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SPRING 2021

AILU

THE LASER USER

ISSUE 100

IN THIS ISSUE:

ULTRAFAST LASER PROCESSING:

RESEARCH UPDATE ON LASER MANUFACTURING TECHNIQUES

THE LASER USER

Editor: **Dave MacLellan**
Sub-Editor: **Catherine Rose**

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

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

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The cover image shows a braided catheter, with a PEBAX outer sheath, metal braid and PTFE inner liner. The outer sheath was removed using short pulsed laser processing. Our thanks to Blueacre Technology for machining the special message in lettering approx. 2 mm high.

Photo credit: Dave MacLellan, AILU

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Elected until 2022

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Hollie Denney	(II-VI)
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Jonathan Lawrence	(Coventry University)
Mark Millar	(Essex Laser)
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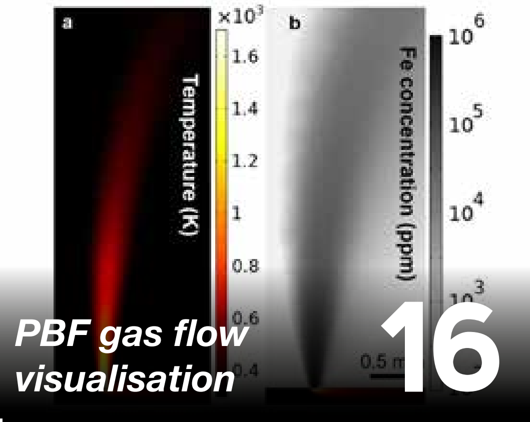
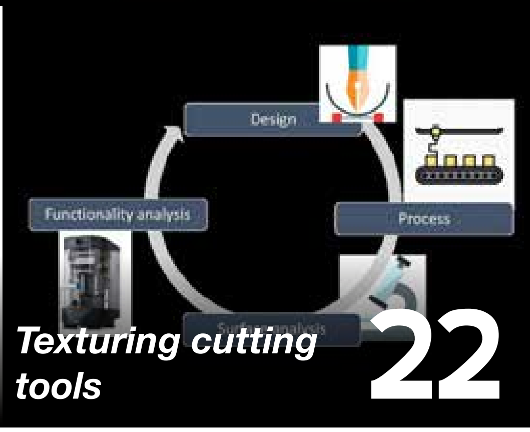
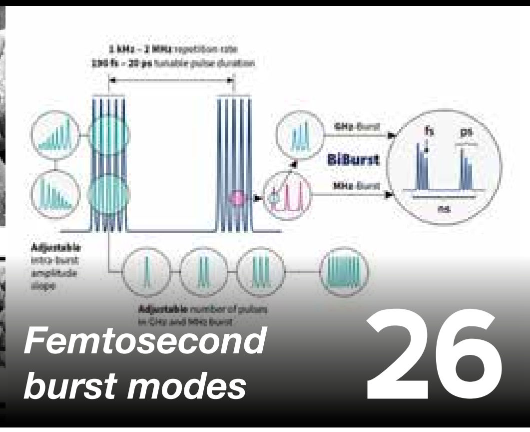
Past presidents and founder members are also able to attend committee meetings. Anyone wishing to join the AILU Steering Committee please contact the Executive Director.

CONTENTS

HIGHLIGHTS...







ASSOCIATION NEWS

FIRST WORD

Today I am reflecting on the milestone that is our 100th issue of The Laser User. It is also 6 years since I took over from Mike Green and I have been editor of the magazine since Issue 78. My job is made so much easier by having Cath who pulls everything together and takes on so much more every year. I know that I am biased, but I do feel a sense of satisfaction when the printed magazine lands on my doormat and I can flick through it. There isn't another laser industry magazine quite like this, and yet we are open to your opinions to keep it fresh and bring in new content.

As well as 100 issues we have delivered our first virtual ILAS, if you missed it the videos are all online and can be viewed by all delegates. If you missed out on registering we are happy to offer the online content at the same price as before ILAS so that you can access the library for a very competitive price. There are almost 24 hours of video content including 83 presentations and more.

Finally we also recently had our 27th AGM (the second one online) and I was greatly encouraged by the new people who were keen to join the committee – you can see who they are on page 5. Hope to see you all physically at some point this year!

Dave MacLellan
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PRESIDENT'S MESSAGE

Fellow laser professionals,

Welcome to the 100th edition of The Laser User, AILU's quarterly magazine. That AILU has reached this milestone is testament to the high regard The Laser User is held in by the laser community. The combination of industry news, new product launches, focus stories, and light touch technical articles makes it particularly accessible to those unfamiliar with the laser industry, as well as those looking for their quarterly 'fix' of laser related knowledge.

Congratulations to all involved at AILU, past and present, for achieving this significant milestone. Of course, the 100th edition would not have been possible without the continued efforts and contributions from all of you in the laser community. A big thank you, on behalf of AILU, to all those who have contributed to The Laser User over the years.

In March, AILU held ILAS 2021. Those of you with a sharp mind will remember this was originally scheduled for 2020, to celebrate another AILU milestone (AILU's 25th anniversary), but was re-scheduled to March 2021 and held virtually for obvious reasons. With a dedicated conference platform, the feedback from attendees was that ILAS 2021 managed to re-create much of the experience of a physical ILAS, with there even being a virtual social evening for AILU members to share some of their hidden talents! ILAS 2021 success aside, I know I am not alone when I say 'I hope the next ILAS is a physical event'.

And with that, my two year tenure has come to an end and I sign off as AILU President in April. It's fair (and probably obvious) to say it has not been the Presidency I envisaged, and has not been straightforward! However, I'm proud of the way we have navigated the turbulence of the last 15 months, and migrated AILU's activities into the virtual world. I'll still be engaged in the laser community and look forward to supporting AILU and Adam Clare, the new AILU President, when needed. There's more on the new AILU committee line-up on page 5.

Stay safe,

Jon Blackburn
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RIC'S RAMBLINGS

I guess it will come as no surprise to you that I want to talk about our recent ILAS event. I have to say for a virtual event that it was excellent. The content this year was particularly strong and I think the fact that we were virtual and therefore reaching a bigger audience than normal was great in that respect. As per my "bit of a moan" about on-line events in the last edition of our magazine – I was still a tad disappointed with the networking side of things. I hasten to add that this is in no way anyone's fault and the platform chosen to run the event was fine – but goodness me I do miss the face to face. Having said that I will have a slight moan – I attempted to make contact with quite a few people and received only 50% replies back from my messages. I suspect that this was due to the fact that many of the delegates simply just didn't enter the networking area to see if they had any messages. Or maybe (thinking about it) they were in fact fully aware of my request but chose to ignore it (and I have to say I can't really blame them!) Whatever the reason when you are face to face it's far more difficult to escape or ignore.

One part I really enjoyed was the panel discussion and video clips of past presidents (well I would say that, wouldn't I). Actually I had no idea if I would feature and was a little nervous as the filming for those clips was done in time for when ILAS was originally scheduled in 2020 –so I couldn't quite remember what I had said – luckily I don't think it was too silly or outrageous. Anyway the real enjoyment for me came from seeing and hearing the discussion between our AILU Officers. It filled me with confidence to see such a considered and intelligent bunch at the helm – and in the majority (apologies Dave) quite a youthful lot. Which brings me to diversity – which of course can take many forms (by definition) and I think age diversity is incredibly important in addition to all the other forms. What a joy to see young(ish) folks (good grief, that makes me sound old) with such a passion and drive for our industry. When I was President I made sure we got on with recruiting to increase diversity in our committee. This has and must continue and I am particularly encouraged by the Early Career Researchers Committee – a fabulous resource from which to nurture, encourage and mine for new and diverse talent to really make a difference and push our industry forward.

Finally a big thank you and congratulations to the AILU team for delivering an excellent ILAS!

Ric Allott
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OBITUARY
JYOTIRMOY "JYOTI" MAZUMDER (1951-2021)

AILU was saddened to hear of the passing of Jyoti in April. Professor Bill Steen (AILU's first President) was Jyoti's PhD supervisor at Imperial College London in the late 1970s, and writes a personal and fitting tribute below.

"It is not usual, it is sad, for a supervisor to write an obituary to one of his top students; but that is what I am doing. Jyoti Mazumder scaled the heights of academic achievement being recognised as a leading thinker in the field of laser material processing by his election to the USA National Academy of Engineering, the Indian National Academy of Engineering and the winner of numerous awards.

He joined my embryonic research group at Imperial College, London in 1977 to work on the newly acquired Control Laser 2 kW CO_2 FAF laser.

Ours was one of the first University-based research groups working in this field. Jyoti was in his element as a scientific pioneer. He sailed through his PhD on laser welding of mild steel and titanium, laying a significant foundation in that topic.

Being at Imperial College in 1978 we had access to one of the few large computers in the world and so together we built a finite difference model of a laser heated spot and a moving laser spot, (all on punched cards). Jyoti was always searching for the next development and he had the talent to exploit it when he found it. He alerted me to the idea that surface treatment might be the next idea to explore. I considered that using the quality laser beam out of focus was missing its value, how wrong I was!

He left my group but stayed in touch and went to the University of Southern California where he developed his own group and network of contacts, with whom he worked in the University of Berkley for a while. He then moved to the University of Michigan at Ann Arbor as a full Professor and flourished through hard work and talent.

From his 400 or so publications one can see a genius at work. His mathematical models became so sophisticated they could replicate the waves on a weld pool and inside the keyhole. He was one of the pioneers to recognise that the laser could produce nano particles through ablation at a time when no one thought nano particles would lead to much. Then came laser cladding and the realisation that cladding repeatedly in one place could build features leading to the subject of additive manufacture.

At root he was a family man who was totally committed to his wife, Aparajita and his two sons, Debashis and Debayan. His attitude to family was such that it included many of his close friends of which my wife, Margaret, and I count ourselves privileged to have been. Many others who have worked with him have lost a dear friend."

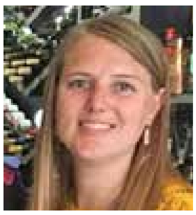
Bill Steen, April 2021

AILU'S 27TH ANNUAL GENERAL MEETING
29 APRIL 2021 ONLINE MEETING

AILU President 2021-2023
Adam Clare, U Nottingham

AILU Vice-President 2021-2023
Mike Poulter, TRUMPF

Cliff Jolliffe, PI



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Danijela Rostohar, HiLASE

Tian Long See, MTC

Clive Grafton-Reed, Rolls-Royce

Prveen Bidare (U Birmingham)

Sinan Bilgin (SS Laser Solutions)

AILU's 27th AGM was held on 29th April as an online event. This being a change-over year for officers, Jon Blackburn stepped down as President of AILU and Adam Clare (University of Nottingham) moved from Vice-President to President. The AILU team would like to thank Jon for his hard work and dedication over his 2-year term as President, successfully guiding AILU through the pandemic. Mike Poulter of TRUMPF stepped up as Vice-President. AILU would also like to extend a vote of thanks to those leaving the Committee, including Ceri Brenner, Shireen Khanum and Mark Thompson.

As is normal at an AGM, there were vacancies for 4 ordinary members of the committee to serve a 3-year term. Also this year there were 2 casual vacancies and an opportunity to be co-opted onto the committee for one year. AILU warmly welcomes the new members (see right) alongside the new leadership team. A full list of the Steering Committee showing their term of office is shown on page 2.

BUSINESS & RESEARCH NEWS

II-VI INCORPORATED TO ACQUIRE COHERENT

II-VI Incorporated announced that it is entering into a definitive agreement with Coherent, Inc., under which II-VI will acquire all outstanding Coherent shares in a cash and stock transaction. Under the terms of the transaction, Coherent shareholders will receive $220.00 in cash and 0.91 of a share of II-VI common stock for each Coherent share.

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TRUMPF & LANTEK IN CLOSE PARTNERSHIP

TRUMPF acquires the software house Lantek and focuses on software in sheet metal processing that runs independently of the machine manufacturer. TRUMPF is taking another big step toward efficient and connected sheet metal production and enriching the Smart Factory solution portfolio.

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NUBURU GET PATENT FOR BLUE LIGHT WELDING

NUBURU announced that it has been awarded a US Patent for blue laser applications of welding copper material and its alloys.

"This new patent covers all forms of 3D printing, welding, and methods of opening up the keyhole using blue laser light," said Dr. Mark Zediker, Founder and Chairman of NUBURU.

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PAMPROD: NEW ADDITIVE MANUFACTURING PROJECT

PAMPROD (Procédés Additive Manufacturing – Productivité) is an industrial project developing a disruptive additive manufacturing solution for producing large parts and components in a cost-effective manner. The project was launched in response to the needs of the Aeronautics, Energy, and Defence sectors for producing large parts of up to five metres.

Designed to be flexible and agile

PAMPROD uses a hybrid additive manufacturing solution that combines both powder and wire deposition. The machine is specifically designed to be both flexible and agile. To increase a user's return on investment, PAMPROD can be used with specialty metals, including the wide range of Nickel alloys for additive manufacturing that Aperam offers as either a powder or wire. PAMPROD can also be used with Titanium alloys and materials such as stainless steel and mild steel.

A proof-of-concept machine has been installed at IREPA LASER. First pre-series parts are expected in 2021, with Prodways bringing the PAMPROD solution to market by 2023.

Why choose PAMPROD?

To ensure a robust, repeatable manufacturing process, the machine is equipped with cameras that are directly linked to monitoring software. This allows the user to monitor the deposits in the melt pool in real time. A thermo-mechanical simulation completes the whole process before the part goes into production. It is this combination of additive manufacturing technology and adaptability that allows PAMPROD to reduce costs and lead times.

The project is the result of a consortium of six companies of which AILU member IREPA LASER is one.

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EVENT REVIEW

ILAS 2021

7th Industrial Laser Applications Symposium

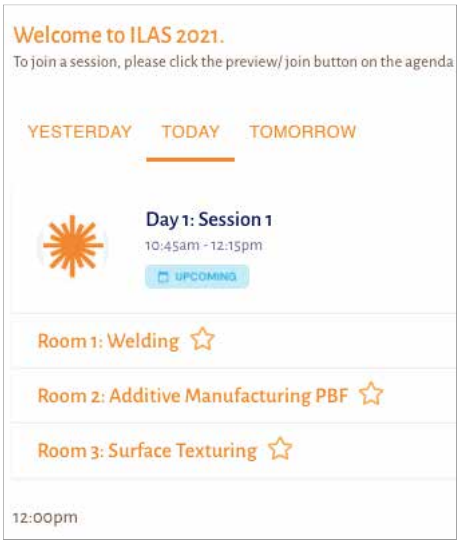
24 - 25 MARCH 2021

Due to the pandemic, ILAS 2020 (where AILU would have celebrated 25 years of operation), was postponed to March 2021 – and in the latter half of 2020, it was decided to move the event online for the first time. The overall objective of the online ILAS was to deliver as much of the same experience of a physical ILAS as possible. This would include a full programme of presentations, networking opportunities and an exhibition with 20 to 30 exhibitors, as well as presentation of awards and a social event in the evening. After some investigation and evaluating different options, AILU chose to use Speakeasy to provide the event platform, a company based in Edinburgh with experience of physical and online events and a platform capable of delivering everything required.

The Platform

The ILAS platform was based around a simple "timeline", guiding the delegates towards the content in a live manner (taking into account offset time zones for visitors all over the world including USA, Europe, India and Japan). Once logged in to the ILAS home page, it was very easy for those attending to navigate to the Meeting Hub for networking, drop in on any of the parallel sessions (using Zoom links) and visit the exhibition either during the live sessions (lunchtimes) or at any time during the event. The platform was very robust without any "crashes" during the 2 days of ILAS, and once people gained some familiarity they found it very intuitive to use and navigate.

As one of the organising team, I could use my 2-screen set up to drop into a session, chat to the session chair and check if any presenters were missing 10 minutes before the session start. Identifying 2 or 3 missing presenters, I could message them from the meeting hub and remind them to make their way to the session in time for the start.



ILAS 2021 - Timeline snapshot

Discussion Forum

In parallel with the technical presentations there was a discussion forum where Jon Blackburn, Adam Clare, Dave MacLellan and Mike Poulter (current and future officers of AILU) discussed a number of points about how AILU could develop in the next few years. This was prompted by the past-presidents who were interviewed by the Early Careers Researchers in 2020. Watch this space to learn the next steps outlined in this discussion.

Awards and Entertainment

During the evening of Wednesday, a Zoom meeting to present the new AILU Fellowship Award (granted to Lin Li from University of Manchester) and the AILU Innovation Award (presented to SPI Lasers, now TRUMPF, and accepted by Jack Gabzdyl). After the presentation of the awards, a number of live and pre-recorded performances by members of the AILU network were enjoyed by around 40 people. Performing live were Hollie Denney (II-VI) and Dan Thombs (Bystronic) with pre-recorded sessions by Derrick Jepson (Aerotech), Lin Li (University of Manchester, Lisa Harman (Scitech Precision), Phil Carr (Carrs Welding) and YouTube videos from Paul Maclennan (ULO Optics) and John Powell (Laser Expertise). There are no doubt several more people with musical talents and I look forward to the occasion where they can play live to an audience at the next ILAS.

ILAS in numbers

Overall 216 people registered for ILAS with 156 attending (logging in) to Day 1 and 141 on Day 2. There were 26 exhibitors and 83 presentations. 111 people watched the opening plenaries and during the parallel sessions there were typically around 35 people watching any of the presenters (the maximum observed was 46 for one speaker). Around 200 connections were made and many more conversations took place in the meeting hub chat.

Dave MacLellan
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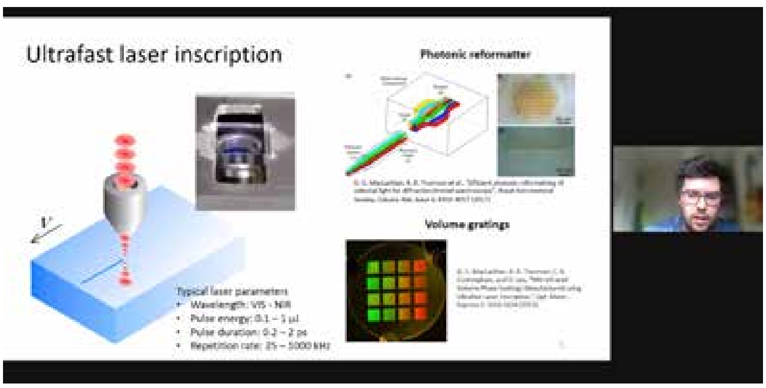
Discussion Forum – the future of AILU



Presentation in the Parallel Sessions

MAZAK HELPS MCLAREN RACING GET SET FOR NEW SEASON WITH RAPID 5-AXIS INSTALLATION

Yamazaki Mazak has helped the McLaren Formula 1 team step up its preparations for the 2021 season by supplying and commissioning a brand new fully-simultaneous 5-axis machining centre in four weeks. The new machine, an INTEGREX i-100S Multi-Tasking machining centre, was ordered in December 2020 and became fully operational at McLaren's Technology Centre in Surrey at the end of the same month. The installation is the latest step in the Formula 1 team's partnership with Mazak, which now stands at in excess of twenty years, and takes the total number of Mazak machines currently used by McLaren to 28.

The machine's versatility will enable it to be used for the manufacture of a variety of parts including those used within the suspension, transmission and engine systems, as well as general car system components.

Malcolm Jones, Manager, Machining & Fabrication at McLaren Racing, commented: "As part of our longer-term investment strategy in manufacturing technologies we plan for regular upgrades to our existing portfolio of machines to ensure we operate with the fastest, most efficient technology available. At the end of 2020 we acknowledged the need to increase the versatility of our in-house machining to help improve our competitiveness on the track. However, with just a small window of opportunity ahead of our 2021 team launch, we needed to act fast.

"Having broached the challenge with Mazak, we quickly identified the i-100S as an appropriate solution. Crucially, the team at Mazak was able to source a machine and arrange for it to be shipped, installed and commissioned in just four weeks. Not only does it complement our machine portfolio nicely, but it also underpins our need for more flexible and capable machines. What's more, features such as the SmoothX CNC and the second spindle will enable us produce components to a higher degree of accuracy and faster than the older generation machines."

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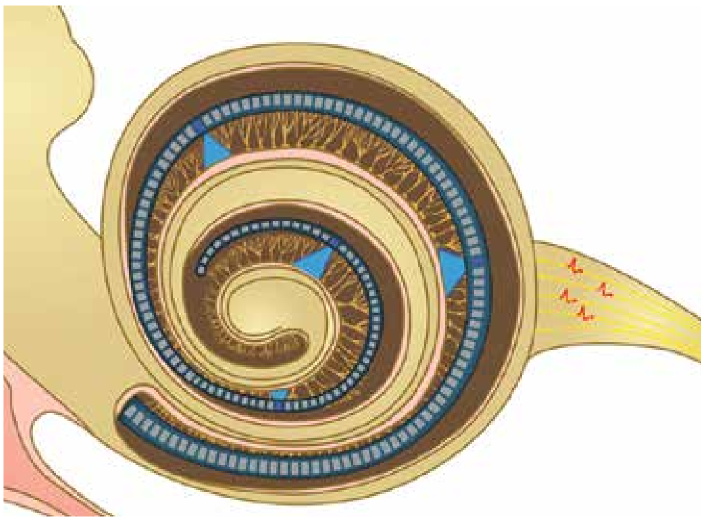
COHERENT'S EXCIMER LASER LIFT-OFF (LLO) ENABLES OPTICAL COCHLEAR IMPLANT

About 700,000 electrical cochlear implants (eCI) have been used worldwide to restore some hearing function for the hearing impaired or deaf. But their limited sound resolution prevents recipients from understanding speech in noisy environments or from enjoying music. One possible solution is to use optogenetics to make the neurons of the ear sensitive to light. Then an optical cochlear implant (oCI) can selectively stimulate different regions of the cochlea with light, according to the frequency of the sound.

OptoGenTech GmbH is at the forefront of this research and development effort, Founder and CTO Dr. Christian Gossler explains, "We reasoned that the best device for oCI development would be a thin flexible device containing numerous highly integrated thin-film µLEDs. A key hurdle was how to remove the LEDs from the sapphire growth wafer and accurately place them on the flexible oCI without any damage whatsoever."

Dr. Gossler and colleagues at the University of Freiburg developed an all wafer level fabrication scheme using GaN µLEDs and based around a laser lift-off (LLO) process using a Coherent COMPex excimer laser at 248 nm. LLO is a proven general methodology where ultraviolet laser pulses are applied through the transparent sapphire. These pulses ablate tens of nanometers thin layer of GaN at the material interface, releasing the GaN from the sapphire. Gossler explains that the high pulse energy of the COMPex enables multiple µLEDs to be gently released with a single laser pulse, and the high pulse to pulse energy stability - better than 0.75% (1 Sigma) – maximises the process window for this critical fabrication step.

OptoGenTech are making excellent progress developing their unique oCI technology having developed and successfully tested pre-clinical prototypes. As they move forward towards clinical trials, they are very optimistic that they have a winning solution to significantly improve the quality of life for the hearing impaired.



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BYSTRONIC & PROFORM LASER ARE FIT FOR THE FUTURE WITH LASER CUT WEIGHTS

Proform Laser, situated on the Wirral, started out in business as a laser cutting subcontractor in 2016 when they purchased a laser cutting system and a press brake from Bystronic. With a successful and growing business, the company was confident to buy two more laser cutting machines, the most recent being installed in January. As the coronavirus lockdown started to bite in 2020, there was disruption to the normal level of incoming orders at Proform for a few weeks, owing to the shutdowns at various manufacturing sites.

The Proform Group is run by the Canner family, father Russ, daughter Laura and son Mike, who are all keen gym members and like to keep in shape. Seeing an opportunity with gyms closed and people unable to access the equipment needed to work out, they decided to make some standard products for weight lifting. To make these plates is a very simple and rapid operation using laser cutting, no bending or welding is required, only some minor finishing when they come off the laser cutter.

Initial production started in a low-key way with sales mainly to family, friends and by word of mouth. Realising the market demand for home equipment during lockdown, the company re-arranged itself and launched the Pro Plates brand with a dedicated website for online ordering and started building a large following on social media.

Growth has been outstanding and the idea that they might make £10,000 out of the business is now a family anecdote. The numbers are staggering, and a truly good news story for UK manufacturing. Since May 2020, the business has quadrupled in turnover where many other subcontractors have struggled to keep busy. In one month recently, Pro Plates turned over more than a full year of 2019 revenue for Proform Group. Each week the company turns 70-80 tonnes of steel plate into weights.

When asked about why she chose Bystronic for the equipment, Laura Canner said “We went on the UK study tour to the manufacturing site of Bystronic at Niederonz in Switzerland and were impressed by the Swiss expertise, the price point for the equipment and the smart red colour of the machines.”

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LASERS IN MEDICAL DEVICES - STATE-OF-THE-ART IMPLANT MANUFACTURING

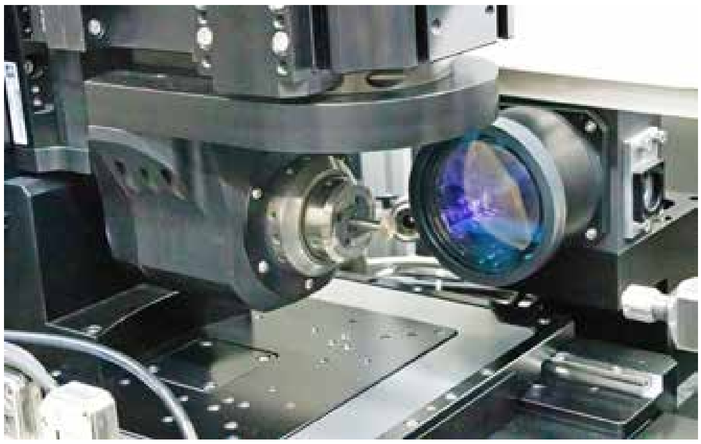
Manufacturing high-quality ceramic implants requires precision tools for micromachining. Dentalpoint AG uses a manufacturing system from Aerotech incorporating an integrated galvo scanner to laser cut the micro grinding pins. The handling robot and measuring system are also linked via the control software.

"Compared with titanium implants, our two-part ceramic product has the advantage that it looks very aesthetic and natural due to its white colour. Biologically, it is more compatible and has excellent osseointegration," explains CTO Philip Bolleter, head of production, research and development at Dentalpoint. Whether single tooth, bridge, bar or telescope restorations, Zeramex covers the entire range of options with ceramic implants.

"We attach particular importance to our tools, because the more precisely we manufacture them, the more precisely the implants can be manufactured," explains the CTO. "This is why we opted for a system from Aerotech as they are known for their high-precision positioning systems with integrated laser technology."

Philip Bolleter remembers the initial talks with Aerotech: "We had no experience with laser technology and integrating it with a manufacturing system was a major challenge. We were aware there was no such thing as an off-the-shelf system with an integrated laser, but we still wanted a supplier who could cover as wide a range as possible."

The complete mechanical part with linear drive, axes and the A3200 control software came from Aerotech, with the housing and the rest of the peripherals assembled by Philip Bolleter's team. In addition, a handling



robot was integrated along with other additional components such as an optical measuring system for in-process measurement. The advantage here was that the same Aerotech control system could be used. "This allows us to expand the periphery at any time without having to purchase new control software, for example if we want to integrate a Profibus or an additional piezo axis - we are absolutely open and not restricted at all."

Contact: Derrick Jepson
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www.aerotech.com


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ECR CAREER UPDATE

Nesma Aboulkhair

Nesma is the current Chair of the Early Career Researchers Committee. Until recently Nesma was a full-time assistant professor in additive manufacturing at the Faculty of Engineering, University of Nottingham. Here Nesma tells us about her recent career progression.

"In April 2021, I took on the new role of the Additive Manufacturing Team Lead at the Technology Innovation Institute (Abu Dhabi, UAE) alongside a visiting academic position at the University of Nottingham to continue my research activities. I have been working in the field of Additive Manufacturing since 2013.

My active research projects span across several metal additive manufacturing processes, including laser powder-bed fusion and high temperature droplet-on-demand jetting of metals. My research interests and expertise are mainly experimental with focus on the process-structure-property relationships. In addition, I have growing interest in new materials for metal additive manufacturing. I am involved in a range of outreach activities to raise the public's awareness about Additive Manufacturing."

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Prveen Bidare

Prveen was the first Chair of the Early Career Researchers Committee, from 2017-2019. When the Committee was formed, he was a PhD student at Heriot-Watt University and his career has progressed since then. Here he tells us about his current position and research interests.

"I am a Technical Research Officer for Hybrid Manufacturing at the University of Birmingham and a chartered professional with more than 10 years of industrial and research experience in laser applications with particular expertise in metal Additive Manufacturing (AM).

I got my PhD from Heriot-Watt University in 2017. In the past, I have worked in companies such as Siemens AG, General Electric and MTC for the design and development of sustainable smart machines and processes. My research interest includes additive and hybrid manufacturing, laser material processing, manufacturing process control and monitoring. In my current role at UoB, I support UK SMEs to adapt innovative technologies through a fully funded AMTECAA project."

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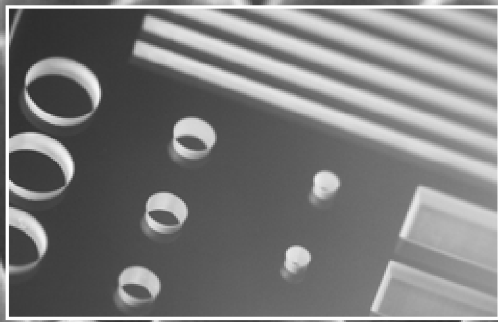

MATCHING WAVELENGTHS & PULSE DURATIONS TO MATERIALS

AN INTERVIEW WITH BEN AGATE

BUSINESS DEVELOPMENT DIRECTOR, PHOTONIC SOLUTIONS LTD

Q. Can you give us an overview of Photonic Solutions?

The origin of Photonic Solutions goes back to 1999, when three individuals left an Edinburgh-based photonics organisation to supply a range of products primarily to universities and research facilities. Sustained growth and diversification of the company culminated in a successful Employee Buyout in 2017, when I joined three other Directors in taking over the running the company, and most of the staff took the opportunity to become shareholders.

Aside from the global financial crisis of 2008, and the current pandemic, growth has been steady - typically averaging around 10% per year. Now, we represent over 40 international manufacturers at the leading edge of technology. Our focus has always been on laser sources, and our broad portfolio covers almost every laser type. Increasingly, we now serve Industry as well as Academia and this market is certainly growing more rapidly.

We service and repair items remotely, in the field, and at our own UK facility. Being a small company, everyone takes on multiple roles, but we have a loyal and dedicated team and an extremely low employee turnover rate. We are also always looking for suitable candidates with the right attitude and skillset to add to our team.

Q. What is it that sets Photonic Solutions apart from your competitors?

We see ourselves as a value-added reseller with exceptional service and support capabilities. We have always ensured that virtually every laser system we supply is fully installed and supported by our own team of factory-trained service engineers, meaning that a time-consuming return to factory is mostly avoided. This ensures fast and efficient local technical support for all our customers, especially at a time when international travel is so heavily restricted. We have our very own optics lab at our HQ in Edinburgh, where we typically check and confirm the performance of each new laser system on arrival in the UK before following up with the subsequent installation and training at the end user site,

Q. How has the pandemic and Brexit affected your business in 2020?

Initially, we were obviously concerned about the effect that Brexit would have on the whole UK photonics sector, especially in terms of reductions in public funding for R & D. In terms of logistics, we have found some small frustrations related to paperwork and some inevitable delays to overland transport, but thankfully these issues have only been minor. The sudden arrival of the pandemic only served to add to uncertainty, so the first half of 2020 was certainly a challenging period. Initially we had all staff working from home, and for a few months we took the decision to furlough several people - especially the service team - as they were then unable to travel, and most workplaces were closed. Overall, we have been truly amazed at the resilience of the photonics sector in the UK and its ability to bounce back. The outlook now is that the year ahead will be much better than we initially feared.

> *"Overall, we have been truly amazed at the resilience of the photonics sector in the UK"*

Q. Do you have anything new in the pipeline?

We are very excited about our new and improved Applications Lab facilities for advanced and customised material processing at Light Conversion and Lumentum. We can now offer bespoke sample processing (laser micromachining) with nanosecond, picosecond and femtosecond sources – in the IR, Green, UV and DUV, and with powers up to 180W. So, when clients approach us for help in demonstrating a given process in their chosen material, there is very little we cannot do. We have also recently signed up a new Principal, UVC Photonics, for their deep UV diode laser technology which sees promising applications in disinfection at 261 nm (a peak wavelength for inactivating pathogens).

Q. What are you looking forward to in 2021?

Most of all, we can't wait to meet our clients and colleagues again to face-to-face. Our service engineers are eager to catch up with the jobs that have been on hold, and we really want to help everyone get back up and running again as we ease out of lockdown. It will also be great to getting back to trade shows once this is possible.

> *"AILU remains the very best way to stay connected with the industrial laser community"*

Q. What are the key markets you serve?

While much of our focus remains on the scientific markets of Universities and research facilities, we most definitely see ourselves as a key supplier to a rapidly growing number of clients in the industrial sector. We are very fortunate to be able to offer world-renowned industrial laser solutions in the fields of Laser Micromachining, LIBS, LIDAR, Bioimaging, Quantum Photonics, Lithography, Non-Destructive Testing, Photoacoustic Imaging and Defence. We are also now looking to break into the agricultural and food analysis markets. Our market reach is extremely wide-ranging, as well as our product portfolio. Perhaps this is one of the reasons we have managed to weather the recent economic disruptions so effectively.

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

AILU remains the very best way to stay connected with the industrial laser community, and to keep up with new and exciting trends and developments. It gives us the opportunity to listen and be heard. I am always very keen to listen to as many talks as possible at AILU events and for me ILAS is not to be missed. Obviously, an online event is never quite the same but the platform AILU used for ILAS 2021 was excellent. We are always happy to support regular networking events such as ILAS and many of the one-day workshops.

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CARRS WELDING ADDS METAL TO RESTORE CLASSIC MASERATI CYLINDER HEAD

Carrs Welding Technologies is equipped with multiple pulsed YAG lasers which are used for laser welding with filler wire for the repair of mould tools and other precision parts in a range of metals. In particular, a niche for Carrs is the repair of broken and corroded alloy blocks for car engines using build-up welding with filler wire to restore corroded, cracked or damaged cylinder heads. There is really no alternative to turn around a rapid repair whilst retaining the bulk of the original casting.

On this occasion Carrs was approached by Andrew Smith of Classic and Racing who restores classic and racing cars at his workshops in Oxfordshire. One of the projects Andrew is currently working on is the restoration of a Maserati Ghibli AM115, a classic Italian sports car from the late 1960s. Andrew approached Carrs with the V8 cylinder head block from this car which needed to be welded with absolutely no distortion and returned for machining, so he could re-build the engine for the owner.

This Maserati V8 engine had several areas that needed attention including a stud that was corroded in and leaking across to the cooling circuit. Once removed, the area had to be ground out and the metal replaced by laser cladding.

Whilst this is a routine job for Carrs, Andrew needed the repair work welded and back very quickly, so that he could meet the deadlines from his customer. Tom at Carrs turned around the welding in a very short time which resulted in a happy customer who appreciates what laser welding can achieve in the restoration of classic cars.

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Image courtesy of Classic and Racing

SIGNIFICANT INVESTMENT ALLOWS YORKSHIRE LASER & FABRICATION TO STAY AHEAD OF COMPETITORS

A £2 million investment in state-of-the-art new production equipment and software is enabling Yorkshire Laser and Fabrication to stay ahead of its competition.

Helping to boost capacity, productivity and cost savings for Normanton-based Yorkshire Laser and Fabrication (YLF) are a new 6 kW Amada Ensis AJ laser cutter, an Amada ATC automated press brake, and an EML-AJ combination laser and punch machine with automatic punch and die changer.

Quicker than previous laser cutting technology, the new machine can switch easily and quickly between different types of metals and varying thicknesses reducing setup time. Its auto-load facility provides fully automated and quicker

loading and unloading of the machine, giving the new laser its 'lights out' operating capability.

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CUTTING TECHNOLOGIES LASER CUTS OLYMPIC WEIGHTLIFTING PLATES

Cut-Tec has been working hard behind the scenes to perfect its latest project, Zenith Plates. When gyms closed in 2020 the company created a design and began to manufacture Olympic lifting plates from raw steel, in-house, at its site in Barnsley.

Zenith Plates was born to provide an alternative to rubber bumper weights and accommodate strength and resistance training. The plates provide customers with a premium product without the premium price tag.

Fast forward 12 months Cut-Tec has built a brand that now distributes Olympic weightlifting plates throughout the UK. As a small retailer operating in the gym equipment market, the response has been phenomenal.

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100TH ISSUE

Welcome to the 100th issue of the AILU magazine. Given the increasingly digital world of short attention spans in which we live, it is quite an achievement that this publication has persevered and remained relevant. Lasers continue to be at the forefront of technological innovation and new applications are still being found or developed, which is why AILU and this magazine continue to be such important resources. Of course if you are reading this, you know much of this already, however AILU is much more than just this magazine.

AILU also puts on many events, such as the Job Shop meeting and ILAS (Industrial Laser Applications Symposium) which are incredibly useful to learn more about lasers but are also a unique opportunity to meet others in the specific area of lasers in which you have an interest.

Whilst I am predominantly interested in high-powered industrial cutting lasers, AILU is an extremely useful network of highly knowledgeable and helpful members covering all types of lasers and applications. If you receive this magazine, you have access to this priceless network, so don't be afraid to make use of it. The team behind AILU will almost certainly be able to direct you to other AILU members who can help with any laser-related enquiry.

The AILU team doesn't often get a mention, but they are the ones that deserve the real credit for this 100th issue, they do an incredible job behind the scenes to put this magazine and the events together and much more besides. Also what you don't see are all those Steering Committee members who give up much of their time to be able to keep AILU at the cutting edge.

Of course AILU is nothing without you, the members, so please consider attending more of the AILU events, providing articles or adverts for the magazine or even just asking a question through the AILU website. I'm certain you will be pleasantly surprised by the outcome, and let us look forward to many more issues of this highly beneficial and informative publication.

Mark Millar

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Ensure the safety of your laser products

BS EN 60825-1:2014+A11:2021 is the standard that classifies laser product equipment and requirements.

This 2021 update deals with specific laser exposure conditions associated with multiple pulses and extended sources, and gives updated guidance on lasers used as replacements for conventional light sources.

It also expands on the information contained in IEC Interpretation Sheets IEC 60825-1:2014/ISH1:2017 and IEC 60825-1:2014/ISH2:2017 and how these changes relate to the EU Low Voltage Directive (LVD).

Buy now from the BSI shop:
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GAS FLOW DURING POWDER BED FUSION: A VISUALISATION STUDY

IOANNIS BITHARAS ET AL.*

The continuous research, development, and adoption of laser powder bed fusion (LPBF) over the past decade have established its usefulness in printing complex, high-performance metallic parts. However, inconsistent part quality still remains an issue, often associated with inadequate extraction of process by-products. High-speed, high-magnification imaging allows us a closer look into the process dynamics that result in such unfavourable conditions. Multiphysics modelling of the laser plume and is interaction with the fluid flow aid in characterising its effectiveness.

Optical diagnostics of LPBF have shown that the process is more dynamic than is generally appreciated and can involve considerable motion of powder particles and agglomerates in and above the powder bed due to the vapour jet on the melt pool surface [1]. Thus, a key component for repeatable and stable operation is the cross-flow of inert gas over the powder bed, which allows the removal of metallic vapours, fumes and airborne particles from the area being processed. Based on studies in commercial LPBF systems [2], guidelines generally followed to achieve acceptable build quality include incorporating a laminar flow, with momentum evenly distributed across the inlet, while avoiding "dead spots" with low flow and gas recirculation in the chamber.

A cross-flow device was incorporated into our open architecture LPBF rig at Heriot-Watt University, that was capable of delivering high volumetric flowrates in the laminar regime. To study by-product extraction in depth, we used long standoff microscopy and schlieren imaging to get clear views of the powder bed and the atmosphere above it during the manufacture of 5x5x5 mm^3 SS316 cubes. This article summarises the key parts of the imaging with our analysis, presented more comprehensively in [3].

Cross-flow interaction with laser plume

Without extraction (Figure 1a), fumes remain over the scanned area. This effect is demonstrated by the refractive index gradients at the edges of the image, captured during the last track of the island scan. The path of the laser beam is visible, owing to scattering and absorption by the diffuse fumes. In the schlieren setup, 1070 nm radiation was blocked by heavy low-pass filtering, suggesting that the white lines in the image are due to thermal radiation emitted by hot fumes. Moreover, regions with a higher fume concentration appeared darker and higher absorption was highlighted by the outline's intensity during scanning.

In the absence of a cross-flow, the primary source of momentum change acting on the airborne particles is the vapour jet. Therefore, during the second and subsequent tracks, the laser plume drags cold particles higher, resulting in a chaotic mixture of hot and cold particles high above the powder bed, Figure 1a. When the cross-flow is on, however, cold particles that are within the cross-flow stream do not remain in place long enough for the laser to interact with repeatedly as shown in Figure 1b.

Particle extraction effectiveness

To understand the importance of crossflow momentum, Ar flowrate was varied to yield a peak velocity between 2.1 m/s (Reynolds number Re ~1400, high flow) and 1.2 m/s (Re ~700, low flow) over the scanned area. Individual particles can be resolved at the optical system's magnification, allowing the number of particles in each frame to be estimated via image processing, using a circular Hough transform (see Figure 2).

For both cases, a rising-and-falling trend is observed in the particle count, due to the alternating laser scan pattern. The count varies significantly during scanning, due to stochastic events such as particle spattering, collisions, agglomeration, etc. A lower number of particles is observed in the atmosphere over the island when using the high flow. Consequently, collisions between particles and laser-particle interactions occur less frequently.

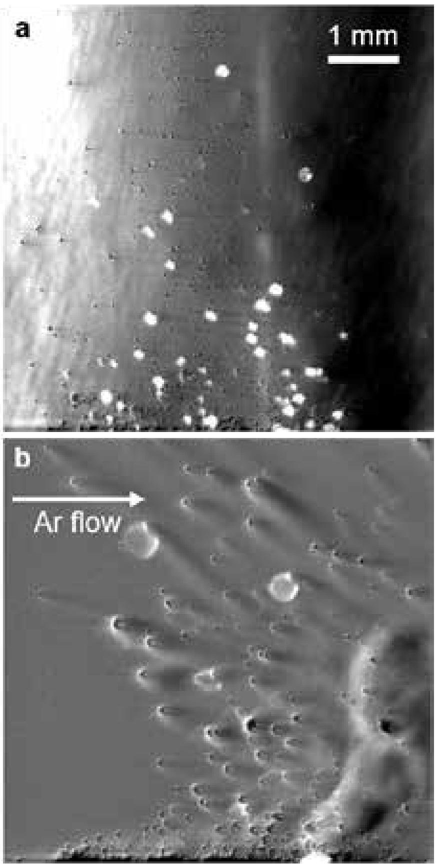

Figure 1: Schlieren images of LPBF (a) without cross-flow (b) with cross-flow. Videos for all images available with [3].

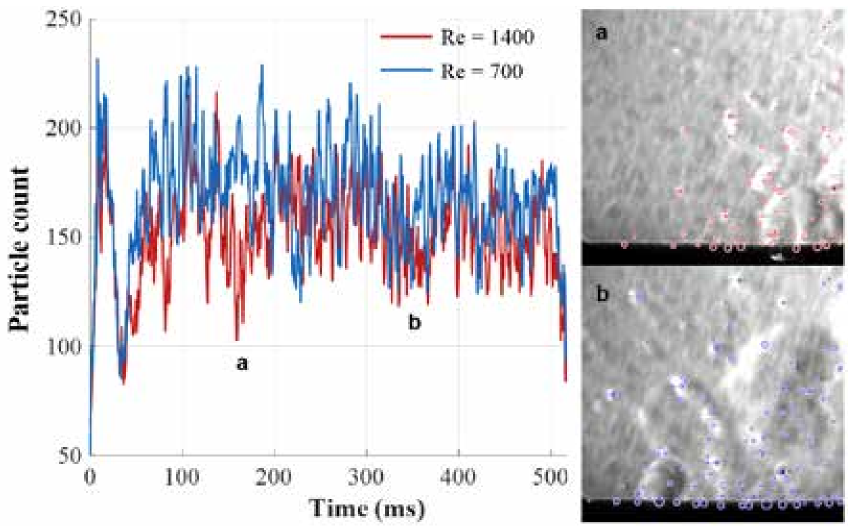

Figure 2: (Left) Total number of particles over scanned area during printing. (Right) Annotated frames of the local minimum count for (a) high flow and (b) low flow. Faster extraction limits laser interaction with airborne particles, thus improving repeatability.

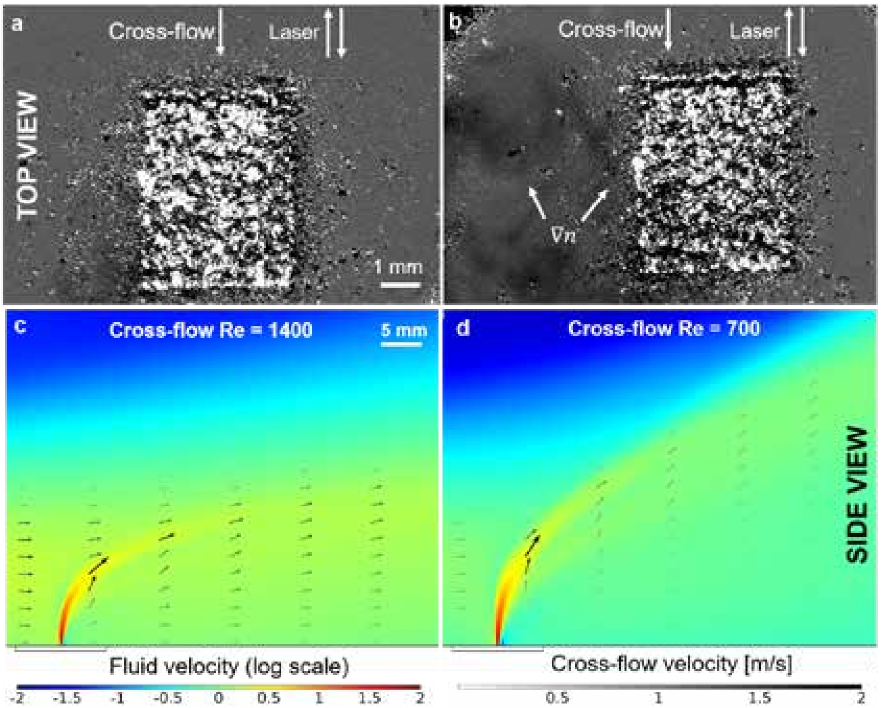

Figure 3: High (left) and low flow (right) comparison. (a – b) Direct imaging during layer 30, showing higher atmospheric fume content under low flow. (c – d) Velocity plot, suggesting plume is not incorporated in cross-flow stream under low flow.

Fume extraction effectiveness

The direct imaging of Figure 3 (a-b) shows that lowering the Ar flowrate reduces the extraction rate and therefore fumes remain within the scanned area longer. Video footage [3] reveals that the beam passed through the fumes more frequently under low flow and especially during the start of each track, as the by-products of the previous track had not yet cleared.

The numerical model, Figure 3 (c-d), illustrates that the laser plume acts as a barrier to the cross-flow, with the high upwards momentum imparted by the vapour jet countering the sideways momentum of the cross-flow. The simulations were in good agreement with the experimental results: the momentum in the low cross-flow is insufficient to fully incorporate the upwards plume, contrary to the high flow case. Under low flow, a fraction of the fumes end up recirculating within the processing chamber, condensing on its upper surfaces.

The observation of stronger refractive index variation in the low flow case is not just due to the slower rate of extraction: the increased height of plume above the bed means that the effect of a given refractive index gradient has an increased effect on the image distortion. A laser beam passing through these refractive index gradients would undergo translation and defocus that increases with the plume height above the powder bed, leading to variability in the deposited energy flux at the required position on the powder bed. This becomes even more important for the simultaneous operation of multiple lasers, where the trail of fumes within the cross-flow stream generated by each laser should be considered, ensuring processing through a clean atmosphere.

Plume atmospheric propagation

The Schmidt and Nusselt numbers of the plume are close to unity, and thus momentum, heat and Fe mass dissipate through the Ar atmosphere at similar rates. Further, a very low Richardson number suggests that buoyancy effects are negligible for the propagating plume, and the main driving force is the momentum of the vapour.

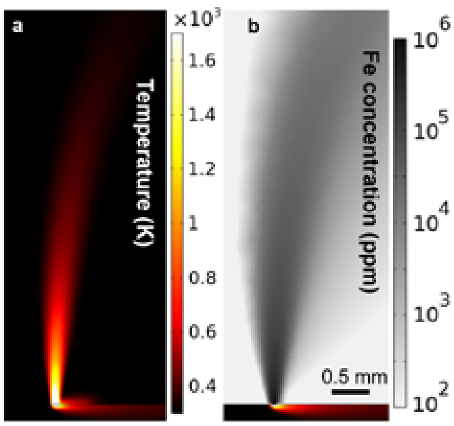

Figure 4: Calculated (a) temperature and (b) Fe content over the melt pool.

Close to the powder bed, the velocity of the laser plume is so high that it is unaffected by the cross-flow, regardless of flowrate. Figure 4a shows that the high temperature zone is restricted within that region; a few mm above the jet's origin, the temperature returns to ambient due to heat transfer from the plume to its surroundings and convective cooling by the cross-flow. Conversely, the strong evaporation from the surface results in appreciable Fe content dispersed within the stream. Hence, the imaged refractive index gradients that extend several mm from the melt pool can be attributed predominantly to metal concentration gradients rather than temperature gradients.

Conclusions

High-magnification schlieren imaging enabled the visualisation of the interactions between the cross-flow, laser plume and individual powder particles in LPBF.

Vapour from the melt pool condenses forming metallic nanoparticles, capable of directly interfering with the laser beam. Radiation tracing the path of the laser beam is often observed in commercial PBF chambers, indicative of condensate accumulation within the chamber and thus, sub-optimal extraction.

The extraction rate of process by-products is a limiting factor the productivity of a given LPBF chamber. The dwell time between laser scans should therefore be adjusted to allow sufficient time for by-products to clear.

Significant distortions due to refractive index gradients were observed when looking down through the plume at the powder bed with the direct imaging. Furthermore, it was shown that stochastic events over the processing area, which often lead to the formation of defects, were more prevalent under low flow conditions. A cross-flow stream with sufficient momentum to extract and disperse by-products efficiently is therefore essential for high quality parts.

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Ioannis Bitharas is a Research Associate at Heriot-Watt University. His research interests are optical diagnostics and multiphysics simulations of manufacturing processes.

SEE OBSERVATIONS P28

LASER INDUCED DAMAGE THRESHOLD TESTING: APPLICATIONS AND RESULTS

JAN VANDA

Laser Induced Damage Threshold (LIDT)is an established method used to estimate the maximum affordable energy or power that a particular optical component may handle without detrimental damage. Although the damage threshold testing procedure is standardised and commonly used for testing optics, the use of its principles for other applications, like laser processing window determination, is relatively scarce. The newly emerging kW-class ultrashort laser systems in combination with advances in their utilisation brings challenges in durability, efficiency and reliability of devices and processes, where proper testing provides the right answers.

Laser Induced Damage Threshold testing is a well-known method, recognised by the International Standards Organisation (ISO) in a series of ISO 21254 standards [1]. These standards were developed in order to ensure reliability and portability of results among different testing facilities. Although testing schemes initially reflected the need of laser optics manufacturers, rapid development of high power laser sources and their applications stimulated interest from other fields, such as machine integrators and (micro)machining [2].

LIDT testing capabilities at HiLASE

The LIDT laboratory benefits from advanced laser development at HiLASE, which gives access to the state-of-the-art diode-pumped solid-state systems which offer incomparable energies for experiments. Two systems are mostly used for tests: Bivoj (10 ns, 1030/515/343 nm @10 Hz, flat-top square beam) and Perla (1.7 ps, 1030/515/343 nm @1 kHz, round Gaussian beam) [3].

With both lasers providing very high pulse energies, it is possible to measure LIDT using a larger beam size, which greatly increases the measurement accuracy. The testing station, as shown in Figure 1, is situated in a clean laboratory with controlled humidity, temperature and dust particle concentration, with a measured cleanliness of ISO class 6. The sample mount and damage detection setup is placed in an experimental chamber with the option of a vacuum (10^{-3} mBar) or non-corrosive atmosphere (up to 2 Bar). A remote-controlled micrometer 2-axis translation stage is used for sample mounting. Online damage detection is realised by an online camera with high magnification that continuously monitors the exposed site. A laser scanning microscope is

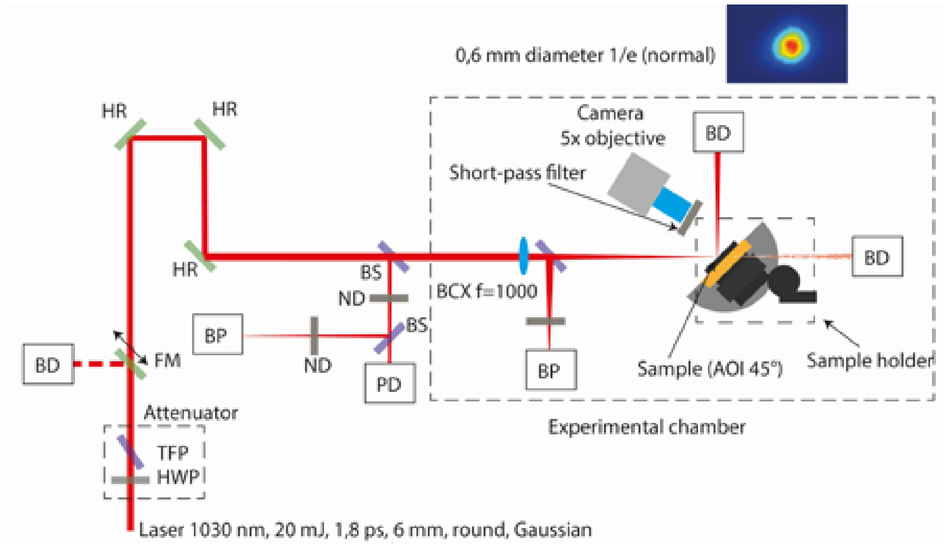

Figure 1: LIDT station layout designed at HiLASE (for Perla laser). HWP - half wave plate, TFP – thin film polariser, FM – flip mirror, BD – beam dump, HR – highly reflective mirror, BS – beam sampler, ND – neutral density filter, PD – photodiode, BP – beamprofiler.

used for the examination of the sample before and after the testing procedure [4].

Development of new optical coatings

A further development of silver mirrors is possible with the deposition of functional dielectric coatings, in order to enhance the mirror reflectivity in a narrow spectral range around 1030 nm. To develop and assess the laser performance of such designs, respective prototypes were tested on LIDT according to ISO 21254 recommendations. At least 100 sites on each sample were exposed to a ~500 µm diameter laser beam at the plane of incidence with ten different energies.

Online camera-based damage detection was used to observe sites during the exposure and damage events were noted. Collected data were used to extrapolate damage thresholds of respective samples and results are plotted in Figure 2.

Although the standard design demonstrated fairly good LIDT, minor changes in design, such as an intermediate layer or different coating material, may offer up to 30% improvement in performance. Further tuning of the technology with feedback from damage testing may lead to even better results, as more than five times higher LIDT of mirror enhanced with dielectric multilayer compared to the commonly used mirror design [5].

Laser processing window assessment

The dependence of ablated material volume on energy is is a key parameter for efficient laser use in various kinds of laser cutting, drilling or other means of material removal. Thus, laser damage threshold testing procedures are ideal to measure such dependency, allowing proper setup of processing conditions and optimalisation of the whole process.

A good example of such application is protective coatings removal, which is used in the industry to increase the wear and oxidation resistance of tools. If the tool needs to be sharpened, repaired, or the protective layer needs to be restored, the current layer has to be removed. Standard removal methods are based on chemical etching which is energy-demanding and brings a significant environmental burden. The replacement with efficient laser ablation could shorten the removal process time, decrease environmental impact and reduce overall costs. Particularly in the case of CrAlSiN layer removal, LIDT testing plays a key role in the determination of two main laser parameters – fluence and number of pulses. Also, the quality of the ablation crater is observed, because it is desirable not to harm the base material.

The graph in Figure 3 clearly shows the trade-off between process energy, volume of ablated material and speed of the coating removal. As a price-per-pulse is given for any laser system,

LASER INDUCED DAMAGE THRESHOLD

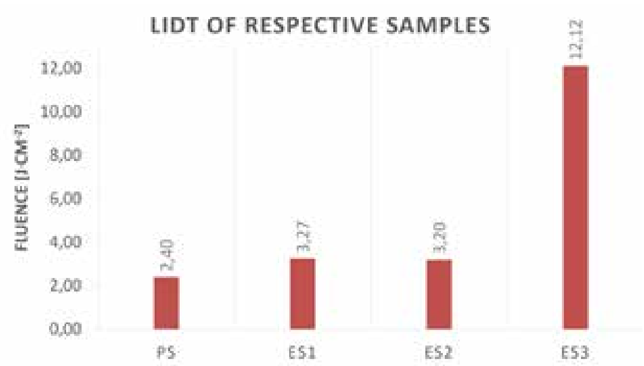

Figure 2: Damage thresholds of tested samples. PS: silver mirror protected with standard SiO_2 layer; ES1: silver mirror protected with standard SiO_2 layer, enhanced with Al_2O_3 intermediate layer; ES2: silver mirror protected with Al_2O_3 layer; ES3: silver mirror protected with dielectric multilayer improving the reflectance at 1030 nm and enhanced with Al_2O_3 intermediate layer.

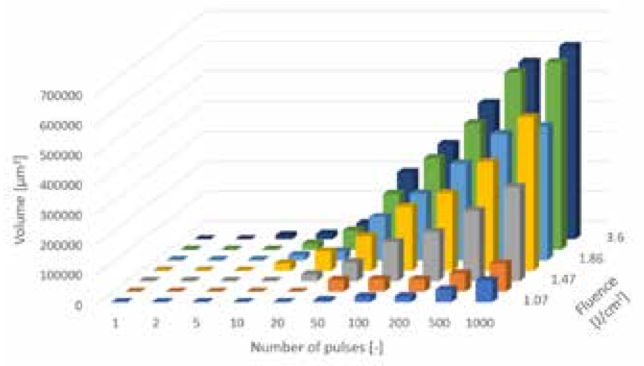

Figure 3: Measured dependence of ablated coating volume on fluence and number of pulses at fixed spot size.

such information is a must when looking for cost-effective lasers to be used in such processes at an industrial scale.

Laser components certification

The emergence and growth of new high-power laser applications keeps pushing the laser industry to its limits both in terms of the achievable laser power and offered laser parameters. This popularity drives forward development in laser optics and components. In particular, when a new material or manufacturing technology emerges, it is essential to validate such a part for laser induced damage performance to determine the scope of its usability. One such example are calomel crystals (mercury chloride). Although well-known and used in other fields, only recently has it been possible to produce the crystals in large batches with sufficient quality to be used in laser optics [6]. LIDT tests are even more important here, as the calomel crystal is composed of two very toxic elements which are released after laser induced ablation.

Results from the testing showed strong correlation of LIDT on the angle between the testing beam and the optical axis of the crystal, with the LIDT being five times larger for the 001 configuration over the 110 configuration. Damage morphology varied from colour centres over small cracks and surface blisters to full craters (see Figure 4). Although further testing and exploration of this crystalline form is still required, related damage threshold and consequently a window of safe usage was clearly defined by LIDT tests.

Integration of new technologies

A typical example of the integration of technologies is where LIDT testing plays a key role in the use of optical fibres as a transmitting medium for high energy laser pulses. Optical fibres offer a stable and safe environment for laser pulse propagation, minimising risks from optics misalignment, beam pointing stability and hazards for operational staff. However, optical fibres are not designed primarily for transmission of high-power laser pulses and the capabilities of standard fibres are quite limited [7]. Recent tests of real large-core optical fibres and their comparison with bulk preforms demonstrated an order of magnitude difference in damage threshold [8]. Observed damage, occurring mostly on the fibre surface, led to the conclusion that more development in technology and in fibre cable manufacturing has to be conducted in order that this technology is suitable for high energies. Proper on-site diagnostics allowing the continuous monitoring of exposed fibre is as important as the precise measurement of the laser beam. Iterative steps to improve fibre front-surface properties, based on feedback given by LIDT testing of respective samples, led to fibre solutions offering transmission of ns laser pulses with a peak power as high as 100 MW.

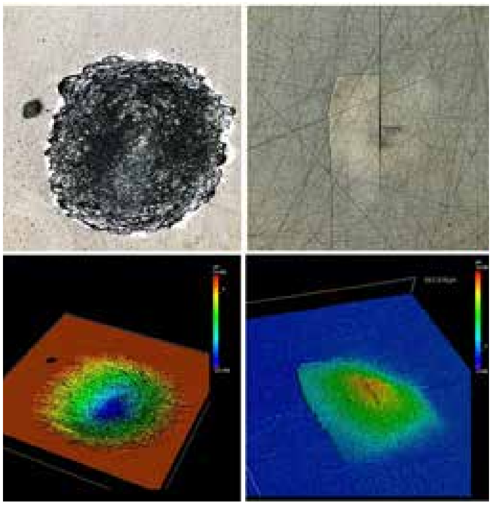

Figure 4. Details of the craters ablated on HgCl crystals with 1,8 ps pulses at 1030 nm. Crystals were prepared in plane 110 (left, damaged at 1 J/cm²) and 001 (right, damaged at 5 J/cm²)

Summary

The growing market for high-power laser devices as well as the evolution of related applications comes together with the need for precise testing and measurement tools. Since lasers are an integral part of modern technologies, which can be found in almost any industrial field, their reliability, traceability and a systematic assessment of their related components, is key when looking at their suitability for a particular application. Although standardised LIDT tests are not the only way to approach such a concern, we have demonstrated several case studies, where our results were essential for successful deployment of assessed technologies and components.

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SEE OBSERVATIONS P28

THE VALUE OF LASER PROCESSING IN THE MEDICAL DEVICE INDUSTRY

JONATHAN MAGEE

From cardiac rhythm management, to neuromodulation, to orthopedic and hearing implants, who would have considered that laser materials processing systems would play such a pivotal role in the production of these life improving devices? These are some of the applications of laser processing systems used in the manufacture of medical devices. The application base is constantly expanding. Even the basis for entirely new products has centred around the availability of laser machine systems technology.

Laser systems have always been important to the medical device industry. When first commercialised in the 1970s, lasers were embraced by the industry and as processing technologies have evolved with the products they are capable of making, laser technologies have enabled new and improved medical product designs. We are now at the stage of using ultra short-pulsed lasers that impart insignificant heat input to machining operations on medical devices.

Orthopedics

Orthopedic implants have for many years been laser marked and engraved, and some devices are laser welded and laser 3D printed from metal powders. The complete laser generation of ortho implants has led to mass customisation using data generated from MRI scans. Laser systems are even able to polish selective areas of the metal implants so that they have a lower surface roughness than the original 5-axis CNC machined surface. Conversely, laser machining systems can structure ortho implants to provide surfaces for cells to osseointegrate to. Diverse functional surface properties can be produced on the same part.

Plastic marking on a hearing aid

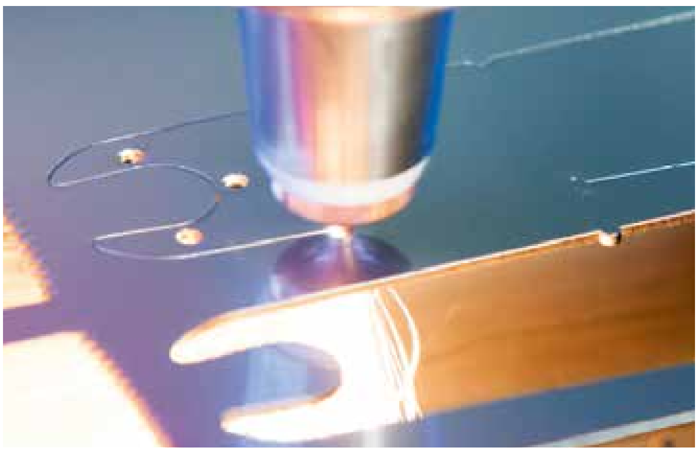
The use of laser-based manufacturing is extensive in this industry and coupled with order data handling interfaces, form an integrated laser system that is directly linked back to the product ordering and verification system. This provides traceability and quality checks for each part, and a log of everything that took place during that laser materials processing operation, eliminating risk and supporting the manufacturer's ability to gain speedy regulatory compliance.

The instrumentation used in ortho implants is also heavily reliant on laser processing, across laser cutting of bone saws, welding of saw cartridges and marking graduated scales for surgical cutting depth and UDIs.

Vision systems, such as smart cameras with attendant software, are widely integrated into laser systems to provide the necessary checks during processing to assure a perfect product. Many of the processes used in the Ortho business are fibre laser based, yet CO_2 and older technologies still exist. Medical device manufacturers tend to seek out the forward-looking technologies to give them competitive advantage and to improve regulatory compliance on production methods.

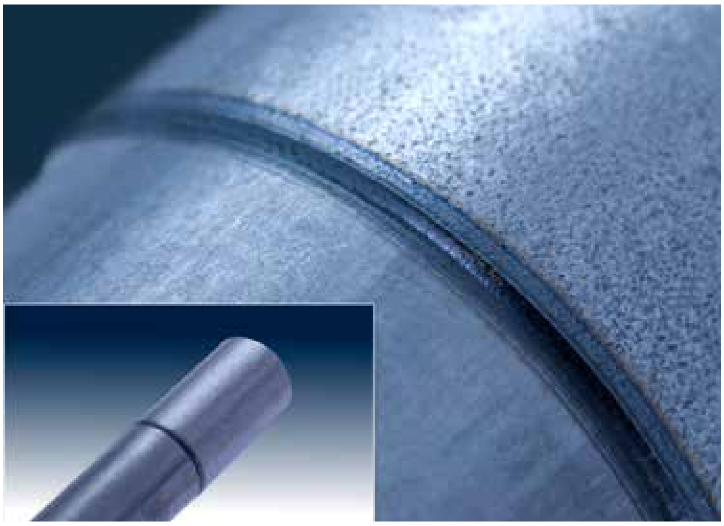
Cardiology

In several critical categories, laser technologies make a difference. For example, cardiac rhythm management is concerned with improving the quality of life for someone with a heart that often beats too slowly, or misses beats. These devices employ several industrial laser processes in their production, such as laser welding with pulsed fibre lasers to provide a hermetical seal on the pacemaker cartridge, wire stripping of electrodes



Laser cutting surgical bone saw blade

High-precision corrosion resistant black laser marking (UDI code) on a laser-cut bone saw blade



Laser welding of medical cannisters for device encapsulation e.g. implantable defibrillator battery cans.

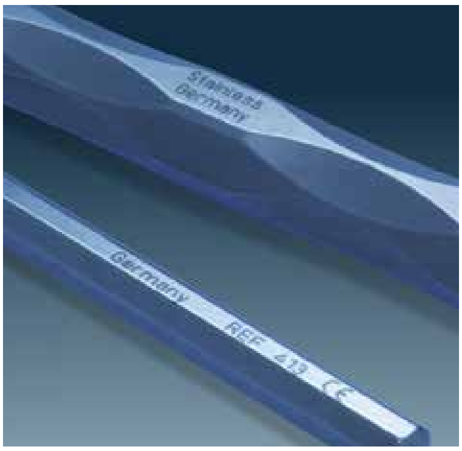
Laser plastic welding and marking of medicine vial

used for the device with q-switched and short pulsed lasers, and laser marking of UDI codes onto the device with fibre laser markers. Pacemakers have heat sensitive electronics in their assembly and originally this was one of the reasons that laser systems were deployed in their manufacture, as the net heat transfer is negligible or manageable with appropriately engineered laser systems.

Lasers also lend themselves to other applications, such as their integration into a glovebox welding system to prevent oxidation of the welded pacemakers.

Neuromodulation

Neuromodulation is a growth area in which medical devices are used to control the effects of conditions such as Parkinson's disease and Benign Essential Tremor. These revolutionary devices can be implanted into the brain tissue or spinal cord to improve motor co-ordination. The electrodes are made from relatively inert metals that are coated with plastics. To reveal the electrodes, which are subsequently embedded in the body, the delicate wires made from materials such as platinum and copper are laser wire stripped of their Fluoropolymer jackets,



Laser marking of steel medical instruments

often PTFE, and other polymers such as PET or Polyimide.

The laser systems used are diverse in terms of the edge quality required on the polymer at the transition zone where it meets the metal. Machining strategies control factors such as lubricity and resistance to delamination at the transition zone. The desired effect on the bare metal can also be controlled, such as the ability to roughen the ends of a stripped guidewire for subsequent device attachment by some form of bonding.

The great advantage of laser systems in these processes is how well they can be integrated into turnkey automated systems for manufacturing, and the fact that they do not touch or impart much mechanical force onto wires that can have a diameter down to one thousandth of an inch. These processes when carried out manually under a microscope, required dexterity, were laborious and were not automated.

An analogous laser structuring technology is used on tiny cochlear implants for improving deafness. The structuring can prevent osseointegration but improve the attachment of neuronal cells through certain machined structures. Laser systems can usually be matched to the physical scale of the product and production volume with a fast ROI.

The tool of choice

It is often the case that lasers are the best tools available to the medical device manufacturer, and this is the reason that the engineering staff of device manufacturers frequently look to a laser system as one of their first production ideas when developing innovative new products. There are many other processes not discussed here, from endoscope manufacture, micro-fluidic assay diagnostic device machining, to engraving and structuring of ceramics and glasses used in medical devices. Cutting of metals and plastics for stents, hypotubes, heart-valves, opthalmology blades and welding of plastics have all now be come chosen specialised topics of large medical device manufacturers and their contractors.

Summary

Since their inception, laser systems have been a major contributor to the successful creation of all types and sizes of medical devices. From surgical to implanted devices, lasers can ensure that parts are identifiable, non-corrosive and non-toxic.

With their versatility and ability to process on a wide range of materials, expect lasers to offer up even more cost-effective and innovative processes as medical technologies continue their rapid advance. These advances will offer benefits to design engineers as well as to healthcare professions in bringing state-of-the-art opportunities to mitigate risks, assure regulatory compliance and elevate patient safety.

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Jonathan Magee has worked closely with the Medical Device industry for more than twenty years on the application of laser technology.

SEE OBSERVATIONS P28

SURFACE TEXTURING

INDUSTRIALISING FUNCTIONAL LASER SURFACE TEXTURING - SHARK PROJECT

TIAN LONG SEE & PAUL BUTLER-SMITH

Three years ago, 11 consortium partners across Europe came together with one mission, to industrialise laser functional texturing, and the SHARK project was born. The SHARK project, lead by the MTC, consist of 3 research and technology organisations (The MTC, IWS and Herriot Watt University), 4 technology providers (GFMS, SENSOFAR, SIMTEC and ATS) and 4 end-users (Sandvik Coromant, Johnson and Johnson, Unilever and MAN Energy Solution). The concept of SHARK is to adopt a comprehensive and holistic approach to the laser surface texturing (LST) process chain by synchronising and optimising the process through incorporating modelling, monitoring and closed-loop processing cycles. The key ambition is to create a knowledge management system to cover the whole LST for functionality from design to parameter and texture optimisation.

What is Surface Engineering?

Surface engineering is a key enabling technology that underpins almost every industrial sector and product [1]. Despite the huge potential and market for surface engineering, the uptake of these technologies is still relatively low and they are mostly seen as an “add-on” or “afterthought” option that can be used to enhance product performance at the final stage of the production line. This seriously undersells their values and results in manufacturing process inefficiency [2].

Surface engineering typically takes two forms; texturing and coating. Laser surface texturing is one of the most promising surface engineering techniques thanks to its excellent repeatability, non-contact process, ability to achieve small feature size and the possibility of achieving high quality finishing. Even though LST is a very mature process and is commercially available through a number of machine tool suppliers, its commercial applications are mainly limited to aesthetic/decorative texturing rather than functional. A general consensus among end-users and technology providers regarding the reasoning of the low uptake is due to i) high cost, ii) poor productivity and iii) lack of knowledge.

Case study: surface texturing of cutting tools

One of the case studies used to demonstrate the SHARK concept was on cutting tools provided by Sandvik Coromant. The performance thresholds of cutting tool geometries, tool materials and machining systems are often restricted by surface friction from workpiece material engagement and flow across the cutting tool surfaces. This is contributed by factors such as cutting tool and workpiece material properties, tool geometry, cutting parameters, coolant application and the machining environment [3].

Friction reduction, wear reduction and cutting performance improvement have been demonstrated elsewhere [4, 5, 6, 7, 8] but the mechanism by which the textures achieve this is still unclear, which has hindered texture design optimisation and industrial uptake.

Surface texture design

Two main approaches have been taken to design and optimise the texture for this particular application; simulation and experimental testing. A commercial Multiphysics (COMSOL) software suite was used to perform optimisation of the texture design for specific functionality, such as fluid flow, thermal dissipation and friction coefficient change. As for the experimental testing, three approached were employed which are orthogonal turning test to capture cutting forces, in-situ friction and laboratory based tribological tests to capture friction forces (Figure 1).

Once a design was confirmed through literature or simulation, the texture pattern was applied to the surface of the uncoated tools using a GFMS Laser P 400 U platform equipped with a femtosecond pulsed IR laser (Pulse duration = 290 fs) from Amplitude.

Optimised laser processes were developed where texture patterns of dimples and parallel grooves with various density were applied. The textured tools were examined using a SENSOFAR white light interferometer and an SEM. Example of surface textures applied to the cutting tools is illustrated in Figure 2. These textured tools were then coated and inspected again to ensure texture compliance to requirement after coating.

Textured tools performance testing

The orthogonal turning tests were conducted on a DMG CTX510E CNC lathe. A bespoke tool holder was designed for the cutting tool and the dynamometer (Kistler: Type 9129AA). The dynamometer was configured to capture the cutting force Fx orientated orthogonally to the tool’s rake face and Fy, the combination of the feed force and friction force components coinciding with the tool’s rake surface. Signal

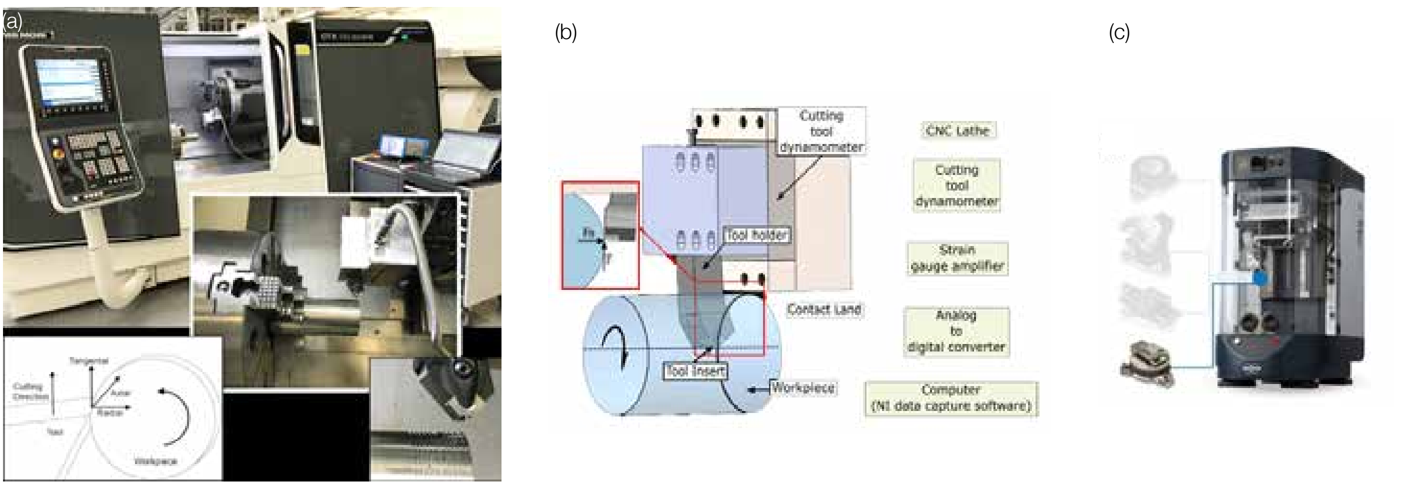

Figure 1: a) Orthogonal cutting test setup b) the data capture diagram and c) tribometer test setup.

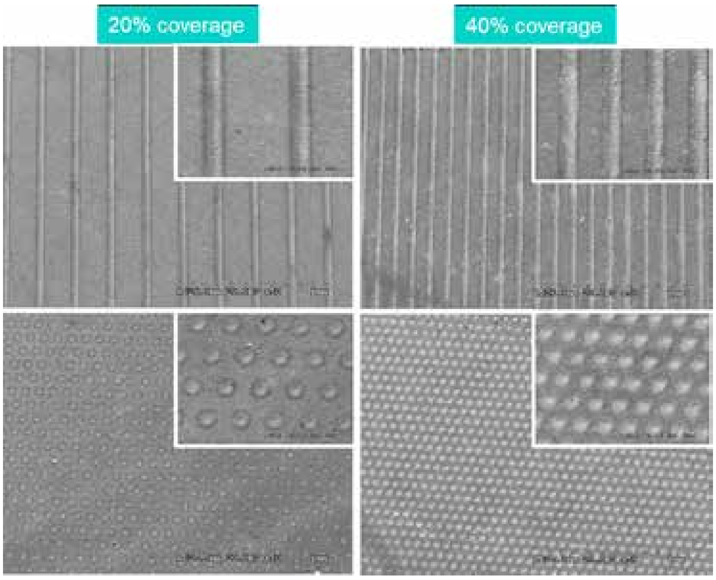

Figure 2: SEM images of laser textured cutting tools with 20% and 40% grooves and dimple density.

processing was carried out using a charge amplifier (Kistler 5070A) and an in-line analogue to digital converter (NI 9205) to provide the inputs to a computerised platform incorporating National Instruments signal acquisition software. Pressurised fluid delivery was employed using a (5:95) emulsified solution (Blaser Synergy 905).

In addition, in-situ friction tests were conducted on the same machine to mimic the actual machining conditions for chip flow across the rake face of the tool, by considering the cutting tool and workpiece material tribo-pair, contact forces, chip velocity and the application of cutting fluid. The load Fn and friction response F were captured.

The high speed tribometer tests were conducted on a Bruker UMT tribometer. Flat ended cylindrical pins with end-diameters of 2 mm were reciprocated against the top flat surface of tungsten carbide inserts. The cylindrical pins were machined from the same workpiece material used in the orthogonal turning and in-situ friction tests.

Outcome of the testing regime

Surface texture design has a significant impact on cutting tool performance which affects attributes such as cutting forces, surface friction and tool wear. The effects of surface textures are also significantly influenced by the machining parameters used. Figure 3(a) displays the coefficients of friction of selected dimple and groove texture designs vs oscillation frequency, from which surface speed can be determined. The trend lines of coefficients of friction show an increased separation above 30 Hz (28.3m/min) and the lowest friction values being produced by the dimple textures.

Figure 3(b) presents the cutting forces Fx and Fy produced by orthogonal turning tools employing these texture designs, which show the dimpled textures produce lower cutting forces for the friction force component, Fy against the untextured benchmark.

These complementary tests were selected to reveal the influence of surface texture on cutting forces (and workpiece chip friction) on orthogonal cutting tools manufactured from laser textured coated cemented carbide. The tests have revealed that surface texturing consisting of closed features (dimples) are able to reduce friction in the mixed and hydrodynamic lubrication regimes of the tool-chip interface for small areas of contact, resulting in reduced cutting forces. The functional performance testing carried out on these coated cutting tools has demonstrated a friction coefficient reduction of 46% which corresponds to a cutting force reduction of 18.4% compared to the untextured tools [9].

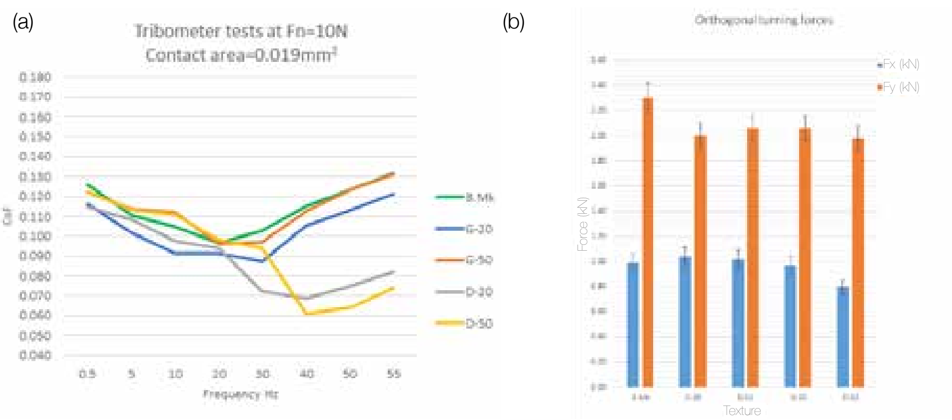

Figure 3: (a) Coefficient of friction as a function of sliding speed from tribometer tests and (b) cutting forces Fx and Fy from orthogonal turning tests for untextured and textured coated tool inserts [9].

Conclusion

Surface engineering through laser surface texturing has proven its capability in improving component lifespan as well as performance and is capable of providing companies with an improved product for their customers. In addition, it can also act as a unique differentiator for products in a crowded, competitive market of similar products. The SHARK project's successful outcome has lowered design and processing barriers, resulting in high quality and more reliable products and components.

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SEE OBSERVATIONS P28

SURFACE TEXTURING

ICE-FREE SURFACES ENABLED BY LASER MICROTEXTURING

TIM KUNZE ET AL.*

In numerous industries such as aerospace, transportation, and energy supply, ice generation and accretion can cause severe issues. For example, a thin layer of frost settling on the wings of an aircraft can adversely affect the aircraft's aerodynamics and ultimately lead to increased fuel consumption, reduced operational performance and potentially hazardous situations. To overcome these challenges, numerous approaches have been developed to delay ice formation and/or to inhibit ice adhesion to technical surfaces. Among them, laser-based surface functionalisation aims to obtain superior anti-icing characteristics as well as to improve the de-icing performances. It has been identified as a powerful approach to tackle future industry demands for ice-free surfaces. In this context, Direct Laser Interference Patterning (DLIP) plays a key role in addressing both a significantly enhanced performance and industry-relevant process speeds.

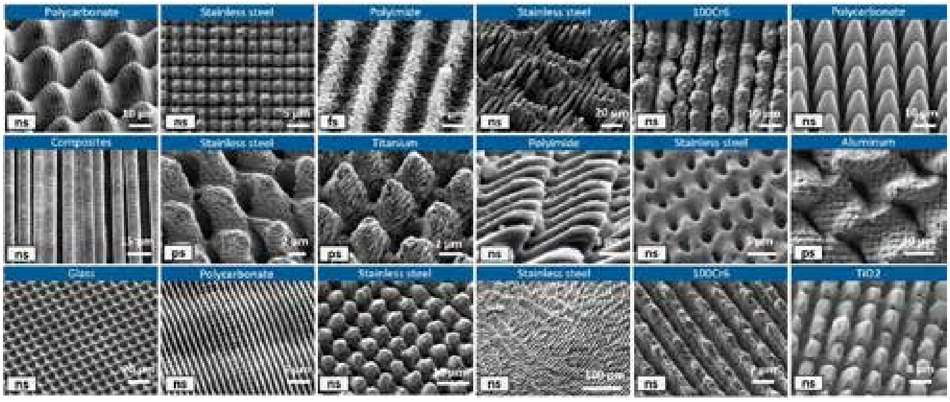

Figure 1: Different microarchitecture designs realised using Direct Laser Interference Patterning.

Icing: the status quo

Ice accretion and accumulation is a potential hazard in various industries including ground, sea, and air transportation. The aerospace industry is particularly affected by icing phenomena on airplane surfaces where ice formation presents a serious safety risk for aircraft. A thin layer of frost settling on the wings, or other areas such as the tail, can adversely affect the aircraft's aerodynamics. As a result, lift may decrease and drag increase. Moreover, ice accumulating on probes and sensors can compromise air speed measurements that are critical to in-flight safety. Therefore, snow and ice must be cleared from aircraft before they take off. On the ground, this task falls to special vehicles that spray chemical agents onto all vulnerable surfaces. However, fluids of this type are harmful to the environment and expensive, since a substantial amount – 400 to 600 litres – is needed to de-ice a plane.

During flight, icing is caused by the impingement of supercooled water droplets in clouds, which may either directly adhere upon impact or flow back as a thin film of water and collect into rivulets due to surface tension. In most cases, ice protection systems (IPS) such as heating elements are employed on board to help getting rid of accumulated ice. The great drawback of these heaters is that they increase energy and thus fuel consumption (ca. 4 W/cm^2) together with an undesirable amount of additional weight. Therefore, a great part of ice protection research is focused on passive countermeasures using icephobic surfaces, which can reduce the adhesion strength of ice and reduce or delay the ice accretion, in principle without using additional energy.

Two approaches typically limit ice adhesion on aircraft surfaces: (i) a polishing process to reduce the mechanical interlocking between the surface and the accreted ice and (ii) functional coatings that lower the surface free energy and thus reduce the bonding strength between ice and surface. Although icephobic coatings are still widely explored, the extensive application of these to aircraft surfaces presents challenges in terms of homogenous coverage, long processing times as well as coating stability against environmental agents.

More recently, laser-based nano- and microtexturing approaches with strong water repellent properties (so called superhydrophobicity) have been proposed as an alternative to surface coatings for reducing ice adhesion [1]. In this context, special rules favouring the perfect icephobic surface texture design have been proposed, where the feature size should be at least one order of magnitude smaller than the average size of impacting droplets, to guarantee water repellence also in the micro-scale [2]. In other words, the superhydrophobic behaviour of a surface alone does not guarantee icephobic behaviour. A technology, which provides all the required characteristics for icephobic surfaces in terms of feature size, superhydrophobicity as well as industry-relevant process speeds is Direct Laser Interference Patterning (DLIP), which will be highlighted in this article.

Direct Laser Interference Patterning as a key enabler

The DLIP approach relies on the overlap of two or more coherent pulsed laser beams on the surface to be treated, where an interference pattern is created. At the intensity maxima positions, the material is directly modified, while at the minima it remains unaffected, creating structures much smaller than the laser beam size itself. For a given laser wavelength, the pattern period can be easily adjusted by modifying the angle of incidence, while several geometries can be produced by changing the number of beams, laser polarisation and the intensity of the interfering beams.

The interference pattern that is formed can be used to generate defined surface structures with structure periods between 180 nm and 30 µm on 2D and 3D components made of metals, polymers, composites, glass, ceramics, as well as on coatings. The functional surface topographies are typically produced in one single process step with proven process speeds up to 0.9 m^2/min, without additional process requirements such as clean-room conditions or process gases [3]. Examples of DLIP-generated single and multi-scale surface topographies are depicted in Figure 1.

Icephobic surfaces with exceptional performances

Within the European Project LASER4FUN as well as the Reinhart Koselleck project, a DLIP process was developed in a concerted effort between Fraunhofer IWS and Technische Universität Dresden to identify the optimised surface texture in view of anti-icing and de-icing applications. Using a two-beam interference optical configuration, periodic pillar-like structures

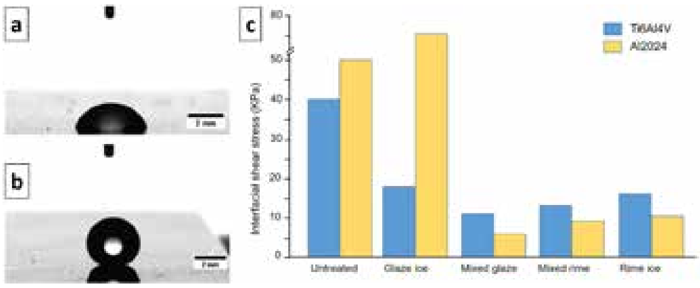

Figure 2: (a) Exemplification of the change in water contact angle on the reference (top) and DLIP-treated surface (bottom) for Ti6Al4V. (b) Ice adhesion of the laser-textured surfaces as measured by the interfacial shear stress under different atmospheric conditions for Ti6Al4V and Al2024 alloys.

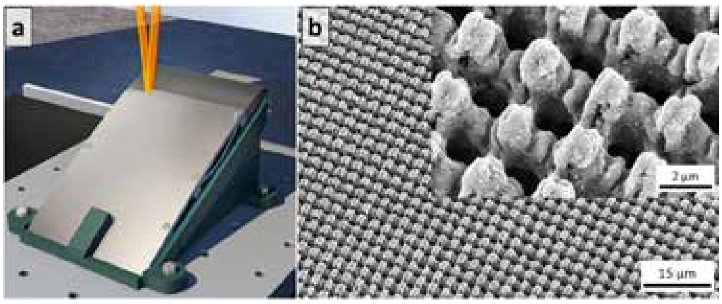

Figure 3: (a) Representation of the 3D processing of the NACA profile through DLIP and (b) resulting microstructures on the Ti6Al4V airfoil.

were produced on Ti6Al4V and Al2024 alloys, with a spatial period of 2.6 µm. The experiments were performed using an infrared (IR) pulsed picosecond laser source operating at a wavelength of 1064 nm. Due to the ultra-short pulse duration, the generated DLIP features also exhibited Laser Induced Periodic Surface Structures (LIPSS), thus creating a multi-scale periodic surface with superhydrophobic behaviour which mimics well-known natural examples such as the lotus leaf (Figure 2a, b).

It is important to mention that in all cases, the size of the laser-generated surface features is much smaller than the median volume diameter (MVD) of supercooled water droplets (typically ~20 µm) according to the typical drop size in clouds under the specifications of the Federal Aviation Administration. The ice adhesion of the laser-textured surfaces was quantified by measuring the interfacial shear stress under different atmospheric conditions, namely rime, mixed rime, mixed glaze, and glaze ice in the iCORE (icing and contamination research) facility located in Airbus Central R&T [2, 4]. Figure 2c summarises that, by using DLIP processing, the interfacial shear stress can be reduced by up to 88 % for Al2024 and 75 % for Ti6Al4V, respectively. An exception was found for the glaze ice type in the case of Al2024, where the shear stress was increased due to texturing.

The validation of the promising results achieved on the Ti6Al4V surface was performed under realistic conditions in a wind tunnel at AIRBUS Central R&T [5]. Therefore, a patterning process was developed by Fraunhofer IWS researchers to transfer the optimised structure onto a complex three-dimensional NACA airfoil which served as a miniaturised but realistic wing pendant (Figure 3).

The icing tests in the wind tunnel included a direct comparison between a structured and an unstructured NACA airfoil (for reference) at different wind speeds, air temperatures and at various humidity levels. (Figure 4). The partners from AIRBUS were able to demonstrate that ice growth on the laser-functionalised surface is significantly changed in the presence of the DLIP textures. On one hand, ice accretion was delayed by 15 s and the ice growth rate was slowed down by 34% compared to the untextured surface. On the other hand, it was demonstrated for the first time that the ice growth is self-limiting. In fact, the ice falls off after reaching a certain thickness without requiring added surface heating. Additional experiments including heating performed at a temperature of -20 °C also showed that it took 70 seconds for the ice on an unstructured airfoil to melt at 1.25 W/cm² of applied power density. The ice on the structured airfoil receded completely in less than 10 seconds at the same amount of applied power density. Consequently, the DLIP approach accelerated the process of electro-thermal heating by approximately 90%. Moreover, it was found that a complete de-icing of the textured surface can be achieved using up to 80% less heating power compared to an unstructured surface [5].

Summary

The DLIP technology approaches developed by Fraunhofer IWS and Technische Universität Dresden highlight a broad spectrum of functional surface applications, which in some cases significantly improve today's material surfaces and provide opportunities to replace established process steps, in some cases completely. A recent example of the enormous potential of DLIP processing has been demonstrated in the field de-icing and anti-icing surfaces, achieving a passive anti-icing ice protection system and, when necessary, reducing drastically the thermal energy necessary to keep an aircraft surface ice free.

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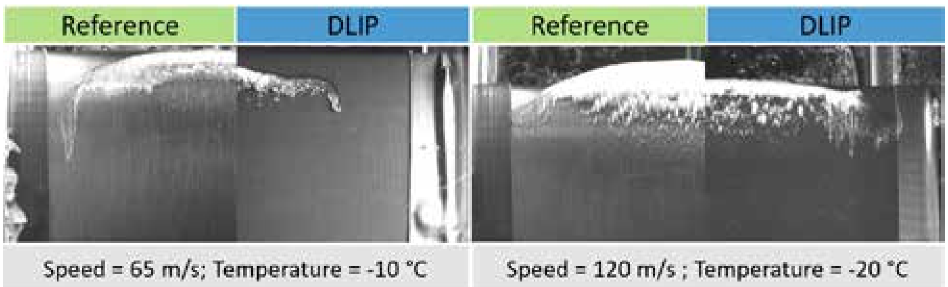

Figure 4: Comparison of the performance of unstructured and DLIP-treated Ti6Al4V airfoils in wind tunnel tests under different air speeds and air temperatures.

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SEE OBSERVATIONS P29

GHZ/MHZ FEMTOSECOND BURSTS FOR ENHANCED MATERIAL PROCESSING

TITAS GERTUS

Femtosecond lasers are highly versatile tools that enable unique material processing capabilities. Due to the high precision offered by ultrashort pulse micromachining, femtosecond laser systems are applied in both industrial and scientific fields. To accompany the needs of the industry, a trend towards high average power (>100 W) femtosecond laser systems for micromachining has recently become apparent. However, upscaling the micromachining throughput is not straightforward and typically results in a decrease in the micromachining quality. To this end, new ideas are sought to increase the efficiency of an ablation-based process.

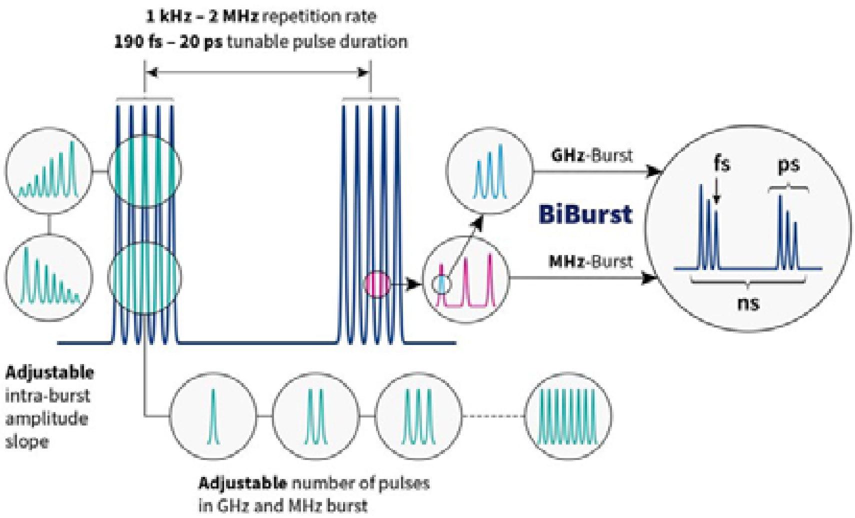

Figure 1: BiBurst - tunable GHz and MHz femtosecond burst scheme

Recently a new technology has been developed that allows the splitting of a singular femtosecond pulse into a train of pulses separated either by several hundred picoseconds or tens of nanoseconds. In other words, the laser can operate in a *burst* regime in the MHz and/or GHz frequency domains (Figure 1). As a result of these significantly shorter delays between adjacent incoming femtosecond pulses, the light-matter interaction mechanisms are quite different when compared to a conventional femtosecond laser, and therefore this regime opens up new frontiers for precision micromachining of many different materials.

The CARBIDE (Light Conversion, Lithuania) is an industrial-grade femtosecond laser system offering burst-in-burst capabilities for simultaneous GHz and MHz operation, and can output up to 80 W of average power, a pulse energy of up to 800 µJ, and can operate at a base repetition rate of up to 2 MHz. The laser can emit up to 10 pulses at MHz and 10 pulses at GHz burst, which is equivalent to an effective frequency of 100 MHz. The number of pulses in each burst regime can be easily selected by software control. The burst-train intensity envelope is also configurable from declining to quasi-flat to inclining. Many degrees of freedom enable the user to quickly find the optimal material processing recipe for their application.

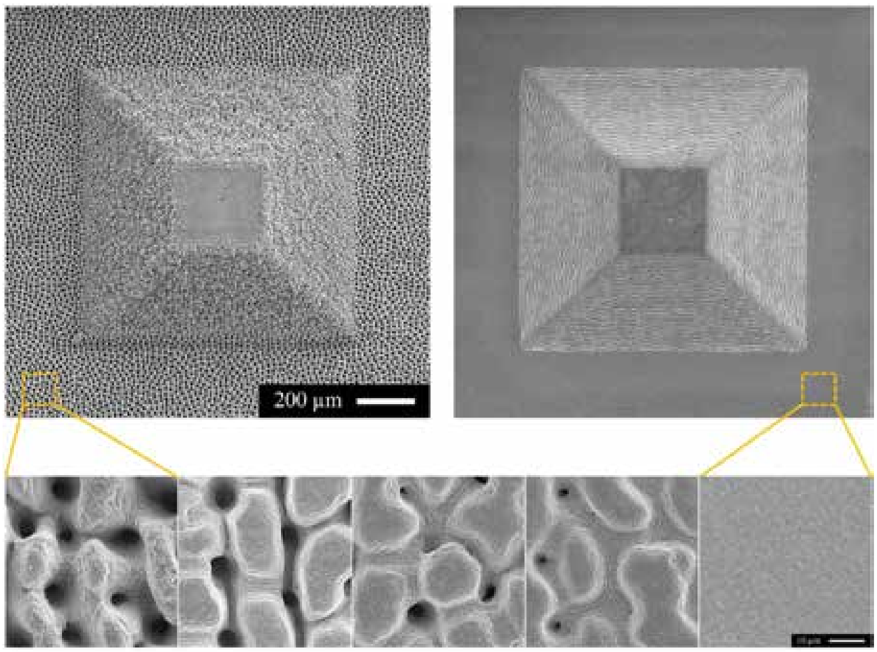

Figure 2: SEM collage of structures fabricated in stainless steel. From 6 µm to 200 nm Sa surface roughness achieved. Results demonstrated by Fachgruppe Physik und Lasertechnik, Laserinstitut Hochschule Mittweida.

It is well known that in using these burst modes it is possible to improve the material ablation rate per unit energy when compared to a conventional femtosecond laser setup. Moreover, the burst mode is particularly useful for drilling of brittle materials, cutting, deep engraving, selective ablation, transparent materials volume modification, high contrast marking or fabricating functional surfaces. In addition, any thermal input applied to material can be controlled by adjusting the parameters of the burst mode, even while it is being micromachined. This is particularly interesting for surface smoothing and polishing applications.

As an example, stainless steel can first be ablated with a MHz burst to achieve the necessary shape, and then polished with a GHz burst to achieve a superb surface finish. Figure 2 shows a semi-pyramid structure ablated in stainless steel and the final result after polishing with such a GHz burst.

Another example is biocompatible polymer materials and composites are used for many different purposes (e.g. catheters, artificial heart components, dentistry products, vision). An

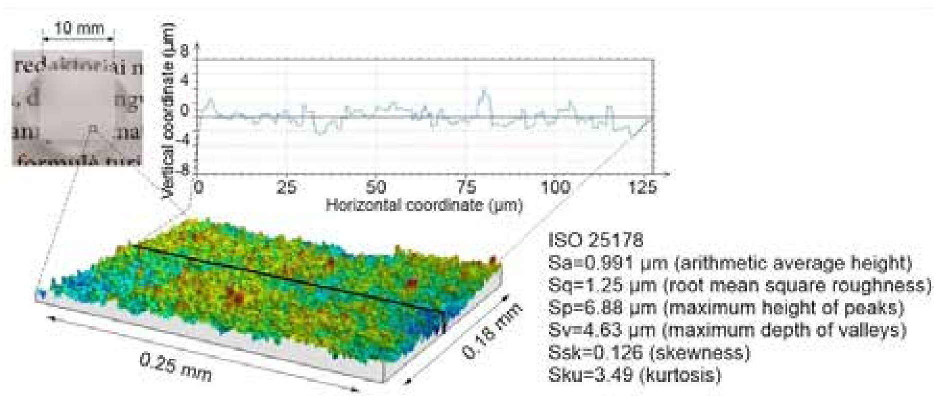

Figure 3: Hydrophylic acrylic polymer surface roughness after ablating using MHz

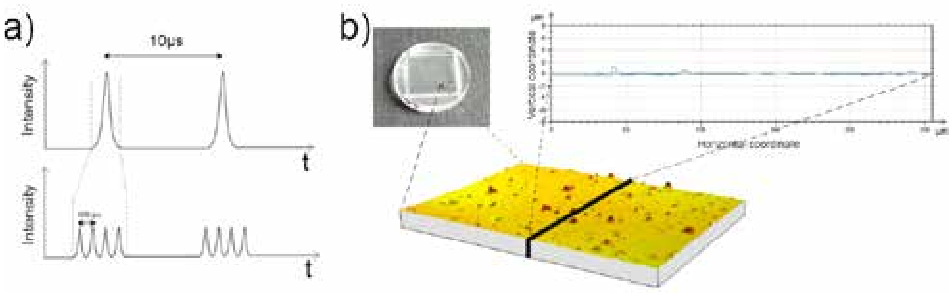

Figure 4: (a) Femtosecond laser pulse divided into bursts, (b) hydrophylic acrilic polymer after polishing parameters used: avg. power = 30 W, scanning velocity = 1 m/s, scanning pitch = 10 µm, number of GHz pulses = 10

important field for biocompatible polymers is the production of vision implants or custom shaped contact lenses. Diseases, such as cataracts, may be curable by surgically replacing the original eye-lens with an artificial lens, known as an intraocular lens (IOL). One of the most favorable materials in IOL manufacturing is hydrophilic acrylic polymer. Typically, curved surfaces are manufactured by mechanical means such as milling, turning or lathe cutting. The 2.5D objects/surfaces can also be manufactured by means of laser micromachining. Here, a MHz burst can increase efficiency of surface ablation. However, due to the nature of the light–matter interaction in the MHz regime, it is difficult to produce a surface finish with surface roughness values lower than 1 µm Ra (Figure 3).

Therefore, laser micromachining with MHz bursts alone cannot produce the final parts with optical-grade quality. Laser machined surfaces may be polished via mechanical methods; however, the process may take up to several hours, which makes the production of implants economically challenging. By switching the laser to GHz mode, a regime has been demonstrated where the surface roughness can be minimised to R_a=40 nm, while the polishing of the entire part takes a matter of seconds (Figure 4). In this case, the polishing process depends on the thermal heat flux which initiates thermodynamical processes that change the surface roughness of the sample. The optimal surface temperature was found to be approximately 357 °C, at which point it was possible to polish the surface to optical quality. The produced surface demonstrates a transparent appearance and the process shows great promise towards commercial fabrication of low surface roughness custom-shape optics (Figure 5). Therefore, the industrial-grade femtosecond CARBIDE laser with tunable GHz and MHz pulse bursts can help overcome the manufacturing challenges of customised intraocular lenses. Figure 5 shows fabricated concave lens is fully transparent, smooth and bends the image like a lens.

Manufacturing of free-form optical components and efficient way of polishing to achieve low roughness surface is now available using a single laser.

References

[1] S. Butkus, et al. "Comparison of GHz, MHz and kHz Femtosecond Burst Mode Micromachining of Invar Foils" Proceedings of LPM2017 - the 18th International Symposium on Laser Precision Microfabrication

[2] A. Žemaitis et al. "Highly-efficient laser ablation of copper by bursts of ultrashort tuneable (fs-ps) pulses", Scientific Reports, volume 9, Article number: 12280 (2019).

Light Conversion is officially represented in the UK and Ireland by Photonic Solutions Ltd.

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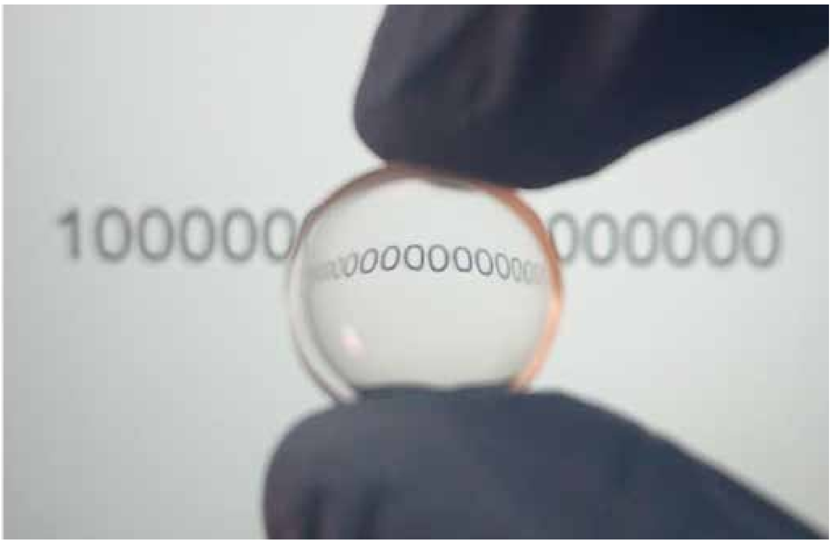

Figure 5: Polished curved surface processed with GHz burst.

Titas Gertus graduated from Vilnius University in 2012, and currently works at Light Conversion as industrial sales engineer.

SEE OBSERVATIONS P29

OBSERVATIONS

GAS FLOW DURING POWDER BED FUSION: A VISUALISATION STUDY

IOANNIS BITHARAS ET AL.

Gas flow within laser powder bed fusion chambers is a crucial factor that needs to be considered when planning larger builds or builds of materials where selective vaporisation may occur. When the laser interacts with the powder, it generates spatter in addition to violent gas flow fields over the powder bed, disturbing the uniformity of powder spreading on the bed. There is an additional risk from the spatter falling back into the powder bed, especially if the spatter reacts with the residual oxygen in the chamber.

The utility of Schlieren imaging has been well demonstrated in this article by Bitharas et al., and it follows from the interesting work that the Heriot-Watt group produced on understanding the gas flow dynamics in powder bed fusion. This work will help inspire future designs of powder bed chambers, especially with regards to the projection of the gas flow over the bed to ensure that any spatter will end up caught in the filter, rather than disturbing the build and eventually its properties.

Moataz Attallah, University of Birmingham

LASER INDUCED DAMAGE THRESHOLD TESTING: APPLICATIONS AND RESULTS

JAN VANDA

From around 1990, optical materials, manufacturing processes and coating technology had matured enough that optical manufacturers could provide components to consistently withstand the highest powered CO_2 and Nd:YAG (CW and pulsed) lasers of the day. In the intervening years the typical laser damage threshold (LDT) of mirrors and lenses kept improving to be 10, or even 50 times the power they would be exposed to.

Laser users occasionally suffered damaged optics, but invariably this was due to external factors, such as back reflections or process debris accumulated over some months of use, not intrinsic laser damage.

As this paper shows, the clock has been "reset". Ultra short pulsed lasers, 1μm lasers in their different forms, frequency doubling, and most recently beam shaping are challenging or exceeding the LDT of the optics available. The race is underway to develop new substrate materials and growth methods, improved coating designs, and coating deposition technology. The availability of quick, cost effective and importantly standardised LDT testing, is going to be a valuable tool to do this.

Mark Wilkinson, LBP Optics

Vanda makes an excellent point regarding the inherently statistical nature of LIDT testing. As any optic will fail from the point most susceptible to laser-induced damage, tests must be conducted on as much of the optical surface as possible. Understanding the value that LIDT testing brings to product design has been critical in II-VI's development of all-oxide ion-beam-sputtered coatings and aspheric sapphire substrates for the fibre laser market.

The II-VI Optics Engineering Team

THE VALUE OF LASER PROCESSING IN THE MEDICAL DEVICE INDUSTRY

JONATHAN MAGEE

I absolutely agree that lasers and laser systems have played a pivotal role in medical device manufacturing, in many instances, with unique processes. The great aspect of the medical device industry is a willingness to consider and develop leading edge technology for design or manufacturing innovation, and production cost benefits. There is an alignment between the laser capabilities and medical device needs based on constant miniaturisation, quality and precision and not forgetting reliability. One example that resonates this idea is medical tube cutting.

Systems in the early nineties using flash lamp Nd:YAG lasers have transitioned through fibre lasers and now femtosecond lasers for certain applications, and arguably outside of consumer electronics this market is the key growth market for femtosecond lasers. Perhaps as a testament to laser systems in this industry, the precision laser cutting of coronary stents is now commoditised with millions produced each year. The partnership with the medical device industry has been a good one, and the future looks bright!

Geoff Shannon, Coherent Inc.

INDUSTRIALISING FUNCTIONAL LASER SURFACE TEXTURING - SHARK PROJECT

TIAN LONG SEE & PAUL BUTLER-SMITH

It is great to read about the success of the SHARK project and how a number of European partners have come together to industrialise laser surface texturing methods. The SHARK project researchers have demonstrated a reduction in the friction coefficient of up to almost 50%, and a reduction in cutting force of up to almost 20%, showing how crucial these surface engineering techniques can be for industry. Such an enhancement can lead to significant business cost savings and even the development of new products and components.

This highlights how researchers can come together to provide real benefits for industry, ensuring that surface engineering techniques are optimised for their intended applications. This is a very exciting time to be working in the field of laser surface engineering and I am very much looking forward to seeing how the SHARK project partners further make use of their optimised technology to benefit industry.

David Waugh, Coventry University

Laser surface functionalisation is indeed a very interesting topic and one that is yet to realise its full industrial potential. The authors give a fine introduction into the topic and provide a good example in the tool wear…I notice the benefit is described in terms of reduced force, but it would be nice to know what impact this would have on tool life.

Many of the presentations on this topic focus on the use of ultrafast laser sources which can generate superb results, but what I would like to point out is that many applications can be tackled with ns pulsed laser sources that can offer "good enough" quality at a lower price point. This is particularly true for surface roughening applications where the ns sources have demonstrated good capabilities.

Many of the surface texturing challenges are associated with large area processing of sheets, or in roll to roll applications, where sophisticated optical solutions are required and still need proving in industrial environments. The continued research focus on this topic will no doubt produce the solutions to make this a mainstream laser materials processing application of the future.

Jack Gabzdyl, TRUMPF

This is very interesting work by Tian Long See. Based on our work with femtosecond and picosecond lasers the material removal rate will be improved by tailoring the laser pulse duration to the material that is textured. That optimisation has the potential to increase the throughput and could enable larger areas to be textured.

Klaus Kleine, Coherent Inc.

ICE-FREE SURFACES ENABLED BY LASER MICROTEXTURING

TIM KUNZE ET AL.

The DLIP technology developed at the TU Dresden and Fraunhofer IWS has great potential in the field of surface functionalisation. Tim Kunze's paper has highlighted the main advantage of the DLIP technology over other laser-based surface patterning techniques: being able to manufacture in a fast single-step process, highly regular single-scale or hierarchical surface structures, with tailored periodicities from a few 100 nm to several microns – and, in some case, covered by LIPSS.

Researchers usually report static contact angle measurements on flat substrates or drop impact at different substrate temperatures, but this article reports real case functional tests performed on a NACA profile by an end-user.

The next steps are probably to investigate the uniformity of textures fabricated on such 2.5D profiles as well as the durability of such laser-textured surfaces. It would be interesting to see how the passive anti-icing and the active de-icing properties are evolving after the end-user's durability tests, such as sand and rain erosion for instance.

Jean-Michel Romano, IREPA LASER

GHZ/MHZ FEMTOSECOND BURSTS FOR ENHANCED MATERIAL PROCESSING

TITAS GERTUS

This article gives nice examples of the different applications possible with the CARBIDE laser with "bi-burst" functionality, consisting of simultaneous GHz and MHz bursts. Although when using the GHz regime, it consists of a GHz burst inside a MHz burst. The two step application - combining the high ablation rate, low quality removal of stainless steel, with a second step of polishing with a GHz burst - is a nice illustration of the potential of this new kind of model. In this article, the polishing process is the main application demonstrated using the GHz regime of this laser, both for stainless steel and polymer.

As written in the article, the nice results are due to the thermodynamic effects that are generated when having such a combination of bursts. Such combination of MHz and GHz bursts enables a fine tuning of those effects and has proven the possibility of impressively high quality surface polishing.

David Bruneel, LASEA

REAL-TIME MONITORING OF THERMAL LASER PROCESSES

Jim Leach, Sales Engineer at Hamamatsu, discusses the advantages of real-time integrated temperature measurement for laser processing, with reference to two recently introduced laser systems.

An important outcome of real-time process monitoring of laser machining is the plethora of new possibilities that become available with sound thermal specifications. It enables simpler and more precise thermal laser processing.

Two laser systems recently introduced into Europe - Hamamatsu's SPOLD and LD-Heater systems - are each based on a diode laser that can be used for thermal processing. There are numerous applications for this technology, including plastic welding, laser-sintering of metal nano-inks for flexible printed electronics, adhesive curing and soldering.

Real-time process monitoring

The basic function of both laser systems is to heat the materials to be processed with the aid of laser energy, thereby initiating the desired thermal processing. The diode lasers used in these systems mostly operate with a wavelength of 940 nm and an output power of up to 360 W. The diodes produce a wide range of laser signals, with spot sizes ranging from 0.1 mm - 6.4 mm in diameter. If required, line optics are available to adapt the laser properties to suit the application.

A 'top hat' beam profile is achieved and the resulting energy distribution allows an optimal and homogeneous heat output onto the objects to be processed.

One of the most interesting points of this technology is the integrated process monitoring - it is possible to monitor the emitting process heat in real time during treatment by the laser, and so control parameters such as laser power or traversing speed. Hamamatsu's SPOLD system allows a relative temperature measurement of the processed object surfaces, while LD-Heaters measure the absolute temperature.

With SPOLD, the temperature measurement is realised coaxially via the same optical fibre that is used to transmit the laser energy to the object to be processed. LD-Heaters, on the other hand, use a second optical fibre to measure the temperature. Here, 2-colour pyrometry is used, where the detectors record two filtered wavelengths and by comparing the ratio on both wavelengths, the absolute temperature can thus be measured.

Many laser applications require precise temperature control to achieve optimum results. For example, when two plastics are welded together, the temperatures must be kept within very narrow limits in order to achieve the desired strength of the joint. If the traversing speed or the laser power is not set optimally, the welding process will not achieve the desired result.

External pyrometers become obsolete

The use of these laser systems brings a further technical and economic advantage to the user. Currently, in order to reduce waste during thermal laser processing, external pyrometers are frequently used to measure object temperatures. The main disadvantage of such a method, however, is that it requires some effort to position the temperature measurement at precisely the point where the machining takes place. The SPOLD and LD-Heater systems are much easier to use and lead to highly accurate results, since the measuring system is directly coupled with the processing laser.

In the SPOLD system, the temperature is measured coaxially using the same optical fibre as the working laser

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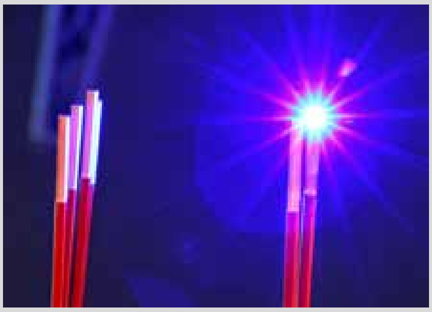
SYSTEMS & SOURCES

IMPRESSIVE BLUE LASER PORTFOLIO



Laserline is optimising its portfolio in the LDMblue high-power diode laser segment with 450 nm wavelength. Primarily developed for copper material processing in the electronics industry, these blue diode lasers are now available in six power levels between 300 and 2,000 watts.

Contact: David Earl
davide@laserlines.co.uk
www.laserlines.co.uk

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INTRODUCING BYSTAR 15 KW FIBRE LASER

With a new laser output of 15 kilowatts, the ByStar Fiber cuts steel, aluminum, and stainless steel with a thickness from 1 to 30 millimeters and brass and copper up to 20 millimeters with high precision. This increases the laser power by up to 50%, enabling sheet metal processing companies to further optimise their production processes.

The technological leap from conventional 3-12 kW systems to the new 15 kW level is tremendous. On average, thanks to the 15 kW laser, the cutting speed of the ByStar Fiber increases by up to 50% (when cutting with nitrogen) compared to a 10 kilowatt laser source.

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INTELLIGENT 12 KW FIBRE LASER

TRUMPF has equipped its latest TruLaser Series 5000 laser cutting machines with a TruDisk 12001 disk laser with 12 kilowatts of laser power.

The new machines also come with intelligent assistance systems that increase feed rates for medium and high sheet thicknesses by up to 50% compared to conventional laser machines with a ten-kilowatt laser.

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PRODUCT NEWS

NEW MINIATURE SEED LASER

The intensifying competition in the industrial laser market is driving the demand for components that are more compact and lower cost to differentiate next-generation laser systems. II-VI's new seed laser, which emits a broadband spectrum of more than 10 nm at 1060 nm, is now available in a 3-pin miniature package. The new seed laser benefits from sharing the manufacturing line with II-VI's telecom pump lasers in the same package, which are already being manufactured at scale.

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ANCILLARIES

NEW 3D BEAM DEFLECTION SYSTEM

Aerotech has launched the AGV3D, a new 3D beam deflection system for laser micro-machining. The thermally stable three-axis laser scanner is particularly suitable for high-precision manufacturing of complex components for the medical, microelectronics, and automotive sectors, including additive manufacturing.

Contact: Derrick Jepson
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www.aerotech.com

SELF-ASSEMBLY LASER SAFETY CABIN

Lasermet has launched the Laser Castle Lite, ideal for small laser operations including small laser robots used for cutting, cladding or welding. The cabin arrives as a flat-pack in a shipping crate, and is easily assembled on site by the customer.

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phil.jones@lasermet.com
www.lasermet.com

HIGH POWER MODULE FOR MICROMACHINING RESINS

Hamamatsu Photonics has developed a high power Quantum Cascade Laser (QCL) module that delivers an average output power of 2 W at a wavelength of 8.6 µm, ideal for micromachining of fluoropolymer resins, such as PTFE, that are used for high frequency device substrates, and a vast range of vehicles and transportation machinery.

Contact: Jim Leach
jleach@hamamatsu.co.uk
www.hamamatsu.com

ALL-IN-ONE LASER BEAM DIAGNOSTICS FOR AM

The strength of the new ScanFieldMonitor (SFM) from PRIMES lies in the combination of many measuring tasks undertaken by the one device. The compact measuring unit allows characterisation at random positions in the working area under actual process conditions and control from outside the unit.

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bradley@lasertrader.co.uk
www.lasertrader.co.uk

SMART SCANNING LASER MARKING PROJECTS

SCANLAB GmbH presents a new scan system. The SCANcube IV, as the primary representative of this product range, features optional read-back functions, thereby providing an essential process monitoring component. Compared to the SCANcube III, the system linearity has been improved by 30 percent.

Contact: Eva Jubitz
ejubitz@scanlab.de
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A FUNNY THING

MY BAD...

As a frequent traveller to Munich (until recently), I have picked up the answers in German to the frequently-asked questions experienced on my journey - including on arrival at breakfast, some variation of "Guten Morgen, Ihre Zimmernummer, bitte?" to which I could answer with a room number in German (I learned to count to 100 more or less and they only had about 30 rooms). Together with my preference for "café bitte" and limited "bar German" which allowed me to order a beer or 3 of an evening, I also picked up several technical laser-related German words which allowed me to follow the gist of conversations about lasers. Apparently, my 25 commonly used words and phrases made an impression on one English traveller who came with me one trip, as he commented that I was "fluent in German".

I had become accustomed to a certain lakeside hotel in the suburbs of Munich which was across the road from the train station but had a few foibles that I had grown to accept and largely ignore (train noise from 6 am to Midnight). Surprisingly for me, although I only made 3 or 4 visits per year, it wasn't long before the hotel staff started to greet me by name.

On one trip, I was meeting 2 visitors at the hotel as they had flights an hour or 2 ahead of mine. The journey from airport to hotel involved either a taxi (40 minutes but expensive) or the local train service (90 minutes). Typically, I would travel by train to save money for the business. On this trip, I suspected a problem early on when I received a call on my mobile as I was midway through my first leg of the train journey. It seemed the customer, who had arrived in the hotel before me, was not impressed with the standard of the hotel, the state of the carpet in the room, and the fact that one room didn't even have an en-suite bathroom. They were phoning round to see if something else was available and I said I would speak to the hotel. A quick call to the hotel confirmed that they had saved me a better room (with en-suite) but that all other rooms in town were sold. So, I asked them to switch me into the worst room and swap my visitor into a better room (the one with my name on it).

By the time I arrived, the situation was looking a little better and my customers were into a bottle of full-bodied red wine and some very nice Italian food in the restaurant next door. Thereafter, it became a source of amusement, and one of the visitors commented that he had never stayed in a worse hotel in all his travels and on no account would they stay there again.

On arrival in my room later, I noticed the door adjacent to the room had the word "BAD" on the door which made me laugh. Not only was this the sign for the "bathroom" (literally "bath") but it summed up the situation quite well. An extra key on the hotel keyring was for this bathroom (only available to me) but I had to go to cross the corridor to shower or brush teeth etc. When checking out the next day, I asked the hotel to add this to the list of rooms never to be offered again to me or my guests (there are also a couple of corner rooms with single bed and tiny en-suite that I chose not to frequent after a bad night of sleep).

What is the moral of the tale? Arrive before your guests, if possible – and be prepared to sacrifice the "luxury" of your room to improve someone else's experience.

Dave MacLellan
dave@ailu.org.uk

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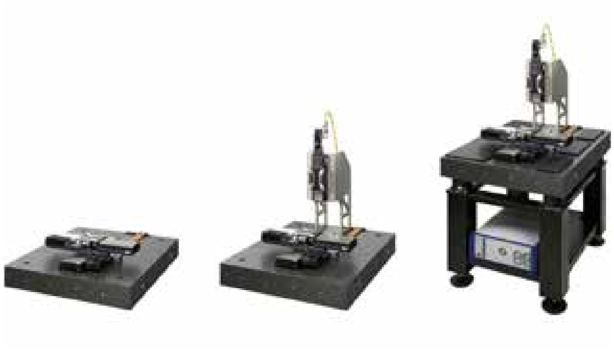
FORTHCOMING AILU EVENTS

JUNE 17 2021 - ONLINE WEBINAR

LASERS DRIVE THE GREEN ECONOMY TOWARDS NET ZERO

Chair: Matthew Wasley, KTN

Join our webinar on the topic of laser solutions for the green economy. Alternative forms of green energy generation like solar, wind and wave power are enabled by laser material processing applications and batteries are used to store energy and provide power for green transportation – here too there are numerous laser applications.



SEPTEMBER 29 2021 - WORKSHOP, GLASGOW

DIGITAL TECHNOLOGY IN LASER MANUFACTURING

Chair: Cliff Jolliffe, Physik Instrumente

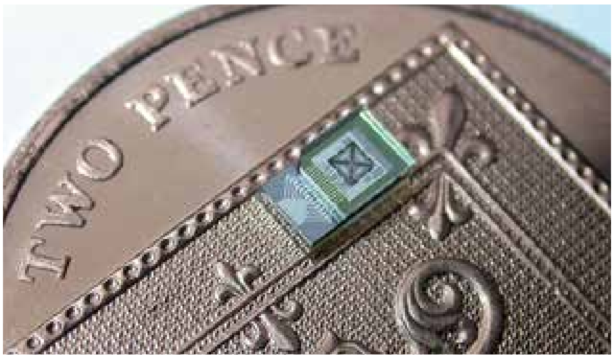
This workshop will cover areas of advanced motion control, modelling, AI and digital technology, highlighting the role it has to play in laser processes. Experts from industry and academia will share the latest technology and applied research in this field.

OCTOBER 2021 - WORKSHOP, VENUE TBA

JOB SHOP ANNUAL BUSINESS MEETING 2021

Chair: Mark Millar, Essex Laser

The annual meeting of our Job Shops covering all aspects of business improvement. Catch up with the latest products from machinery providers and gain insight from surveys and our discussion forum. If you are a laser job shop, you should come along and meet your peers.



NOVEMBER 2021 - ONLINE WORKSHOP

MEDICAL DEVICE MANUFACTURING WITH LASERS

Chair: Richard Carter, Heriot Watt University

Held at the new Medical Device Manufacturing Centre (MDMC), this workshop will allow delegates to catch up with the latest in precision processing to make medical devices. Includes a tour of the new facilities at MDMC.

DATE	EVENT	LOCATION
8-11 June 2021	The 22nd International Symposium on Laser Precision Microfabrication (LPM)	Hirosaki, Aomori, Japan
17 June 2021	Lasers Drive the Green Economy Towards Net Zero (AILU Workshop)	Online Webinar
21-24 June 2021	Lasers in Manufacturing (LiM) 2021	International Congress Center Munich, Germany
24-26 August 2021	18th Conference on Nordic Laser Material Processing (NOLAMP)	Luleå, Sweden
29 September 2021	Digital Technology in Laser Manufacturing (AILU Workshop)	Glasgow
October 2021	AILU Job Shop Annual Business Meeting	Venue TBA
November 2021	Medical Device Manufacturing with Lasers (AILU Workshop)	Online