. In addition, the findings presented in this article are only showing measurements of the surface. Upon sub-surface and cross-sectional characterisation it will further reveal how deep the effects have rendered, particularly, using the 532 nm wavelength.

The measured roughness of a polished and smooth surface finish was 1.08 µm (Ra), and 4.82 µm (Sa). At the same time, the roughness of the laser shock peened surface measured 3.88 µm (Ra), and 8.89 µm (Sa). It is evident from Figure 2, that dimpling can be visible from the optical image and the 2-D roughness profiles showing deformation in the peened areas. This is indicative of the deformation and the respective residual compressive stress found in Figure 1.

Summary

The results herein are subject to initial observation of LSP interactions with the materials using the new Bright-Beams Compact system. The trials have shown that this new system is capable of improving both the hardness and inducing residual stresses of an additively built metal, as well as other materials by applying low energy LSP. This technology can be deployed at low capital investment, low cost per Watt with higher wall plug efficiency, aided by a turn-key solution requiring minimum effort/space to implement, as well as set-up the process. This helps to take the field of laser peening forward, aids the industry uptake of LSP technology and enables end-users to solve some of their issues around fatigue, wear, tensile stresses, microstructural defects and ultimately, improve part performance, including additive builds.

Upon optimisation of process parameters using this system, the scope for improvement and part performance can be significantly higher. Further validation will include in-depth residual stress measurement of the sub-surface area, and a full microstructural analysis, and mechanical property measurements. Detailed results on these tested materials will be communicated in a longer publication.

References

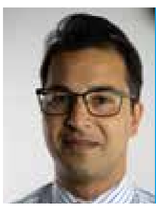
[1] Navin Kumar et al. (2019), Study on Effect of Laser Peening on Inconel 718 Produced by DMLS Technique, SAE Technical Paper 2019-28-0146.

[2] Jinoop, A.N. et al. (2019). Int. J. Precis. Eng. Manuf. 20, 1621–1628.

[3] Jan Kaufman et al. (2019), Laser shock peening of aluminium alloys to enhance surface properties, MM science journal, 3638 – 3642.

[4] Changkyoo Park et al.(2020) Applied Surface Science, 514, 145917.

Contact: Pratik Shukla
info@bright-beams. com
www.bright-beams.com



Pratik Shukla is a founding director of Bright-Beams Laser Technology and also an Editor-in-Chief of the International Journal of Peening Science and Technology.

SEE OBSERVATIONS P28

OBSERVATIONS

BEST OF BOTH WORLDS: A FRAMEWORK FOR COMBINING AM AND IM

NAMEER SYED, NICOLAS DILL & ALISA KAMMER

The use of Additive Manufacturing (AM) in conjunction with Injection Moulding (IM) can be beneficial for manufacturing especially when high production numbers and customisation are required. However, the use of both techniques must be carefully assessed for each organisation.

It is important to realise that the introduction of new manufacturing process such as AM cannot always replace all the benefits of conventional processes such as IM. Therefore, the combination of both techniques can have a positive impact on the production of certain products.

This article gives us an insight into the use of both manufacturing techniques must be assessed in consideration of economic, technical and organisational circumstances before providing recommendations to the stakeholders. A careful assessment of each scenario and organisation readiness is fundamental for the correct decision making and this article provides a useful summary of how such assessment should be made.

David Rico-Sierra, Cranfield University

As additive manufacturing (AM) matures, the benefits of integrating it with well-established production methods are becoming clear. Injection moulding (IM) is currently the gold standard for high-volume manufacturing, but it is not without its disadvantages. Firstly, making tooling is an expensive and long-winded process, only worthwhile in mass production scenarios. Moreover, inherent limitations in part manufacturability through IM may dictate that several parts be combined to make complex shapes, resulting in poor stack tolerances.

On the contrary, AM is most suited for small to medium-sized batches of individually customisable, complex parts. Its capabilities to consolidate assemblies into single parts and rapidly iterate through different mould designs can significantly streamline product development. It is therefore not surprising to see that in many scenarios, using these technologies synergistically can be an attractive proposition. Careful consideration of the technoeconomic factors laid out in this framework by EOS and KraussMaffei will certainly facilitate this transition for advanced and basic users of either technology.

Ioannis Bitharas, Heriot-Watt University

INCREASING THE BUILD RATE OF HIGH-STRENGTH ALUMINIUM ALLOYS

GIUSEPPE DEL GUERCIO & MARCO SIMONELLI

Increasing the productivity and build rate in laser powder bed fusion is indeed a legitimate target to maximise the throughput of the process. Strategies to increase the build rate through controlling the laser power, scan speed, layer thickness, or even using multiple layers have been previously attempted, but they all appear to have a physical limit. Increasing the laser power may trigger keyholing defects if the scan speed is not sufficiently increased to reduce the net energy input. Still, increasing the speed itself may disturb the powder due to the recoil pressure in the meltpool and the denudation that typically happens at the vicinity of the laser track.

High laser powers can also promote selective evaporation of low boiling point elements (e.g. Mg in AA2024). The same applies for layer thickness; our previous work (Qiu et al., Acta Materialia, 2015) showed that increasing the layer thickness to ~100 microns promotes the formation of spatter, but this can be mitigated by controlling the gas flow speed inside the chamber. Overall, it appears that there is a physical limit for controlling the process productivity, while ensuring the microstructural and mechanical integrity of the builds. As such, this study is a timely investigation to explore how the physical limit for process productivity control can be further expanded.

Moataz Attallah, University of Birmingham

MANUFACTURING MEDICAL DEVICES USING FEMTOSECOND LASERS

BOGUSZ STĘPAK ET AL.

Femtosecond lasers have been used in medical devices for years in cutting of both metal and bioresorbable stents, the article presents some of the advantages of using this source specifically for cutting the polymer stents and scaffolds.

Today, the use of FS lasers is growing but primarily for cutting metal stents that enable finer resolution and smaller tube diameters, while decreasing production costs as the sublimation cutting process eliminates the post process of burr removal.

FS laser adoption has been accelerating for stent cutting, and many other applications in medical device manufacturing as a “perfect storm” now exists; superior cut performance enabling product innovation, reduced production costs, and better ROI as laser prices continue to come down with volume production proven platforms that offer 24/7 reliability.

Geoff Shannon, Coherent

IMPROVING THE SPREAD OF LIGHT IN TIN OXIDE THIN FILMS USING DLIP

HERMAN HEFFNER ET AL.

With an increased demand for sustainable energy sources to combat climate change, there is an ever growing need to further develop renewable energy sources such as solar cell technology. It is very encouraging to see the work of Herman Heffner and his co-workers at Technische Universität Dresden, applying Direct Laser Interference Patterning (DLIP) for the enhancement of optoelectronic devices.

Heffner et al. have successfully demonstrated that by producing Laser-Induced Periodic Surface Structures (LIPSS), via DLIP, the surface of Fluorine-doped Tin Oxide (FTO) can be modified to enhance photoactive materials, especially when applying them to cost effective solar cells such as dye-sensitised solar cells (DSSCs). With advancements such as this, this will make these renewable energy technologies more attractive for mainstream use and will help to further the development of the technologies needed to reduce carbon emissions.

David Waugh, Coventry University

NEXT-GENERATION LASER SHOCK PEENING: A COMPACT LSP SYSTEM

PRATIK SHUKLA

This article introduces a potential paradigm shift in the use and application of laser peening. Currently, the majority of laser peening is conducted by specialist companies for large-scale multinational corporations. Shukla, through his company Bright Beams, is proposing to democratise laser peening by offering low cost, compact and transportable solutions. Uptake of this approach could change the market for materials enhancement techniques.

By offering affordable, easy to use systems it will be possible for engineering and materials departments at Universities to offer practical skills training in important surface and sub-surface enhancement technologies. In addition, many more companies of all sizes could take up laser peening to improve the properties of their components and products - extending material lifetimes and improving wear resistance being just two of the advantages offered by laser peening. Shukla reports some initial test results that look encouraging. It remains to see the effect below the surface and to what depth the compressive stresses can be applied, something we should keep a keen eye on.

It would be good to see some order of magnitude figures for the reduction in cost per watt offered as compared to conventional LSP systems available on the market in order to conduct a cost/benefit analysis.

Ric Allott, STFC

Despite many unique benefits LSP has shown over the years, the technology is still struggling to be implemented in industrial production outside its already established domains such as the aerospace and nuclear industries. The main reasons are process complexity and cost. While the complexity can be somewhat outsourced, the investment and operational costs for smaller scale production are often economically unviable.

One of the major reasons is the laser source which can be rather expensive and often requires additional labor in terms of maintenance and operation. Having a small compact turn-key laser source solution available such as the one presented here could be a great step towards widening the scope of industrially viable LSP applications which do not require high laser pulse energies.

Some of the suitable materials are already presented in the study. Obviously, the laser isn't everything, but it is the critical component to get LSP on the factory floor.

Jan Kaufman, HiLASE

SOLVING RAW MATERIAL CHALLENGES FOR METAL FABRICATORS

With the uncertainty of today's supply chains and the rising cost of raw materials, automated material storage systems provide a reliable buffer for metal fabricators. With costs for raw materials at a premium and deliveries out sometimes weeks, this poses a major problem for fabricators and their customers. With automated material storage systems, raw materials can be purchased in bulk providing a price advantage over traditional single-sheet orders, and materials can always be ready. The risk of losing an order or even worse a customer, due to delivery or pricing, is an everyday challenge.

With today's fibre laser cutting machines and their capability to process a vast amount of sheet metal on a daily basis, maintaining materials at the ready is essential to maintaining a consistent pace of production. For this reason, it is important to have some form of automated material storage and material handling so that the raw materials are cycled to the machine in a timely manner.

Reducing Material Costs

What if you could buy your sheet metal in bulk when material prices are lower and then not only receive a lower price but more than likely a higher discount for a volume purchase? But then where would you store it? Storing it on the production floor takes up a lot of expensive lateral real estate. It is also very inefficient when you need to access the material, especially when it's located behind another stack of material.

The solution is an automated material tower or warehousing system that not only enables you to store bulk sheet metal purchases but also eliminates wasting valuable production floor space. Instead of lateral storage materials are stored in vertical towers containing automated shelves. Accessing the materials is just a click away with your automated material tower or warehousing system with delivery directly to the required machine location.

Efficiency and Material Storage

The benefits of automating material storage lay in the efficiency factor: Material storage systems enable the seamless transition of material changes from job to job, reducing non-productive waiting times. How often have you seen a laser cutting machine sitting idle because it doesn't have the material to process the job? Keeping a machine supplied with the proper materials in a timely manner is a task that requires precision timing. Often, it is the task of a forklift operator or even the machine operator to make sure the laser has the required materials, but timing is everything and inevitably this leads to inefficiencies and lost production time. Maintaining materials at the ready is essential to maintaining a consistent pace of production and reducing non-productive time. Material storage towers can be dedicated to serving single machines or serving multiple machines.

An Essential Component for High-mix

If you are operating in a high-mix material environment, automating the material storage and handling is essential. Each changeover of material is an opportunity to either maintain your pace of production or add non-productive time. The higher the changeover rate, the higher the risk of production loss due to not having the proper materials supplied to the machine. Today's modern laser cutting machines are able to gather statistical data on the productivity of the machines and also non-productive waiting times. If you are in a high-mix material environment it is prudent to measure the non-productive waiting times for continuous improvement purposes and to justify material automation.

Competitive Advantage

Maintaining materials 'at the ready' with automated material storage systems eliminates inefficiencies when changing materials from job to job and maintains a consistent pace of production. You now have a plan that compensates for fluctuating market condition prices, is able to deliver parts faster and less expensively, is more efficient with material handling, and will most likely win more business.

Frank Arteaga
Regional Director of Marketing, Bystronic Inc., Hoffman Estates, IL

Voice.bystronic@bystronic.com

PRODUCT NEWS

SYSTEMS & SOURCES

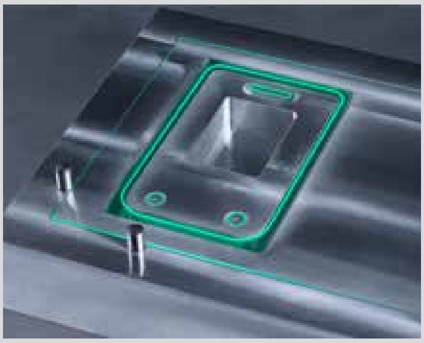
HIGH-END TUBE CUTTING EQUIPMENT

Sheet metal processors accelerate their tube laser business with Bystronic's new ByTube Star 130, a high-end tube laser packed with many features. A laser power up to 4 kW, accuracy, ease of use, and a fully automatic setup with open profiles and ellipses lead to more flexibility and higher quality in production.

Contact: Caroline Wood
caroline.wood@bystronic.com
www.bystronic.co.uk

NEW MICRO-PROCESSING LASERS BOOST POWER

TRUMPF has unveiled the next generation and new lines of its TruMicro ultrashort pulse (USP) lasers. The two TruMicro 6000 and TruMicro 2000 product families feature new technology platforms to boost power and enhance versatility.



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

SYSTEM FOR IMPLANTABLE MEDICAL DEVICES

Coherent has introduced its AP 530 S, a fully automated laser system for texturing and marking implantable medical devices. The laser-based process is contactless, which eliminates any risk of contamination and ensures a very high level of quality and uniformity required for medical devices.

Contact: Michael Batchelor
michael.batchelor@coherent.com
www.coherent.com

NEW COMPACT FEMTOSECOND LASER

Fluence is proud to announce the launch of the newest addition to the well-established Jasper range of femtosecond lasers. Jasper Micro is air-cooled and very compact, making it advantageous for integration where space is limited.

Contact: Jeryl Adcock
JerylA@laserlines.co.uk
www.laserlines.co.uk

NEXT GENERATION OF DEEP UV FIBRE LASERS

Three new Deep UV lasers have been introduced by IPG Photonics. These include: a 5-watt nanosecond pulsed fibre laser for micro- cutting, drilling, texturing, marking and selective material removal on challenging materials such as glass, diamond and Teflon; and a 5-watt picosecond pulsed fibre laser designed for micro- cutting, drilling and selective material removal for PCBs, flex circuits, LEDs and flat panel display applications.

Contact: Stan Wilford
swilford@ipgphotonics.com
www.ipgphotonics.com

ANCILLARIES

NEW RANGE OF LASER PROTECTION PRODUCTS

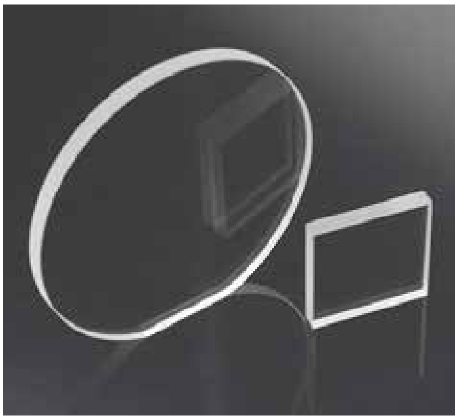
Brinell Vision has launched a range of safety products specifically for the latest industrial laser processes such as Additive Manufacturing, laser welding, surface structuring and precision laser cutting.

Contact: Adam Brierley
info@brinellvision.com
www.brinellvision.com

PRODUCT NEWS

DIFFRACTIVE OPTICALS FOR HIGH-POWER LASERS

Coherent has introduced a product line of diffractive optical elements (DOEs) for high-power industrial lasers. The company offers a new line of highly customised DOEs that achieve very high optical efficiency and extremely uniform laser beams.



Contact: Michael Batchelor
michael.batchelor@coherent.com
www.coherent.com

150 W LASER FOR LARGE OLED GLASS CUTTING

New from Coherent: the Monaco infrared industrial femtosecond laser configuration with 150 W of output power that is ideal for cutting of large OLED display glass. The new Monaco 1035-150-150 outputs more than double the power and pulse energy of existing configurations, enabling high-precision cutting of large glass panels in very high volumes.

Contact: Michael Batchelor
michael.batchelor@coherent.com
www.coherent.com

WIFI MEASUREMENT APP FOR AM CHAMBERS

MKS Instruments Inc. is proud to introduce the Ophir® StarViewer iOS App which delivers laser power/energy measurements wirelessly to iOS iPhones and iPads. Data can be displayed in a variety of formats and users can also capture a screenshot and share it.

Contact: Stuart Thomson
stuart.thomson@mksinst.com
www.ophiropt.com

EVENT REVIEW
ADDITIVE MANUFACTURING
UNIVERSITY OF BIRMINGHAM, 25 JANUARY 2023

Presenters L-R: Chris Austin (Mazak), Raja Khan (TWI), Ravi Aswathanarayanaswamy (Renishaw), Vimal Dhokia (Bath Uni), Khamis Essa (Birmingham Uni), Filomino Martina (WAAM3D), Andrew Moore (Heriot Watt), Amanda Cruchley (MTC), Moataz Attallah (Chair, Birmingham Uni). Stephan Kuehr (Sigma Additive) presented remotely.

Due to train strikes in the UK, the Additive Manufacturing event planned for December was re-scheduled to January and was hosted by the University of Birmingham in conjunction with the EU Regional Development Fund, Midlands Engine and AMTECAA (a joint project with many members). The workshop was chaired by Moataz Attallah from the host university.

The first session with Khamis Essa and Andrew Moore included summaries of all the research going on at Birmingham and the analysis of weld plumes using high speed photography at Heriot Watt. Amanda Cruchley then highlighted specific research on porous structures at the MTC.

After the first break, Vimal Dhokia gave the fascinating account of the path from initial development to commercialisation and sale of the generative 3D design software which was finally purchased by ALTAIR, a major USA software company. Raja Khan from TWI highlighted the issues around powder for additive from size of particles to recyclability. Finally Filomeno Martina from WAAM3D spoke about laser and wire arc additive which enables large structures and high build speeds with excellent quality and efficiency.

After an excellent lunch and time to chat and browse the 4 exhibitors (Brinell Vision, Laser Trader, Oxford Lasers and Pro-Lite Technology), Stephan Kuehr from Sigma Additive presented remotely about in-process monitoring solutions, acquiring data in real time to validate the process or identify issues. Ravi Aswathanarayanaswamy from Renishaw highlighted latest results in processing Titanium and Nickel Superalloys and comparison of build rates with a single laser or 4-laser machine.

Finally Chris Austin from Mazak presented hybrid manufacturing by laser powder DED and the extreme high speed repair of automotive brake discs which are accountable for 21% of all traffic emissions.

After another short break, the workshop closed with a tour of the laboratories at Birmingham University and the opportunity to see the various systems in action. Feedback on the day was very good and most people made at least 5 new connections and gave excellent feedback on the day.

EVENT REVIEW
EARLY CAREER RESEARCHERS' SEMINAR
UNIVERSITY OF NOTTINGHAM, 30 NOVEMBER 2022

This was the first Seminar organised and run by AILU's Early Career Researchers Committee since its launch in 2017. Ably hosted by Marco Simonelli and his team at the Universityof Nottingham, Committee members had the opportunity to share their technical and research expertise with other members and a wider audience.

Marco welcomed everyone to the event and speakers presented their work in 10-minute sessions. The scope of presentations was wide-ranging and included AM, laser beam shaping, hybrid manufacturing, laser machining of advanced materials, new product development, thulium-doped fibre lasers, welding dissimilar materials, and lasers in surgery and robotics.

Delegates and presenters at the Early Career Researchers' Seminar.

Following lunch there was an interesting tour around the AM facilities at Nottingham at which delegates were shown examples of fascinating 3D metal designs and applications.

If you would like to find out more about the ECRs Committee, or think you or a colleague might like to join, please visit the AILU website here www.ailu.org.uk/early-career-researchers-committee.

A FUNNY THING

SENT IN ERROR...

As I am sure you are all aware, care must be taken when using social media and in particular to avoid the pitfall made by Ed Balls (a British politician of some renown in the past labour government). According to legend, in April 2011 he was urged to search on Twitter for an unflattering article about himself which was being shared, but unfortunately instead of writing "Ed Balls" in the search box, he created a tweet with the contents being his name. This went viral with lots of retweets, and since he didn't know that tweets could be deleted, the tweet remained for all to see. The twitter-sphere rejoiced in this public ridicule and ever since the 28 April has been celebrated as Ed Balls Day – look out for retweets coming to a phone near you.

Sending emails to the wrong recipient is very easily done, especially when the email address will auto-complete when typing in Outlook. I have received lots of emails to the "wrong Dave" but none of them have been newsworthy. I have on occasion sent a text or picture to the wrong WhatsApp recipient, but thankfully not with embarrassing results.

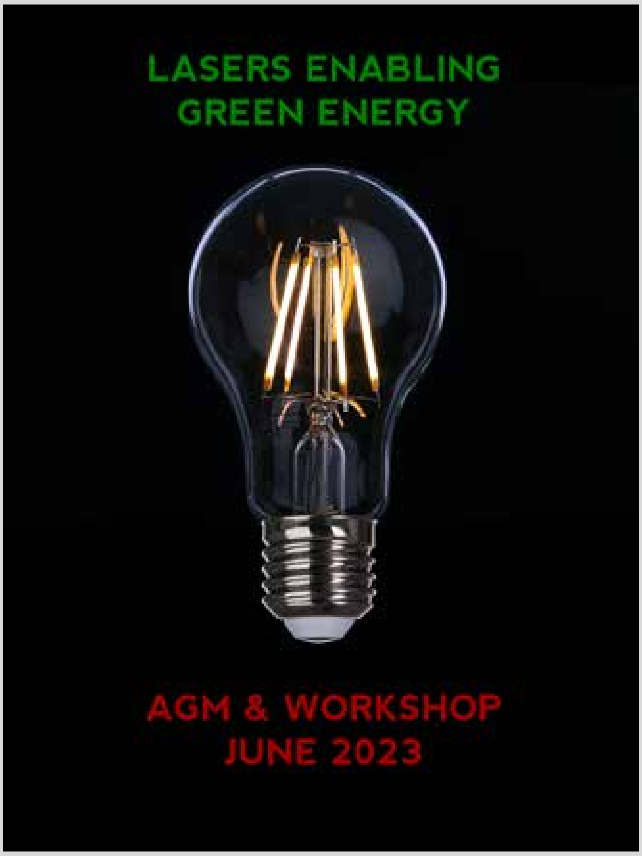
Some of the older readers of The Laser User will remember the ancient Fax Machine – a popular piece of office equipment from the 1980s and 1990s, now virtually extinct. By the way, on a business trip to Tampere, Finland I found the Finnish Labor Museum – if you ever find yourself with 3 hours to kill in Tampere I highly recommend it, as long as you are interested in historical phones, computers, typewriters and other technology.

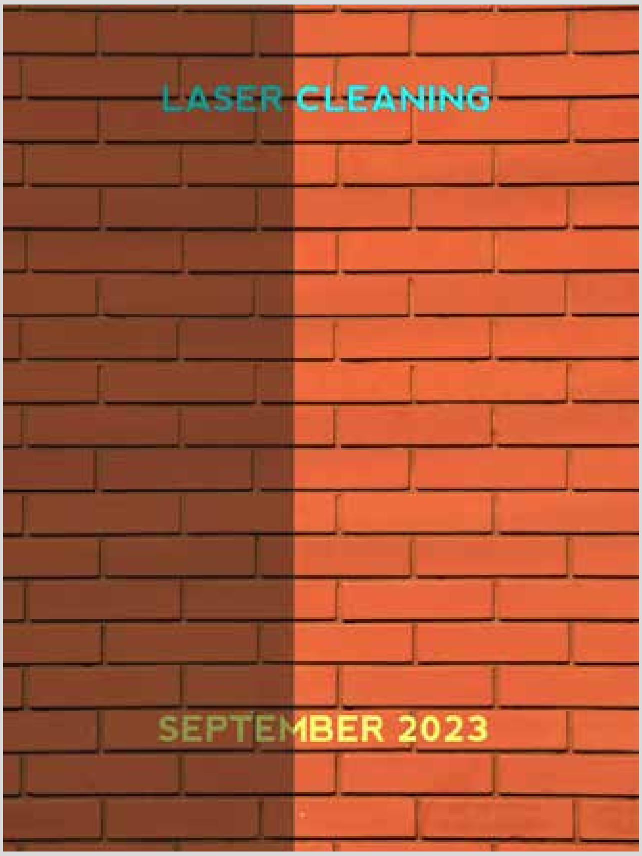
My story is related to a mis-sent fax in the early 2000s. A local company was a target for the sale of a laser welding machine for a specific application. We were convinced that they should buy one and tried to convince them too. In the process of quoting the system, it transpired that they had received a quote from our major competitor, and they were willing to forward it to us via fax (probably easier than scanning and e-mailing at the time). Having received the fax with the vital information (so rarely acquired), my colleague was keen to share it with the product manager in Germany – to see if we could provide a better commercial and technical alternative. A good delegator, he wrote in pencil to send it to our German factory for the attention of the product manager. Crucially, our receptionist mistook the number to which it should be sent for a different German fax number (the original competitor who had quoted it). Talk about a smoking gun! On receiving a fax from our fax machine (consisting of a quote to our potential customer) the competitor was on the phone to our would-be customer asking, in the strongest terms, what was going on. Our would-be client quickly became a would-not client after this fiasco and our receptionist nearly became our ex-receptionist too. In the end, it turned out to be something of a storm in a teacup and to my knowledge the client never bought a laser anyway – but I am sure you can appreciate the embarrassment of the error.

What is the moral of the tale? Check carefully before you hit the send button. Are you sending the right content to the right recipient? Take time, especially with social media, to understand what you are doing before you make an embarrassing mistake…

Dave MacLellan
dave@ailu.org.uk

AILU EVENTS THIS YEAR





DATE	EVENT	LOCATION
22-23 March 2023	Industrial Laser Applications Symposium ILAS 2023	Daventry
13-16 June 2023	Laser Precision Microfabrication LPM2023	Aomori, Japan
26-29 June 2023	LiM 2023 – Lasers in Manufacturing	Munich, Germany
27-30 June 2023	Laser World of Photonics	Munich, Germany
22-24 August 2023	NOLAMP 2023	Turku, Finland
27-28 September 2023	PLI Conference	Rennes, France