

OBSERVATIONS

Short comments on papers in this issue

The marking of stainless steel using Nd:YAG lasers

Charles Dean

A good article outlining the basic applications of NdYag laser marking. The sort of article that would provide a useful guide to (prospective) customers.

Dave Lindsey Laser Process

This is a useful article that outlines the wide range of possibilities that exist for laser marking stainless steel – the combinations are almost endless and only limited by imagination! The article includes some beautiful examples of marked components, particularly the gold marked trophy and the black-white combination marking. It's a shame that the key pictures didn't have a scale bar (and a detailed close up in the case of the trophy) in order to be able fully appreciate the intricate achievements of the marking process. The colour marking is fabulous and I'm looking forward to the day when colour laser marking fully enters the industrial arena – soon, I suspect.

The article clearly aims to inform at the customer/end user level about the array of marking styles, but it also raises some questions that are relevant to people considering using this type of service. Some topics that were touched upon within the article are just the tip of the iceberg, for instance, how to assess the quality of black marks – contrast ratios, viewing angles, etc. so that repeatability is achieved.

Are any standards emerging from the laser marking community in order to address this? And why in practice are black marks limited to 40 mm in size? Within the scope of this article I would have liked to see just one addition, which is a discussion of how the grade and surface finish of the stainless steel (or any other material) affects the marking process.

Paul Harrison SPI Lasers UK

Laser micro manufacturing in the UK: a service provider's perspective

Nadeem Rizvi

An interesting article that shows the range of materials, industries, company sizes and product development stages that look for a laser material processing solution. The overall thrust came as no surprise to me but the detail was thought provoking.

Any subcontractor tends to pick up work that can (or sometimes just might) be done with the equipment and expertise available. The cus-

tomers list is filtered by capability even when the capability is as wide ranging as LMLs is. Picking up on the suggestion in the article that data from many micro - and perhaps milli and nano - scale users be sought and aggregated to give a better picture of UK activity is something that I think AILU should lead on. It would get my backing and participation.

Neil Main Micrometrics Ltd

The article gives an interesting but not untypical perspective on the laser micromachining jobshop services in the UK.

Oxford Lasers, which are well known as an integrator of high-end laser micro-machining systems, has also been providing laser micromachining job shop services for over 16 years. In the early years the reaction we got to our first demonstration samples was typically "that is very interesting - but why would you want anything as small as that!"; whereas today the demand for micromachining services is driving us to add new facilities. Our view of the market is similar to that in the article but with slightly different emphasis in certain areas. The biggest fraction of our customers are SMEs but we see fewer micro-SMEs and owing to our international sales force, a larger percentage of clients from outside the UK. We see demand from a broad and increasingly wide range of industries and this reflects the increasing use of micro-features in everyday products.

Martyn Knowles Oxford Lasers

Nadeem Rizvi's article is very interesting in its detail on laser applications in terms of sectors, materials and users of laser technology. As Laser Micromachining Ltd works very much with SME companies it also is a valuable insight into what companies are looking for in terms of the internal R&D.

As an Irish company that works mainly with Medical Device companies, we can see a lot of similarity between Nadeem's findings and our own customer base. Polymers and thin metals make up the majority of the materials, and a lot of our work is done for companies that are in the early stage of product development. Our base would generally be larger than SMEs, however the overall picture points to customers without internal laser experience but eager to explore the possibilities. This has to be encouraging given the general economic outlook.

I agree that a more open approach to markets would help everyone, but even with the best of intentions time and confidentiality can get in the way of openness. When I talk with Nadeem on the phone, we tend to share details on what customers are looking for, and I maintain the same informal relationship with

many of the other 'competitors' in the market. Maybe it is time to put this on a more formal basis, which may be of benefit to everyone.

David Gillen Blueacre Technology

A laser alternative to the micro-needle array

Daniel Lloyd et al

In the active field of drug delivery, it is good to see that lasers are finding many applications. The micro-needle arrays referred to in the title are currently being manufactured by various means. Whilst the techniques currently employed do use chemical etching, laser ablation has also been tried and two-photon polymerisation has been shown to have promise. The latter has been combined with silver deposition for antibacterial properties. Daniel Lloyd and co-workers have gone one stage further and removed the needle array entirely, replacing it with fine hole drilling by parallel laser processing. Studies of biological systems are always problematic due to the statistical nature of the material. It can be seen from the figures that measuring hole dimensions is particularly difficult in the case of skin. Collagen shrinkage occurs at fairly modest temperature rises (~60 °C) and I expect that this will modify the expected hole morphology. Additionally, scattering of the laser light may result in an irradiance that is enhanced subsurface. All-in-all, a complicated system with what I would imagine are difficult to predict results. I would be interested to know to what extent the "pain-free" aspect is due to the small excised volume rather than being intrinsic to the laser process itself.

Howard Snelling University of Hull

The article portrays the potential value diffractive optical elements offer in transforming any mathematical defined laser beam shape into another. It also portrays the role of diffractive optical elements in fully utilising laser beam energy by distributing it over a larger area than just a single laser spot. In the current times of solid state sources with high repetition rates, short pulse durations, and large pulse energies, it is an exciting technology.

While not an expert on drug delivery, I presume each micro-needle must administer a precise drug dose to the body. Traditionally, this involves using a mechanical needle to penetrate the skin and immediately using this to administer a precise dose from a pre-filled chamber. The many advantages of replacing the mechanical needle with a laser-based alternative are described; it is non-contact, pain-free, motion-less and offers access to effective drug incorporation. The

principal challenge that remains, however, is how a dose can be administered precisely. Assuming this dose can be diffused from a patch or other reservoir placed over the laser treated skin; this would appear to place tight specifications on the shape, size and depth of laser drilled features and, in particular, how these evolve in time.

David describes the accuracy of mathematically generating computer generated holograms, the dependence on the beam profile of the incident laser, and the requirements for the presentation of tissue to the laser process. His results indicate that fundamentally the laser-tissue interaction is complex and perhaps this, and the temporal evolution of the laser treated skin, will ultimately be the challenge for precisely administering drug doses which the medical community require.

Gerard O'Connor National Centre for Laser Applications (NCLA)

The pulsed Er: YAG laser operating at $2.94 \mu\text{m}$ is a valuable surgical tool for treating lesions and scars since this wavelength is absorbed strongly in water molecules and proteins in the epidermis (outer layer) of the skin which is $\sim 0.5\text{--}1.5 \text{ mm}$ thick. Skin is thus ablated very effectively with minimal residual thermal damage.

This interesting paper demonstrates highly parallel drilling of the epidermis by combining the output of a pulsed, 1 J Er: YAG laser system with DOE's designed to produce spot arrays. At a fluence of $\sim 2 \text{ J cm}^{-2}$ and 30 pulses with temporal pulse length of $200 \mu\text{s}$, the drilled holes have width up to $\sim 0.3 \text{ mm}$ and $\sim 200 \mu\text{m}$ deep. This depth is adequate to allow a drug to be wiped on and so introduced directly via these micro-holes, and absorbed efficiently by the Langerhan cells, found $\sim 0.1 \text{ mm}$ below the surface of the skin. Drug uptake is therefore much faster than conventional injection – with a painless procedure.

The DOE's are reflective 3D Computer Generated Holograms with 256 levels and diffraction efficiency is quoted to be $>90\%$ so that little radiation is lost in beam delivery. As the laser output was slightly non uniform and the DOE's were used off axis, this lead to some variation in the pulse energy between spots, more significant in the 9×9 spot array. Nevertheless, the elliptical micro-holes are no doubt adequate for their purpose, which is to deliver the required drug. DOE depth of field can be as large as $\pm 20 \text{ mm}$ so that exposure of curved surfaces on the skin presents no drawback.

It is always pleasing to see a new potential application of laser technology in medicine and the authors are to be congratulated on

this work, including the design of DOE 's which perform remarkably well.

Walter Perrie University of Liverpool

Autogenous surface feature generation with a 200W Yb-fibre laser

Jonathan Blackburn and Paul Hilton

We have experienced over 50 years of laser applications and are now very familiar with subtractive and additive laser based process technologies, so it is great to know that lasers are still delivering surprises. Blackburn and Hilton's work on surface feature generation has offered a new process capability that is formative in nature. The paper presents some fascinating surface structures that can be produced quite effortlessly with rapidly scanned laser beams. Whilst the detailed mechanisms have yet to be determined the TWI team are well on the way to greater levels of understanding. They have produced some quite complex structures that could be of great value to industry.

Given that the laser was a solution looking for a problem, it is also still highly capable of delivering novel process solutions looking for an application. I have no doubt that this process will be seen rapid development and will find a firm place in the laser jockey's toolbox.

Bill O'Neill University of Cambridge

The influence of laser-induced focus shift on high power fibre laser welding

Daniel Reitemeyer et al

This study by BIAS Germany is of practical importance for using high power fibre lasers above 1 kW and users should be aware of this problem. The focus shift stems from thermally induced refractive index changes (and some geometrical changes) in the optical fibre, cover glass and also the space between the welding nozzle and the workpiece (plasma/vapour plume and shock waves) and is towards the laser beam. The article shows the first two of these effects. The focus shift is shown to be quite significant (up to 3 mm for a 7 kW laser power). Cleaner cover glass is helpful. Effective cooling and cleaning of optics would be another way of reducing the effect. Placing the beam focus below the workpiece also normally reduces its effect on the welding process.

Lin Li University of Manchester

The development of high average power CW fibre lasers that can generate up to 8 kW from a thin-disc laser and up to 20 kW from a fibre laser are generating wider industrial

interest, particularly from industry sectors such as automotive, aerospace, chemical, defence and power generation. Their main attribute is high beam quality, which allows the transmission of laser energy through a small diameter ($100\text{--}300 \mu\text{m}$) fibre optic. It has been well documented that these lasers can offer a number of advantages in high power laser welding i.e. weld depths, welding speed etc, but very little has been published on the problems that can occur when welding thick sections with small spot size and high beam quality, including fit up of the parts, the effects of laser-induced plasma/plume emerging from the deep penetration key-hole and, the subject of the article by Daniel Reitemeyer, the shift in focus position.

Long exposure of focusing optics to high laser power shifts the focal position, which leads to penetration fluctuations in a long length weld. It would be interesting to see if the focus shift position can be minimised by water cooling the welding head. As pointed out in the article, contamination of the cover glass slide caused by spatter and fumes from the keyhole can also change the focus position drastically. It may be possible to overcome this problem by either using a longer focal length lens or by having a high velocity cross jet air-knife.

Mo Naem GSI Group

This interesting piece of work highlights the need for laser users to be aware of time dependant process instabilities (diameter changes and/or focus shift) and their potential effect on weld quality; and it begs the question of whether there are laser welding facilities where, during everyday production, significant focal shifts are occurring but for which no compensation/control has been made to achieve optimum conditions. If this is the case, have changes in weld quality achieved during commissioning simply been compensated for by some other means (reduction of weld speed for example) or do some facilities simply run at less than optimum?

One factor not mentioned is the time taken for the spot diameter to return back to a minimum size in the original focal plane following completion of the weld. For high production volume applications, where the 'off-time' between welds is minimised the laser system may be running for most of its time with the focus in its shifted position. If this has been compensated for by some means (including an offset in focus position) then it could be expected that during daily start-up the weld quality on the first component(s) will be poor. Are such observations made in some production applications, and is this the likely explanation?

Andrew Woloszyn TWI

Continued over ...