

USA job shop tour

The AILU job shop mission to the USA will take place from 8 to 12 November 1999.

This DTI-sponsored trip will visit world class job shops across the USA, starting on the East Coast and finishing in San Diego, California in time for the ICALEO conference. Its aim will be to assess the technological base (processes, lasers, levels of factory wide integration) of job shops, their sub-contract diversity including provision of services using advanced laser technology, and the influence of new markets such as micro-engineered products etc. E-commerce, workforce management and strategic business development will also be assessed.

The mission team of six UK laser job shop managers will be led by Dr Bill O'Neill of Liverpool University. The detailed mission report will be produced and presented at a laser cutting meeting in February 2000.

Job shop of the future

The launch of the AILU Laser Job Shop Group will take place on 19 October, with a morning meeting at the National Motorcycle Museum.

To mark the launch, senior representatives from three laser machine builders (Edi Buchmeier of Bystronic Laser, Ian Fletcher of Trumpf Ltd, and Xavier Rouchaud of Mazak Nissho Iwai) will present their views on 'The Job Shop of the Future' in the context of how the technology and management of the laser sub-contract industry is developing around the world.

Members of the laser job shop community from around the UK and Ireland will be invited to attend the launch.

The new job shop steering committee (see Issue 15, page 3 for committee details) held their first meeting on 29 June 1999. In addition to planning the launch, the committee agreed the first three of a series of surveys to be conducted within the laser job shop community. The surveys will address: (i) the degree of satisfaction with machine suppliers after-sales service, (ii) gas prices, and (iii) monthly survey of business confidence and level of activity.

Maurice Gates wins 1999 AILU award

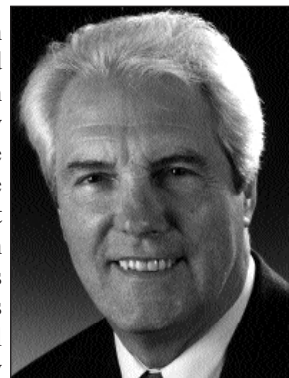
Maurice Gates MBE, founder and MD of Micrometric Techniques, will receive the 1999 AILU award for his outstanding contribution to the industrial use of lasers in the UK.

In the context of the award, Maurice's main achievement has been to build a successful laser-based business which embodies a wide range of types of laser and a wide range of laser services including cutting, welding, marking and drilling, particularly of small precision parts.

Maurice started his career with AEI working on cathode ray tubes and was the manager whose team first introduced lasers in 1973 for machining graphite electrodes for power tubes, one of the very early applications of lasers. The process is still in use at EEV and has expanded to other components.

Maurice was awarded an MBE for his services to industry and to applied tech-

nology in 1987 and received an Honorary Doctorate from De Montfort University in 1997. He sits on the CBI's National Technology and



Innovation Committee, the Steering Group for 'Make it with Lasers', the Industrial Advisory Panel for the University of Hull, and ITEC, a former DTI initiative for IT training. He is a founder member of AILU and served as a committee member during its first three years.

The award will be presented to Maurice at the members' meeting at Loughborough University on 15 September.

of tin oxide and silicon. He pointed out they continuously review these and their manufacturing operations with regard to improving productivity and reducing costs.

After a lively question and answer session, Mike Green of AILU closed the meeting by thanking all speakers and delegates for making what was a very crowded technical agenda so successful. Delegates then left to tour facilities at the Central Microstructure Facility, RAL and Exitech Ltd, Oxford. The universal view expressed by delegates was the workshop went some way toward its original intention of starting to bridge the wide awareness gap currently existing between the microengineering and laser communities.

Many more meetings in the UK and overseas along similar technical lines together with the networking opportunities they provide will be required before the gap is bridged.

As always, the tireless professional efforts of Mike and Liz at AILU guaranteed the event ran smoothly and was enjoyed by all.



Speakers at the AILU Microengineering Workshop.
L to R Steve Temple (Xaar Ltd), Malcolm Gower (Exitech Ltd), Joan Tourne (Viasystems Tyneside Ltd), Stan Brotherton (Philips Research Laboratories), Steve Wittekoek (ASML Lithography), Otto Mårten (Nederlandse Philipsbedrijven BV) and Spencer Jansen (Intersolar Group).

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Letters to the editor

Economic use of lasers

I have attended a number of exhibitions, many of which feature laser technology and am always impressed with the equipment on offer from suppliers. I have, however, been disappointed in most instances with the response from suppliers when I question the economic sense of what is exhibited.

The ability of the exhibited equipment to cut components to tight tolerances and with no final finishing in not in question. However, I often note that the value of some machined components exhibited is small, out of all proportion to the amount of process time required using expensive capital equipment. Do laser cutting machines really justify their capital cost when used in the simpler applications, or are the simpler applications for demonstration only?

I would be interested to hear readers views.

Jonathan A. C. Knew (CEng, MIMechE)

John Barker of Balliu UK kindly volunteered to respond

Jonathan Knew has quite rightly identified that in many cases the parts exhibited may well be of small value and out of proportion with the process time required and or the level of equipment cost. Equipment exhibitors tend to show parts that are well produced and which serve to represent laser processing at its visual best for exhibition purposes and not necessarily to the full flexibility or capability of the system exhibited.

Any purchase of a laser system has to be preceded by a careful study into the economics and commercial aspects of the investment and I can only guess that the writer has been unfortunate during a busy show not to have been fully advised of this. I also suspect that he has not had the opportunity to speak with the users of industrial laser systems, as we all know there are too many successful installations in the UK alone to question the return on investment.

Once the criteria of processing has been satisfied the evaluation of the overall investment needed has to be examined. Although the laser process may provide the productivity, quality and flexibility looked for, the factors of initial investment and long term running costs play a significant part in any payback.

As a responsible manufacturer, NVL Balliu recognise that it is not always sufficient just to satisfy the application of technical aspects of a customers requirement, we also have to be prepared to look together with the customer at the commercial justification and help to quantify the potential return on investment. Laser processing systems may seem to be expensive when viewed against conventional machine tools costs, and should be specified with great care to show if an acceptable return on investment can be achieved.

John Barker NVL Balliu

Shortsighted approach to lens costs

Isn't it interesting - it appears that there is nothing new under the sun?

About five years ago we (P-OE) developed a set of lenses with an extended depth of focus by purposely introducing spherical aberration into the surface.

These lenses (tested at TWI) showed a 40% (yes, 40%!!!!) increase in cutting speed for N₂ assisted cutting of stainless steel. Whilst many people were interested in the lenses it appeared that like most of the industrial laser community they were solely concerned with up-front cost - not being able to look at the long term cost saving of reduced time on machine.

I wish V&S all the best with their new product and hope that they have more luck than we did.

Ian Johnstone Precision-Optical Engineering

I thank Ian Johnstone of P-OE for his good wishes.

Dual Focus™ lenses are already a tremendous commercial success compared with our original expectations. Our marketing efforts do emphasise the economic aspects of the product as well as the underlying technical advantages.

Life would be easier if we could avoid the optical/technical issues completely, and simply offer a money printing machine (priced at about £700.00) that would churn out a £10 note every ten minutes-or-so for the next three months. Dual Focus lenses are perhaps the closest economic analogue, and have the added virtue of enabling me to stay out of jail.

David Greening V&S Scientific Ltd

PS Should HMG ever give permission for the money printing machine, I look forward to a deluge of correspondence telling us the machine is too expensive, and/or requesting a free machine for trials. Maybe an academic could be found to express an ill-informed guess that the machine only works by virtue of being connected to its own Power Station?

A note from the editor

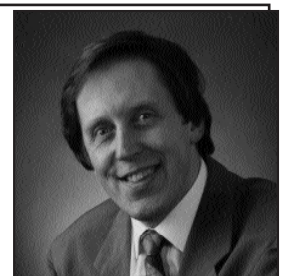
Reaching issue 16 means that we have been going for 4 years. To celebrate this milestone you will find on the back pages of this issue a full listing of articles from past issues. At the same time we have, at last, added back issues to the AILU web site in case you're missing any.

Despite the many improvements we have made to how we organise and publish the magazine, the soliciting of articles remains a major headache. Our aim for Year 5 is to improve our forward planning of magazine articles and for this we need your help.

Included with the magazine is a general questionnaire, covering topics including

what sort and level of material you would like to see in future issues. Please take this opportunity to express your views to ensure that the material in the magazine addresses all our readers interests.

Apologies to members with an interest in laser marking because, for a second issue in a row we have been unable to include an article on this topic. Due to the healthy state of the laser marking market all our authors have been pleading a shortage of time!



Letters (continued)

A reflection on Laser '99

I was there at Munich from Wednesday to Saturday and I had the intention of taking leisurely strolls around the exhibition looking at new products, renewing old acquaintances. Unfortunately, this did not happen. When I arrived on our booth, it was crowded. While there were a lot of Rofin people on duty, there seemed to be twice as many visitors. So I put on my stand hat and waded in.

We were frantically busy all week, surpassed the total number of visitors we got at the last Munich laser show sometime Wednesday afternoon.

Rofin were showing several products for the first time, including the new 4.4kW diode pumped YAG, the 1.8kW fibre delivered diode laser, the 300W sealed off CO₂ laser and a range of new marking machines: the 15W frequency doubled diode pumped YAG marker, the 1 MW pulsed diode pumped YAG glass marking laser, the 100W diode pumped YAG marker and the Blazer Flexscan CO₂ dot matrix marker. The nearby Stiefelmayer stand was showing our 1.8kW diode laser performing hardening applications with temperature feedback and our 2.5kW CO₂ slab laser on a linear drive system capable of cutting at 200 m/min. The test program was 500 off 10 mm diameter holes in 0.5 mm thick mild steel in 1 minute. Truly amazing!

Tim Holt Rofin-Sinar Laser

Purging of CO₂ laser beamlines

I would like to respond to Mike Osborne's letter 'More hot air!' in the last issue, and to reiterate that clean dry air is as good for purging CO₂ laser beamlines on laser cutters as is dry nitrogen.

About a year ago I did a survey of CO₂ laser cutting machines for a large company that wanted to buy one. I got in touch with all the big system manufacturers (and a few small ones), most of which came back with a system proposal. Looking into these for the specification of the purge gas for the beamline, either air (to some specification) was mentioned or the topic was not addressed. For example, one leading CO₂ laser manufacturer specifies air with a dew point below -70°C that is oil- and particle free. They even specify which filters to use and how often to replace them. Very well!

Of course, filters need replacing regularly and if that or maintenance of the air compressor slips then the result will be a gradual but steady decline of the purge air quality, letting in beam degradation by the back door. It is likely that this will remain hidden for some time before the deleterious effect of beam degradation on machine performance is noticed. It can be for this reason alone that nitrogen purge is specified as the preferred purge gas by some manufacturers (including the one mentioned above). Specifying nitrogen is playing safe. One would hope that the gas is always clean and dry, thereby removing one potential source of trouble if machine performance falls off.

However, choosing nitrogen does not totally remove the beam degradation issue. Running out of nitrogen is not the only issue to consider. De-gassing of bellows and other beamline components,

perhaps assisted by laser heating, leaks and other sources of beamline contamination need to be addressed by the manufacturer and user (I know someone who could go on and on about the design of beamlines, optics mounts, greasy slideways and beam quality!).

But does it make commercial sense to install a nitrogen facility just to purge the comparatively short beam lines of an average CO₂ laser cutting machine? In the end it all comes down to cost and convenience. You may, for example, be considering installing a liquid nitrogen tank to meet the high nitrogen consumption of your expanding stainless steel cutting business, in which case it can certainly make sense to use the boil-off for beamline purge. The article by Geoff Parkin in Issue 14 amplifies this point and I know of one laser cutting job shop that is considering this option. More generally, however, the laser cutter user needs to recognise that both are practical options, and he should make an objective cost vs. convenience comparison of air and nitrogen. In this regard it would be helpful if an objective cost of ownership comparison by an industrial user were prepared for the magazine.

Yours realistically

Jim Fieret Exitech Ltd

Microfabrication by stereolithography

I read with interest the article in Issue 15 on high resolution stereolithography by Chris Chatwin and his team. The article discusses a very interesting area of rapid prototyping which concerns the production of micro parts for MEMS related products. Chris's is one of the few groups active in the development of micro stereolithographic prototyping technology. Despite the surge of activity in the development of microengineered products, designers have very few options for prototyping and verifying designs compared with the macro-engineer. Scaling down the traditional point scanning systems is not the best approach as built in stresses can occur, resulting in high levels of distortion.

This dynamic amplitude modulation approach adopted by the Sussex team increases the resolution and build quality substantially. And with layer thicknesses as low as 0.5 µm one is able to produce smooth profiles without the need for downstream finishing, which is just as well since it would be pretty difficult to hand finish a model 2 or 3mm³. Another major benefit of working at this scale is that normally problematic aspects such as surface tension seem to assist the process by minimising the need for supports, which is fortunate since it would be extremely difficult to remove supports from an object with micron sized features.

Micro RP systems are in reality very close to the family of production processes developed for silicon based electronic products and it is therefore far more likely that micro RP processes will mature into actual manufacturing processes for large scale batch production. This likelihood would be increased if researchers could develop micro-RP systems for a wider range of materials instead of the photocured polymer systems which have limited functional value. I very much look forward to the next phase of work from the Sussex team in what is a very exciting and important technology.

Bill O'Neill Liverpool University

Microengineering with lasers

continued from p 1

Bridging the gap between the microengineering and laser communities

Malcolm Gower

The first AILU workshop on microengineering with Lasers was held at the Rutherford Appleton Laboratory on 9 June 1999. Over 70 delegates registered for this highly successful event.

The meeting brought together leading European industrialists who use lasers for microengineering in manufacturing. The range of industries represented was diverse: semiconductor, microelectronics, computer peripherals, display technologies, solar power generation and microsystems technologies (MST). Apart from their use of lasers, the common thread between each of the speakers was the aggressive drive of their (high-tech) industries towards ever-increasing miniaturization of parts having higher functionality.

Malcolm Gower introduced the meeting and highlighted the rapidly growing opportunities in MST for new manufacturing technologies like laser materials microprocessing. Steve Wittekoek, formerly head of lithography at ASML, the world's leading wafer stepper manufacturer based in Veldhoven, The Netherlands, reviewed the status of photolithography and the pivotal role excimer lasers now play in manufacturing the latest generations of silicon microprocessor and memory chips. Spanning the wavelength range between 248 – 157nm, such lasers are extending by at least 15 years the use of optical lithography in the semiconductor industry. Ultimately capable of replicating on a silicon wafer circuit features as small as 70nm and with annual sales of around \$5B/year, excimer lasers and associated exposure tools now represent the largest value sector of all laser systems.

The use of lasers for drilling microvia holes in electrical packages that interconnect chips and other circuit components (e.g. printed circuit boards, ball grid arrays, etc) was presented by Joan Tourné of Viasystems, Newcastle, who are one of world's largest suppliers of processed circuit boards. With an installed base of ~500 units growing at a rate of >50% per year this market is also experiencing rapid growth in the take up of laser technology. He compared the use of CO₂, 3rd harmonic Nd:YAG and excimer lasers in terms of the tools currently on the market, hole quality, drilling speed and cost per hole.

The principles of operation of thin film transistor (TFT) flat panel displays (FPD's) and the need and use of lasers for melting the as-deposited amorphous silicon film to form a high-mobility layer of polycrystalline material were introduced by Stan Brotherton of Philips Research Labs in Redhill. Such low temperature annealing with line beams from excimer lasers allows low cost glass substrates to be used for the display and is now in widespread use by Japanese companies manufacturing FPD's. Expensive fused



Exhibitors and delegates at the Microengineering Workshop.

silica substrates would otherwise be needed in order to withstand the high temperatures in an oven-annealing cycle.

The workshop's strong Dutch connection continued with Otto Märten head of the Laser Group at Philips Centre for Manufacturing Technology in Eindhoven, describing the many laser microprocessing applications (joining, labelling, decoration, scribing, cutting, etc) used within Philips to manufacture a wide range of consumer products. He emphasised the need for laser equipment suppliers to provide turnkey solutions to manufacturing problems tested according to international standards.

After lunch and a tour of an exhibition of equipment suppliers, Steve Temple the Technical Director of Xaar plc in Cambridge, described the use of lasers for drilling ink jet printer nozzles. The very stringent accuracy requirements of this application (hole diameter tolerances of <1µm with <5mrad parallelism) make laser drilling the only viable manufacturing technology. Steve described the pros and cons of in situ (reverse taper) versus ex situ drilling, together with the various materials, laser beam shaping and speed issues in their development of high resolution page wide arrays that incorporate 3,000 – 4,000 nozzles.

Ron Lawes, head of the Central Microstructure Facility of the Rutherford Appleton Laboratory highlighted their activities in the area of excimer laser micromachining. In terms of prototyping and parts throughput and cost per part, he then compared it with other more widely used technologies for micromachining like chemically etching silicon, X-ray 'lithography galvanofarming' (LIGA) and uv lamp resist exposure - concluding that laser ablation is the most cost effective process of all.

In the final presentation of the day, Spencer Jansen of Intersolar Ltd in Bridgend described the principles of operation, application areas and manufacturing cycles of their photovoltaic p-i-n silicon solar cell products. For isolating cells and the edges of the glass panel, he discussed their use of fundamental (1.06 µm) and frequency-doubled (532 nm) Nd:YAG lasers for scribing thin films

UKCPO Web site

Almost a year ago, the UK Consortium for Photonics and Optics (UKCPO), of which AILU is a member, received DTI funding for a two year programme, code named ALERTT, to set up a database of information on UK manufacturers, researchers and other organisations working in the laser and photonics area.

As part of that initiative a new directory web site has been set up at www.ukcpo.org.uk.

The UKCPO web site provides free advertising for all who register, at least for the remaining 14 months of the ALERTT programme. After that time it is envisaged that the member associations, including AILU, will help support the site. A free registration form is enclosed with this issue of the magazine and further copies can be requested from the UKCPO secretary, Geoff Hogan at: ALERTT Project, FREEPOST (SCE8461), Oxford OX1 3YJ.

New secretary at UKLEO

Bridget Marx, for many years the Chairman and Secretary of UKLEO (the UK Laser and Electro Optics Trade Association) has stepped down to concentrate on her other consultancy roles.

Bridget has steered the development of UKLEO for many years and is leaving the association on a high, having helped mastermind the launch of UKCPO and the ALERTT programme to establish an active network between research and industry. She is not leaving behind her links with the UK laser community, however, and will remain European Editor of the Laser Focus World magazine.

Shaun Coles, who is now an independent consultant after 12 years as MD of Burleigh Instruments UK, takes over the Secretarial role.

Closer links between AILU and IoP

AILU has been granted associate membership of The Applied Optics Division of the Institute of Physics. As an associate member, we will be invited to submit items for the IoP events calendar (which is produced approximately twice a year), but more importantly the link will give AILU a direct line of communication with the IoP and thereby a wide section of the UK Photonics research community.

As a first combined activity, AILU will support a laser materials processing meeting for researchers, to be held on 8 March 2000 at IoP headquarters in London.

LIA Connections

The Materials Processing Committee of the Laser Institute of America has launched a Connections Bulletin, a regular newsletter to help develop a network for members. The Connections Bulletin will be produced quarterly, and the first issue is just out. Still under construction is an on-line bulletin board on the LIA web site.

The first issue of Connections Bulletin had a surprisingly strong UK bias, with features on the Lairdsie Centre and the new AILU job shop group.

New president at CLP

Olivier Fréneaux, General Manager of IREPA Laser in Strasbourg, has been elected President of Club Laser de Puissance, the French scientific and industrial laser association. He takes over the position from Alain Quenzer, who held the post for many years.



Olivier Fréneaux

In announcing this change, the industrial members of the board of administration clearly and strongly affirmed their wish to increase the orientation of CLP activities toward meeting the needs of industrial laser users. Activities include providing information on laser technology and applications, and encouraging communications between the various sectors of the laser community, including research, education, technology transfer, laser and systems providers, large and small companies.

Immediate action will be taken to undertake a technology survey, to produce a professional yearbook of members, and to orientate the CLP bulletin more towards industrial applications. In order to realise these actions, the CLP are seeking to employ someone on a permanent basis.

"This could be a great opportunity to strengthen the collaboration between AILU and CLP, mainly in the field of diffusion of information oriented to industrial needs," commented Fréneaux. Ideas to be discussed by both associations include the translation of some French articles and news items from the CLP's bulletin for inclusion in *The Industrial Laser User*, and visa versa.

AILU web site developments

Visitors to the AILU web site at www.ailu.org.uk will have noticed a number of important developments, not least of which the home page layout has been improved to give more prominence to our links to the European Laser Applications Network (ELAN).

Perhaps the most important improvement for members is that the restricted area now contains a full set of articles from back issues of *The Industrial Laser User*. The original plan to provide complete back issues for downloading was aborted when it was realised that downloading the files, in excess of 2 Mb each, would take an unacceptably long time.

The back issue collection will be an increasingly valuable reference source for members.. (See page 34 of this issue for a full listing). We have provided cross-referencing on the web site to speed up the search for articles, which can be individually downloaded and read/printed using (free) Adobe Acrobat, details of which are provided on the site.

Other changes include a link to the full results of our survey of UK laser research centres (see summary in Issue 15) from News and e-mail links to equipment and service providers from the Directory

The pictorial database of applications is on the web site but is currently under test. It should be accessible from 1 October.

Members' News

Twenty years in laser cutting

In 1979, when Coherent (UK) of Cambridge got together with Lasercut Products Ltd, then in Bishop's Stortford, to build a moving optic cutting machine it became the first such machine to be operated in the UK and one of the first in the world.

The first industrial CO₂ lasers were of such poor beam quality that flat-bed laser cutters invariably employed a design where either the laser plus fixed beam delivery optics was mounted onto a moving head of a machine or the laser kept stationary and the work table moved underneath it. However, with improvements in laser beam quality, moving optics cutters, in which the laser remains stationary and the beam delivery mirrors move, became feasible.

John Bishop, MD of Lasercut Products, came across an old newspaper clipping from May 1979 (from which the picture across is taken) reporting this historic event.

'The significance struck me,' said John, 'that we recently installed a state-of-the-art Trumpf 3.8 kW CO₂ machine, 20 years to the month that we operated the first moving optic machine in the UK.'

'We obtained the base machine from the DTI via Coherent. It was one of three water jet machines made for cutting leather for the shoe industry, but the unions at the time would not allow them to

be used. Coherent got hold of one of the machines but was unable to complete its conversion to a laser machine. I was looking for a laser to cut metal at the time and they asked if I would take over the project. The rest, as they say, is history.'

In May '79 the machine was cutting 6mm mild steel, 3 mm stainless steel and 1.5 mm aluminium. 'Nobody told us that we couldn't cut aluminium at the time!' added John.



Newspaper clipping from May 1979.
Lasercut Product's general manager, Brian Sandford watches the progress of a 'computer controlled roving nozzle' on the UK's first industrial laser machine with moving optics.

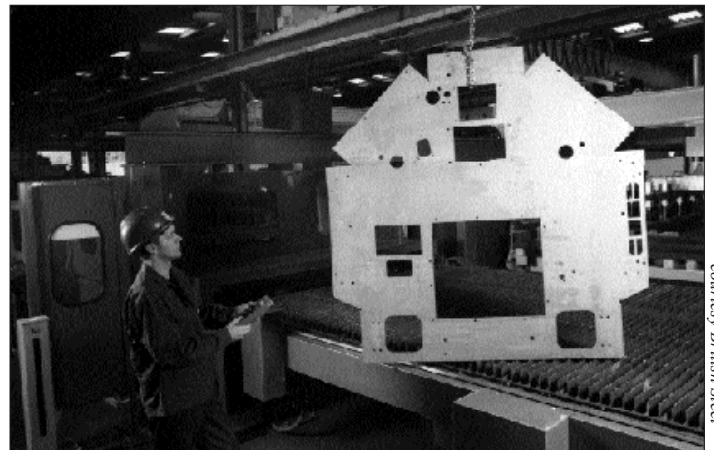
Additional laser profiling lines commissioned at BSD

British Steel has recently commissioned two new 3.5 kW laser profiling lines at its specialist HR Coil Processing Centre in Leeds. This brings the total number of laser profiling machines at the Service Centre at Wortley, Leeds to five, and is the latest phase in a £3 million investment programme in laser profiling technology which began three years ago. Since then the laser profiling business has become a major supplier to the construction and earth moving equipment industry.

The largest of the two new machines, a Bystar 4025-8, has a 4 m x 2.5 m cutting area with an extended cutting table and an automatic repositioning facility for handling sheets up to 8 m x 2.5 m. It is the only one of its kind in the UK.

"Customer demand for laser accuracy has grown rapidly over the past three years, most notably in the 'yellow goods' industry, to meet the requirements of the latest automated production facilities, such as robotic welders," said General Manager, Steve Rowland. "Typically, we can now profile components to within ± 0.5 mm, and laser cut holes to within ± 0.15 mm. This eliminates the need for further downstream punching, drilling and finishing operations. Manufacturers are also specifying laser accuracies for much larger parts than in the past, such as base plates for excavator cabs. The addition of the two new lines means that we now have an unrivalled capability to satisfy this growing demand, in addition to our existing order-book for high volumes of smaller parts and sub-assembly kits."

"The service centre has also seen a significant growth in demand for shaped components, as manufacturers increasingly out-source non-core processing operations. An Ursviken 640 tonne press



A laser profiled cab base plate on the new 3.5 kW Bystronic Bystar 4025-8 laser cutting line at British Steel Distribution's Hot Rolled Coil Processing Centre in Leeds. This machine has a 4m x 2.5m cutting area with an extended cutting table and automatic repositioning facility that can handle up to 8m x 2.5m. It is the only one of its kind in the UK.

brake, which was installed last year, adds further value to many of the laser cut profiles by forming them into components before they are dispatched to customers. This can accommodate profiles up to 25 mm thick and 7.5 m long, and it produces a diverse range of products including shaped base plates for excavator cabs, mast and hull parts for ship kits, deck plates for bailey bridges and beams for trailers. A 300 tonne machine is also available for smaller parts.

British Steel will formally merge with Dutch steel group Koninklijke Hoogovens in the Autumn.

DTI helps Oxford laser engineer to learn from USA

Supported by the Department of Trade and Industry's International Secondments service*, Exitech's Dafydd Thomas is spending a year in the USA to study the operations of Excellon Automation at their 440-strong plant at Torrance, California. Excellon are one of the world's leading suppliers of mechanical drilling machines for the printed circuit board industry, and have an agreement to work closely with Exitech on the development, manufacture and marketing of laser-based drilling tools.

"We want to consolidate our relationship with Excellon and raise our profile to help sell laser machine tools in North America", said Dafydd. "The potential for our products there is absolutely huge."

Dafydd added, "It is a great opportunity to gain greater knowledge of USA technology and engineering, their methods of working and to benchmark our company against their operations."

**DTI's International Secondments service supports UK companies in overseas secondments of individuals from any discipline to any country for periods of three to 12 months to learn best practice, improve productivity and develop overseas links.*

The service focuses on companies with up to 2000 employees. There is additional financial support for companies with fewer than 250 staff to help cover the cost of filling the gap left by the secondee during the secondment. Firms employing more than 2000 people receive practical support and limited financial help. There is also help with training in language and presentational skills.

To learn more about the DTI's International Secondments service, telephone 0171 215 3879 or fax 0171 215 3934.

Coors Ceramics Company Limited

Vacancy: CO₂ Laser Technician

Coors Ceramics Company Limited supplies ceramic substrates for electronic applications throughout Europe.

Our busy laser production facility in Glenrothes, Fife, requires an experienced CO₂ laser technician* to help maintain our operations twenty-four hours per day, seven days a week. (*Additional training on ceramic characteristics will be given)

The successful applicant will be required to work weekend nightshift comprising three twelve-hour shifts on Friday, Saturday and Sunday.

As well as an attractive salary with shift premium and profit-sharing, we offer a contributory pension and life assurance benefit.

Relocation assistance will be considered.

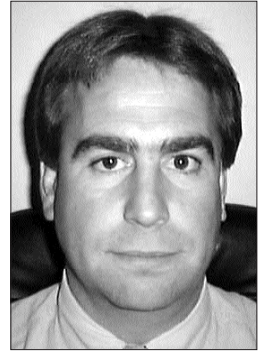
Applicants should apply in writing to:-

Mrs. Susanne Stevenson
Coors Ceramics Company Limited
64-66 Cavendish Way
Southfield Industrial Estate
Glenrothes
Fife, KY6 2SB

New appointment at BFi Optilas

BFi Optilas Ltd has appointed David Switzer as Product Manager to head its new Industrial Laser Division in the UK.

David has worked in the field of lasers and optoelectronics for over 17 years and specifically in the field of industrial lasers since 1990. Based in Milton Keynes, he is responsible for all sales and technical support activities for BFi Optilas' range of industrial laser and related products.



Coventry Laser Group set to expand

Following a management re-organisation, the Coventry Laser Group, led by Group Chairman Martin Rourke, are embarking on an ambitious expansion policy to develop its existing 7 strategically placed sub-contract laser cutting, marking and abrasive water jet operations. Key to the group plan is the provision of services across a broader spectrum of materials and industries.

The business has recently been strengthened by the appointment of Tony Pettinger as Group Sales Manager, with existing General Manager Mark Dadley being appointed to the Board of Directors.

There are immediate vacancies for experienced Sales Engineers and Service Engineers within the Group's Laser Marking and Special Systems Division. These positions would be at Quantum Laser Engineering Ltd. in Coventry. Anyone interested should contact Tony Pettinger at Coventry Lasers Ltd.

Address: Padstow Road, Coventry CV4 9XB, Fax: 024 76466112

Shake-up in the gas supply industry

A major rationalisation of the gas supply industry is underway. On 13 July 1999 a joint news release announced that BOC had agreed to terms of a cash offer for its total acquisition jointly by Air Products and Air Liquide. The BOC operations worldwide are being divided between the two purchasers, with Air Liquide taking all the UK and Irish operations of BOC.

One month later, on 16 August, Linde of Germany announced that it is to make a public offer for the Swedish gas giant AGA. Linde's aim is to complete a merger of the technical gas business of the two companies as soon as possible.

The global technical gases market is currently about EUR 28B, with sales by Linde plus AGA accounting for 25% of the total.

Situation Wanted

Colin Cole PhD, an AILU member, is looking for a position in industry. He is keen to continue working in the field of laser engineering where he has gathered experience in both commissioning and operating laser systems.

Colin is nearing the end of a successful three year research contract in the Department of Mechanical Engineering at Loughborough University and is currently writing up his PhD thesis on the industrial applications of kinoform diffractive optical elements.

For a full CV contact Liz at the AILU office on 01235 539595

High Speed Laser Cutting Grant Set to Push Processing Speeds To The Limit

Dr Bill O'Neill, Dr. Dave Brookfield and Dr. C. Sutcliffe have received a grant of £566,000 from the EPSRC Responsive Production committee to develop a high speed laser cutting system capable of pushing laser cutting to the limit on stainless steels and mild steels in an attempt to reduce the dependence on punch press operations for those companies engaged in sheet metal operations. The program is funded for three years and will involve a number of key sponsoring companies: BOC Gases, Howden Lasers, British Steel, V&S Scientific, Stoves, Vosper Thorneycroft, and Laser Expertise.

The primary aim of the project is to develop a high speed automated laser cutting solution for processing of sheet steel parts in the range 0.75-10 mm thick. This will not only provide a new process solution within laser based manufacturing activities, it

will extend our knowledge of high speed laser materials processing and create a new generation of laser cutting system that will be manufactured by a UK based company. In addition, the provision of design rules and performance characteristics of high speed processing systems will prove useful for other laser based applications such as welding and surface treatment. A high speed gantry system delivering a Howden LE3000 3.0 kW CO₂ laser system will be used in conjunction with an array of controlled parameters to maximise cutting speeds. The system itself is capable of producing 5g linear accelerations and a maximum interpolated speed of 240m/min.

Further details: Dr Bill O'Neill, telephone: 0151 794 4903, fax: 0151 794 4693, e-mail: w.oneill@liverpool.ac.uk

Diode-pumped lasers preferred for scribing of thin-film photovoltaic modules

Photovoltaics (solar cells) are solid-state semiconductor devices that convert light directly to electricity. PV modules provide energy without emissions, noise, or use of fuel. They are reliable, modular, and capable of providing maintenance-free electricity in remote locations. A typical photovoltaic module can generate up to 60 watts in 2' x 4' panels. With scarce supplies of cheap solar grade silicon, it is necessary to buy top grade silicon resulting in high cost per cell. The solution to this problem is thin-film PV technology.

As well as setting records for efficiency, thin-film photovoltaic modules use a factor of 50 to 100 less semiconductor material than crystalline silicon solar cells. This is important to meet aggressive cost targets. Thin-film materials include copper indium diselenide (CIS), amorphous silicon (aSi), and cadmium telluride (CdTe). Thin-film materials are deposited in layers on glass panel substrates. The final deposition layer is typically a metallic conductor.

Laser Scribing Application

To create electrodes on the thin-film PV module, lines are scribed in each thin-film layer along the length of the module. Line spacing is about 1 cm. After the next thin-film is deposited, the module is scribed again with a line offset of approximately 10 µm from the preceding scribe line. Mechanical scribing often produces considerable damage surrounding the scribe, whereas laser

scribing has the potential for superior scribe widths and profiles for many of the materials involved with thin-film PV.

Numerous types of lasers have been evaluated for this laser scribing application. Lamp-pumping Nd:YAG lasers have been used for their high power and relatively low cost. Recently, however, the increasing demand for reliable cell interconnects, PV efficiency, and PV module yield has prompted researchers to re-evaluate the laser process. This research has shown that wavelength, pulse duration, mode quality, and pulse stability can have a substantial impact on the scribe quality. As a result, some PV module manufacturers have switched to diode-pumped solid state lasers. The investment in higher quality laser technology is returned through higher PV module yield and efficiency. Diode-pumped solid state lasers operate from standard 13A sockets and eliminate the need for external water cooling. Their compact and robust packages ease system design and integration.

The diode pumped laser also offers improved mode and energy stability. Researchers have shown improved thin-film scribing using visible and UV wavelengths.

Abridged from a Spectra Physics report provided by David Jones and presented by him at the 'What's New in '99?' AILU meeting at TWI on 7 April 1999

Further details: David Jones, Spectra Physics, tel: 01442 258100, fax: 01442 268538.

Laser coding can now be integrated in cartoning machines

With the recent introduction of GSI Lumonics' new Xymark® Efx laser system, Uhlmann Pac System of Laupheim, Germany, are realising new possibilities for integrating coding procedures in packaging machines.

Uhlmann are a market leader in the manufacture of packaging machines for the pharmaceutical industry, and have long exploited laser marking technology. Their deep drawing machines, equipped with GSI Lumonics coders, are used for blister packaging, cartoning and collapsible cardboard boxes, but until now it has proved impossible to integrate the laser-coding head in cartoning machines because of the limited space available. Coding was carried out by using an additional conveyor belt, whose speed, for technical reasons, had to be greater than the speed

within the cartoning machine itself. As a result, impairment of the print quality could not be completely avoided.

The problem has now been overcome with the Xymark® Efx 10 system, which processes without a laser coding head. The laser marking now takes place shortly before the transfer of the collapsible cardboard box line to the despatch conveyor. The collapsible cardboard box is guided so precisely in this area that even with 400 collapsible cardboard boxes / minute a text of up to 4 lines of excellent quality can be maintained.

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International SEMATECH purchase Exitech 157nm Microstepper

In July of this year, silicon chip manufacturers consortium International SEMATECH, Austin, Texas purchased an Exitech 157 nm Fluorine (F₂) laser Microstepper. A month later, at an Advanced Lithography Critical Review meeting in Chicago, a task force recommended that International SEMATECH fund a 157 nm programme in 2000 targeted at the 100 nm node. This node requires photolithography on wafers of critical features having sizes ranging between 70-100 nm, for use in the manufacture of 4 Gbit memory and 1 GHz processor chips around the year 2006.

Scheduled to begin exposure work in the first quarter of 2000, the Exitech tool incorporates a 6 watt 157 nm Lambda Physik Novaline F630 F₂ laser and a 0.6NA 157 nm imaging objective manufactured by Tropol Corp. With a 1.5x1.5 mm image field size, the tool will be used primarily to carry out high-resolution exposures at 157 nm for the resist development programmes of International SEMATECH, its member companies and resist manufacturers.

The Exitech 157 nm Microstepper is the world's first F₂ vacuum ultraviolet laser processing system commercially available. Capable of imaging tiny circuit features on silicon wafers with 25 nm focal precision, this tool far surpasses the optical imaging, metrology and automation performance of other laser materials microprocessing tools.

Other EXITECH news from the USA

Exitech Ltd has announced the formation of a US-based subsidiary company Exitech Inc located in Menlo Park, California. Facilities at Exitech Inc include an applications trials laboratory fully equipped with the latest generation of laser micromachining systems with associated diagnostic tools. The company is responsible for US-based sales and service support of Exitech's wide range of industrial laser micromachining systems.

Exitech has a long-term Strategic Alliance with Excellon Automation, California for supplying laser microvia drilling and routing systems to the electrical interconnection market.

Products & Services

Early look at Xymark® EFX S series laser coding system

GSI Lumonics has launched a new model in the Efx series - the Xymark® Efx 10S. This dot matrix laser coding system has many of the characteristics of the Efx 10, but with its additional module, has up to three times the speed, better print quality as well as stationary coding capabilities. Bigger codes to be produced and a wider range of materials to be coded. The system also offers simple, flexible programmability.

The new machine is capable of reproducing graphics of logos and its unique five part articulated arm means it can be positioned in any orientation. A compact galvo scanner module, a fraction of the size of the Xymark Sprint II module, goes on the end of the articulated arm, allowing the new system to be used in many space-restricted applications

GSI Lumonics' Xymark™ Efx 20S dot matrix coder is up to six times the speed of the Xymark Efx 10, with an effective character generation rate of up to 3000 characters per second, marking products at line speeds of between zero to 400 m/min. It can code up to 5 lines of text, or single line characters up to 10 mm high and 16 dots wide. Its simple programmability allows manufacturers to meet the exact requirements of their customer base, whether it be batch, real time/date or best before date.

The system will code on a wide range of materials, with exceptionally high quality print, offering an economic coding solution for many high speed applications. It is ideal for coding materials

Info

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such as labels, glass, various plastics, PET, rubber, printed or anodised surfaces, producing a repeatable, indelible and contrasting code.

Linde offer up to 300 bar from LN2

For users of the industrial gases nitrogen and argon requiring upwards of about 1000 Nm³/month supply the storage of the gases in cryogenic liquefied form is an interesting alternative to cylinder bundles. The outlet pressure, however, is limited to 18 bar by the design pressure of the vacuum-insulated tank in which the gas is stored. In laser cutting the user would like a higher gas pressure and Linde's pressure boosting DES300/100 plant represents an economical and excellent technical solution. The DES 300/100 generates up to 100 Nm³/h gaseous nitrogen with a pressure of up to 300 bar from the liquefied nitrogen being stored in the tank.

A 6 or 18 bar standard tank with evaporator is connected to the pressure boosting plant. The tank is filled by conventional road tanker without additional pressure boosting equipment. The DES300/100 pumps the required quantity of gas from the tank to meet user demands, even when strong fluctuations in gas requirements occur, so no storage tanks are needed on the high pressure side. Loss-incurring start-up procedures are also largely avoided.

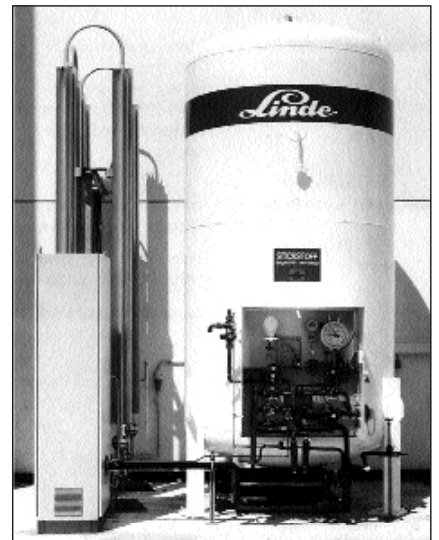
Info

Mike Jones

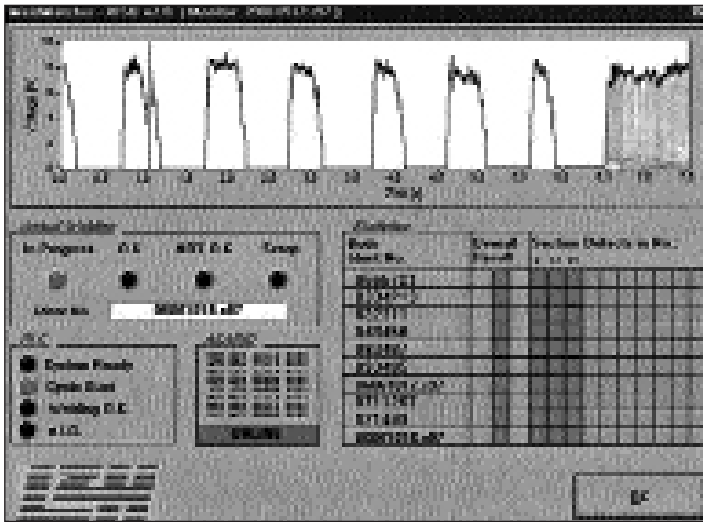
Linde Gas UK Ltd

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Monitoring process and product at Precision-Optical Engineering WeldWatcher



A typical Weldwatcher screen display shows the automatic comparison of process data with a reference weld trace. Faults are clearly visible..

The WeldWatcher is an industrial process system for monitoring and controlling laser beam welding. It provides on-line control of laser welding for the automotive and aircraft industries, as well as in electronic production. The prototyping and research and development was undertaken by Laser Zentrum Hannover.

Welding faults, which can arise from unstable process parameters and material inhomogeneities, lead to quality rejects. WeldWatcher detects both weld defects and system faults. A typical screen display shows the automatic comparison of process data with a reference weld trace, with faults clearly visible. The software enables users to carry out trend analysis of their welding process and to print out quality reports.

Minifire interferometer

Precision-Optical Engineering has added the minifire, a one inch aperture Fizeau optical test interferometer, to its Interfire range of interferometers.

The Minifire is a compact instrument designed for testing on optical production lines. Testing has been made as simple as possible, with an alignment screen for setting up the optics. The Minifire may be mounted vertically or horizontally according to the production and testing layout and the test fringes are viewed on a nine inch high resolution fringe monitor. A full range of transmission spheres, mounts and accessories are available for particular testing applications. Despite its small size and low cost,

the Minifire boasts better than $\lambda/20$ accuracy. The Minifire's capabilities can be extended with phase shifting and static fringe analysis options to allow more extensive testing of lenses.

Info

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New range of lasers and power meters

New 9.3 μm wavelength sealed CO₂ lasers

Synrad Inc now offers sealed CO₂ lasers models with a 9.3 μm wavelength. These lasers, like Synrad's standard 10.6 μm wavelength models, feature Synrad's durable all-metal tube construction. The 9.3 μm series lasers were developed to better address cutting and marking applications of materials with a higher absorption at the 9.3 μm wavelength. The most notable of these materials is Kapton[®], a polyimide film commonly used in flexible circuits manufacturing, and gaining popularity in the automotive and aerospace industries.

Available with output powers of 18, 90 and 170 watts, the 9.3 μm series lasers can easily be integrated into a wide variety of motion systems, such as gantry systems, X-Ytables and robotic arms. They are also compatible with Synrad's galvo-based digital marking head.

For any company considering the benefits of laser technology, Synrad offers a free process evaluation. Send them a description of your current process, an example of a 'finished' product, and some material samples. Your samples will be returned to you, cut, drilled or marked according to your specifications, complete with a written materials evaluation, and additional information on implementing laser technology.

The Power Wizard low cost laser power meter

Laser Lines Ltd now offer a new improved version of Synrad's Power Wizard pocket-sized laser power meter that can be used with practically any laser. The Power Wizard now has enhanced accuracy and can be used to measure powers from 10 mW to 250 W.

Info

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The Power Wizard weighs only 80 g and features automatic data hold and autoranging. This product is available from Laser Lines for only £495 including next day delivery.

Lasermet safety products and services

Laser safety eyewear

Lasermet are able to offer CE marked laser safety eye-wear from as little as £140 (1 off price), with discounts for larger quantities. Eye-wear is available for all types of lasers and in various frame styles to suit all needs, with protection levels (L numbers) suitable for a wide range of laser powers and wavelengths.

Laser Protection Adviser service

Lasermet are launching a Laser Protection Adviser service to provide laser safety specialist support at a reasonable cost, for companies and organisations who find training an employee to LSO level prohibitively expensive.

Info

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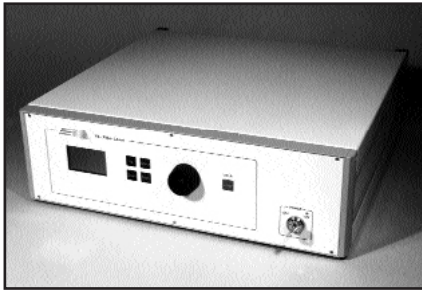
The service comprises an annual laser safety audit and telephone advice throughout the year. This is included in the basic cost. Any additional site visits required will be undertaken at a reduced rate.

AG E-O introduce new laser and detector products

COBRA – A New High Efficiency Fibre Laser

The new fibre lasers of the COBRA series from Advanced Photonic Systems have a single-mode Yb-doped fibre as the active laser medium, pumped by laser diodes.

The laser resonator is completely sealed for maintenance-free operation and excellent beam pointing stability. The TEM₀₀ beam profile enables the beam to be focused to very small spot sizes. The user can choose any wavelength between 1.07 µm and 1.15 µm with an output power of 5 or 10 Watts.



SPARROW - The New Series of Microchip Lasers

The Sparrow series of microchip lasers are compact turn-key devices with emissions in the green (532 nm), blue (473 nm) and deep-blue (457 nm) spectral regions. The output power is specified up to 100 mW.



Two different series are available. An affordable version, designed for applications like display or medical diagnostics, delivers laser radiation with an excellent beam profile and pointing stability. The more sophisticated version has single frequency emission capability and exhibits reduced noise. Applications include display, printing, medicine, spectroscopy, illumination and pointing holography.

MSM photodetectors up to 40 GHz

Advanced Photonic Systems offer a series of high-speed (up to 40 GHz) photodetectors based on MSM (metal-semiconductor-metal) technology. Special structures and dopants enhance the responsivity and minimise the electrical noise. All detectors are optimised for minimal pulse tails and oscillation free impulse response even at very high signal speeds.

The wavelengths range from 400 nm to 1.6 µm. For the optical input signal, a single mode fiber with FC/PC connector is standard.

VIVACE - The New 65 GHz Photodetector Series

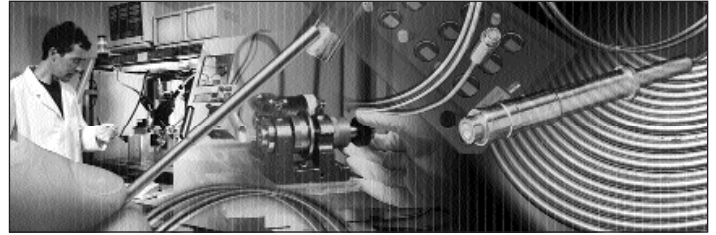
In Autumn 99, Advanced Photonic Systems will offer a new ultra-fast photodetector series with a bandwidth to 65 GHz, a <5 ps FWHM pulse response, and a wavelength response of 400 nm to 1.6 µm. These features exploit the inherent advantages of the MSM detector configuration such as low capacitance, low series resistance, and large active area.

Info

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The detectors are an ideal choice for precisely characterising the time and frequency response of high-speed optical sources and lightwave systems.

Thermoheat sub-contract laser welding



Thermoheat have opened a sub-contract laser welding service using their existing in-house facilities and welding specialists.

The sub-contract service accesses a number of CNC workstations that have been engineered to provide flexibility and quality precision Nd:YAG laser welding. Their custom built systems are equipped with System 3R™ 3Refix™ technology, enabling swift and precise set-up from component to component and from batch to batch.

All the laser welding is CNC and Thermoheat can work from drawings, templates, samples or compatible CAD/CAM files.

Info

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Welding, assembly and inspection jigs and fixtures can be rapidly built by skilled craftsmen using their conventional machining facilities.

BFi's industrial laser news

Industrial Laser Division Expands

BFi Optilas Ltd has expanded its industrial laser division with the recent signing of two new distribution agreements with DEOS Inc. of Bloomfield, USA and Swiss laser manufacturer OPL Laser Technology.

DEOS have supplied RF excited sealed-off CO₂ lasers since 1994 and offer sources with output powers up to 100W for applications such as cutting, marking/coding, engraving and rapid prototyping. OPL Laser Technology was formed in 1997 after a management buy-out of Oerlikon Precision Laser who had been supplying lasers to the industrial market since 1990. They continue to offer a range of high power fast axial flow lasers of up to 4kW output power for all materials processing applications.

CW Arc Lamp Power Module

Analog Modules Model 5901 CW Arc Lamp Power Module o delivers up to 45 A of current into xenon or krypton arc lamps for solid state laser applications. The Model 5901 provides up to 6 kW average output power in a 8.05" × 4.85" × 4.14" (L×W×H) package and weighs only 4.5 lbs. The module is 90% efficient, drives lamp loads from 50 V to 250 V and provides a switched boost output for energising AMI's Model 592T lamp ignition module. The Model 5901 has opto-isolated enable and proportional current control inputs and isolated current sense and voltage sense outputs. Protection features include an over-current limit and over-temperature shutdown making it an ideal choice for scientific, industrial and medical OEM applications.

Info

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Heraeus' New Reference Book

Heraeus Noblelight offers a new technical guide book to laser lamps. The 36 page book has been produced to help laser system designers specify lamps and match them with particular systems. As such, the guide contains a range of information, never previously been available in a single convenient source.

Sections of the book deal with quartz properties, power loading, power supply design, connector styles, electrodes and failure mechanisms. Formulae are provided to work out the design parameters affecting lamp operation, as well as relevant conversion tables to facilitate calculations.

The new reference book removes much of the 'black magic' from laser lamp design and attracted a great deal of attention at Laser

'99, with virtually all the visitors to the Heraeus stand requesting a copy.

Info

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Neslab Catalogue on the Web

You can now download the new NESLAB catalogue from the world wide web:

www.neslabinc.com

Select 'catalogue' from the Publications list and print off the pages you want, or even the whole catalogue.

A Day in the Life of ...

Karen Williams

Life in a university research department

I'm usually awake as my alarm clock clicks, just before it rings to welcome the new day. I put on the kettle, feed the goldfish, and race around trying to get out of the front door before it rains – I cycle in when it's fine.

When I get to work I shut the office door behind me to stop passers-by from dropping in! I check the mail, check the answer phone, check the email. The summer is my favourite time of year – the students are gone, there are no fiddly one hour slots for lectures and tutorials at the other end of campus, no undergraduate students trying to pin you down with questions on assignments as you walk down the corridor, no lab classes to prepare. It's the time for me to learn - to concentrate on the reason I selected academia, by following up on research that I wanted to do and somebody else decided needed doing enough to support it!

High power laser materials processing is part of the Optical Engineering Group in the Mechanical Engineering Department at Loughborough University. It has a large group of academics and researchers working in various engineering related aspects of laser applications. The high power laser section is small but innovative. One of the reasons that the job was attractive to me was the diffractive optical kinoforms for high power laser beam shaping research being done in the laboratory. The optics are calculated and manufactured in the laboratory and I saw the chance to extend the applications for their use. By applying the principles of heat conduction to the problem of the distributed beam intensity profile I am showing that many conduction limited heat processing techniques can be improved by designing the heat source shape and intensity profile.

When I have finished this article I will be continuing with this research – I currently have a mathematical model working that predicts the temperature distributions obtained by a beam intensity distribution. The temperature distributions can be used to determine microstructures and stresses. I am presently gathering more experimental data to collaborate the experimental predictions. I have some experimental data for shallow melting and transformation hardening of plain carbon steels and I have to take

micrographs this afternoon for photographic prints to complete a paper for submission to a journal. I am also extending the ideas to tool steels that need to "soak" above the transformation temperatures and I will prepare the metallurgical samples to gather this experimental data this afternoon too.

I am also supervising PhD students in the Optical Engineering Group. There are two students writing up who need thesis chapters reading and correcting and one currently involved in fume analysis during laser processing of different materials – the work has provide links with Liverpool University, BNFL and BAe and some interesting results from the cutting of metals, which the student and I are currently trying to correlate with published cutting models. This work is done on our trusty Everlase CO₂ laser – we have CO₂, Nd:YAG and Excimer lasers available for use. I check some mathematical programming and fill in the diary space for tomorrow morning to analyse the experimental and theoretical correlation found so far.

In the evening, when the phone has stopped ringing and the laboratories have shut, I may prepare exhibition material for the AILU visit on 15th September, or finish an industrial report (if the experimental data arrives), or design an experiment for a local laser machining company which I hope will solve some of their processing problems and open a new avenue of research for the group. I will leave the computer calculating temperature fields over night for finite element stress analysis by a colleague later in the week. Even when I'm at home, the work is still continuing!



A perspective on the industrial laser market

David Belforte

Editor - Industrial Laser Solutions

As we approach the end of the 20th Century it is an appropriate time to look back at the first 35 years of industrial laser technology and to look ahead to the first decade of the 21st Century.

For the most pragmatic of reasons (I started collecting data then) I date the beginning of the industrial laser market to 1970. I believe I'm the only resource with access to this data which includes both unit sales and revenues. Actually the number of lasers sold into industrial situations before that date were inconsequential in the scheme of things, with due respect to old friends at Coherent, Ferranti, Messer Greisheim and BOC, who had some initial successes in the late 1960's.

The first noticeable market began in 1970 with a few dozen unit sales, worth less than a million dollars, into the electronics market for relay can welding. It was a start, albeit a painfully slow one for those trying to build a business in an industrial sector that could have cared less for a high technology solution to their processing problems. But hats-off to those risk takers. Because of the pioneering efforts and persistence of some early laser and systems suppliers the industrial laser business grew.

From that modest start, more than 120,000 industrial lasers have been installed worth more than \$5.7 billion (when integrated into systems the total is in excess of \$14 billion). As those who follow the market in the pages of Industrial Laser Solutions magazine know - an additional 17,000 lasers are expected to be installed this year, with a value of almost \$1 billion.

In the 30 year history of industrial laser sales there has been only one worldwide economic downturn, 1991, but it was a beauty, taking the industry nearly three years to recover to pre-recession sales levels. I only mention this because of concerns that a similar event may happen in the coming decade. There have been regional setbacks in the 30 year period and although the effects were serious locally, the total world growth numbers were relatively unaffected.

Over the 30 year period annual unit growth rates averaged around 14%. In the same period revenues approached 22% growth on average. This discrepancy in rates is explained by some dynamic shifts in the first five years of record keeping which produced dramatic rate swings but small incremental number changes. A classic case of statistics dis-

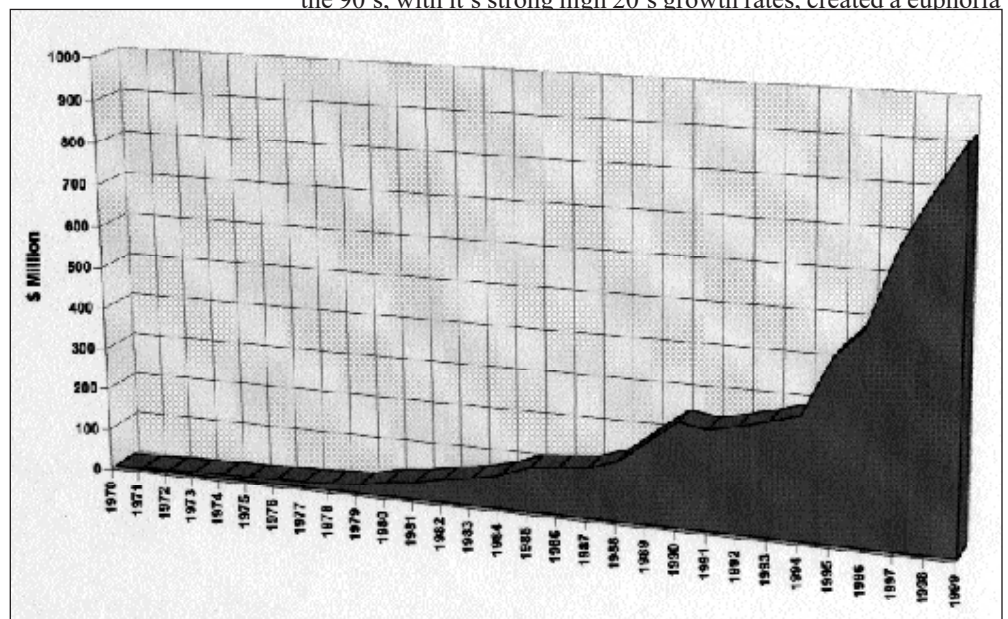
torting the total picture.

This decade has seen the most remarkable market growth. When and if the history of industrial lasers is ever written the 90's will be referred to as the golden years of laser growth. Japan set the tone with annual 30% growth rates in the first half, only to stumble in the second half ending up as number three in market size. Europe, led by Germany, enjoyed continual high growth rates, except for one stumble in 1996 from which they recovered nicely, led by the U.K., to rise to the number one position. The U.S. a poor third when this decade started has assumed the number two position, although signs of a decade ending slow-down are evident. Asian markets, the mid 1990's glamour performers are essentially stagnant right now and what is called the 'rest -of- the- world' is not big enough to sway any of the market numbers.

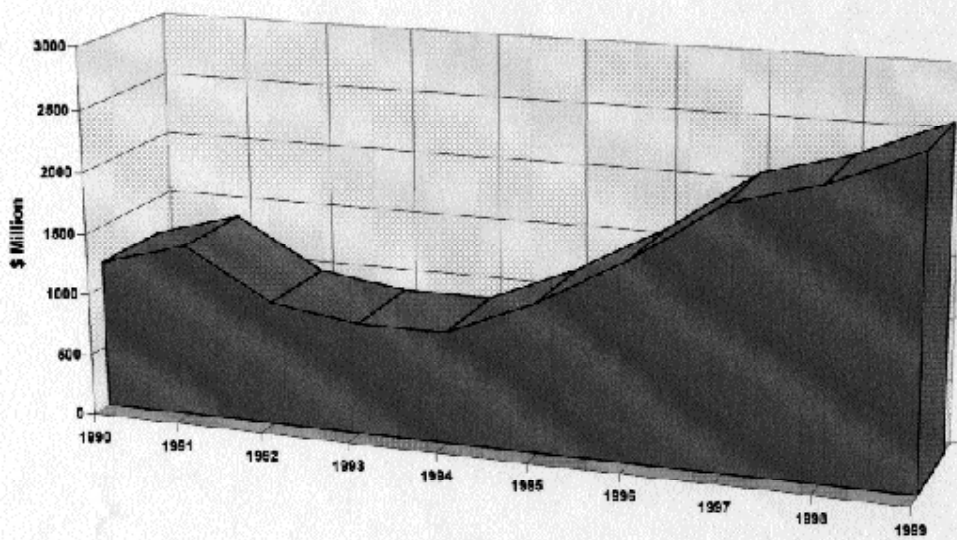
From my perspective there are a number of significant laser events that drastically changed the market. In the early years, the availability of high average power Nd:YAG lasers opened applications in hermetic sealing and airfoil drilling. The development of fast axial flow, carbon dioxide (CO₂) lasers created the market for laser sheet metal cutters in mid 80's. In the 90's, the introduction of low power, sealed-off, CO₂ lasers for non-metal processing, low average power Nd:YAG units for medical device fabrication, high power CW Nd:YAG lasers for auto body cutting and diode pumped solid state lasers for microfabrication applications opened markets that now total installations in the thousands.

After recovery from the 1991 recession (in 1994), the market of the 90's, with it's strong high 20's growth rates, created a euphoria

When the history of industrial lasers is written, the 90's will be referred to as the golden years of laser growth



The growth in annual industrial Laser Sales



Industrial Laser System sales in the 90's

which may be hard to sustain in the next decade.

Today, among the CO₂ applications, we can count more than 18,000 flat sheet metal cutters installed, over 175 high power units for tailored blank welding, more than 1500 - 2 to 15 kW installations for auto component welding, at least 2000 engraving systems, more than 4500 steered beam and mask markers and over 4000 units for desktop manufacture. And lesser quantities for another dozen applications.

In the solid state laser sector, mainly Nd:YAG, we know of 250 units for turbine blade drilling, more than 3000 systems for circuit trimming and the major application for solid state lasers - steered beam marking using more than 4000 units. Microprocessing accounts for another 2000 units, medical device welding about 1000 units and auto body cutting and welding about 450 systems. Additionally, smaller numbers of units now serve growing application sectors.

As the decade comes to a close industrial laser system sales will represent about 8% of the world machine tool sales. These will be led by high power CO₂ and CW Nd:YAG cutting and welding systems and diode pumped solid state units for microprocessing and marking. System sales revenues will increase even though laser units sales prices will decline.

As the new century arrives laser cutting will remain as the largest application although it's share of the market will decline slightly as marking, enjoying steady growth takes over the number one

spot in unit sales. Microprocessing, the application of the next decade will begin to take major market share and that long neglected application, surface treatment, will finally achieve market success.

For the next decade I envision a nominal 10% per year growth rate, even though I have concerns about the potential for another 1991 type market decline. If this does occur and it takes three years to climb back to pre-recession levels than all bets are off that the market will reach 45,000 units per year worth some \$6.7 billion.

Looking to the next decade, metal cutting installations should be able to grow around 10-15% per year, marking will likely average about 20% per year, with microprocessing about the same, if not more, and welding- led by the auto

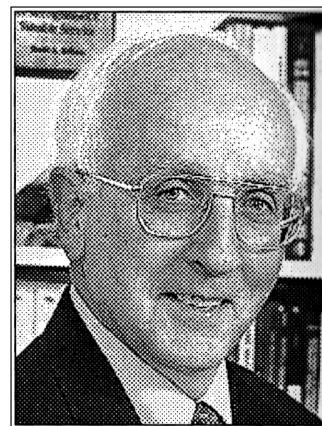
industry could finally achieve 15% per year sales.

Among the applications I expect to show significant growth are plastic welding, high speed blanking, on-line auto body welding, microvia drilling, flex circuit machining, tailored blank welding, soldering/brazing, heat treating and small hole drilling.

The lasers for these applications will be the CO₂ and Nd:YAG units we know today, joined by diode-pumped solid state slabs and disks and finally low cost, high power, direct diodes.

So what's my forecast for the year 2009? How about 35,000 systems worth \$5 billion. That would represent a doubling, in one year of the total numbers for year 1999.

David A. Belforte has been involved in various aspects of industrial laser material processing since 1970. For the past 18 years he has been consulting in this technology and since 1986 he has also been the editor of Industrial Laser Solutions (nee Review) and authored several books on this subject. He counts among his honors the award of the Arthur Schawlow Medal for contributions to industrial laser technology.



COMMENTS

Higher powers, higher speed

Pullmax have seen a rapid growth in laser cutting machine sales in the last 3 years accelerated by both higher powered resonators and faster positioning speeds. The faster cutting speeds have increased the need both for automation and adjacent storage systems. A trend towards automation in general will, we believe, increase. Further developments will continue to offer faster cutting speeds, this is likely to be particularly evident in the cutting stainless steel.

Kevin Brien Pullmax

Small fish feeling

The figures in David's paper make me think about the UK market. If 17,000 lasers are expected to be installed world-wide this year, the UK market this year is, what, 250 total? That's about 1.5%. Or have I missed some lasers somewhere? Very small fish/ large pond feeling.

David is also perfectly correct in his comments about the swift expansion in the diode market. It is amazing what a little money in the right places will do.

Tim Holt Rofin - Sinar

Continued over ...

Comments (continued)

Don't ignore the CVL

Since 1977 Oxford Lasers have been copper vapour lasers for industrial applications around the world. In the early days the main industrial application was Atomic Vapour Laser Isotope Separation in uranium enrichment plants. Increasingly though CVL's are being used for precision micro-machining in advanced manufacturing.

Into the 21st Century the cutting edge of engineering is in precision micro-machining. For these applications the CVL has proven the tool of choice for the most demanding work e.g. machining orifices for advanced fuel injection systems and for drilling high resolution inkjet printer nozzles in hard materials.

Martyn Knowles Oxford Lasers

Lasers in high tech industries

This overview of the historical growth and future size of the industrial laser and laser systems market by David Belaforte is very interesting. Over the past 30 years, to have had only one downturn at average growth rates of 22% is indeed a remarkable achievement for any market. Long may it continue!

I have one critical and important comment. David neglects a key market sector that is increasingly one of the most valuable to the industrial laser community. This is hardly surprising since a similar omission occurs in the annual audits of industrial laser and system sales carried out by trade journals like Industrial Laser Solutions and Laser Focus World. The area I refer to is the rapid growth and market importance of excimer lasers and associated technologies to hightech sectors such as the semiconductor, microelectronics, computer, and MST industries. Of course, the actual number of excimer units sold annually does not and probably never will, compare with numbers of CO₂ and Nd lasers and systems sold each year. However, what is overlooked in such surveys is that prices for production tools associated with such hightech industries are often as much as a hundred times higher than for relatively simple laser welding, cutting or marking systems. The actual value of the market for excimer laser based tools is growing at a faster rate and now exceeds that for most other industrial laser system types.

Take the use of excimer lasers in the semiconductor industry. Since 1995, excimer lasers have enabled at least a 15 year extension to be made to the lifetime photolithography can be used to manufacture silicon chips. The processor chip and many of the memory IC's in all PC's now have had some part of their critical microcircuits defined by an excimer laser. As an enabling technology, the excimer laser is truly allowing the burgeoning \$150B/year semiconductor industry to continue its growth the software and telecommunication industries are now so reliant upon. Within the next 10 years predictions show the electronics sector, of which the semiconductor industry represents 20%, will grow to be the world's second largest industry after agriculture! This is a huge industry, which in my view the laser community with some exceptions largely neglects.

Currently around 500 excimer laser systems are sold annually for photolithography - called within the industry 'deep-uv

(DUV) wafer steppers'. Each currently sells for around ~\$10M giving this sector a total annual market value of \$5B - already worth more than a third of the total \$14B installed base of laser systems estimated by David! Incidentally, although stepper tool costs are high capital costs are soon recovered since each is estimated to earn around \$100k/hour! Forecasts within the semiconductor industry show annual growth rates for DUV steppers in the next 5 years to be anywhere between 20 - 40%. Laser costs alone for this application are \$0.5-1M/tool, so in the space of 5 years an industry of around \$0.5B/year for laser sources has been created! Other examples, albeit of smaller size with less dramatic growth, are excimer laser tools used for manufacturing flat panel displays and ink jet printer heads.

There are tremendous opportunities for the industrial laser community to work together with such hightech industries in helping solve their manufacturing problems. My concern is many are missed through a lack of awareness of the problems along with the potential manufacturing solutions the laser industry is capable of providing.

Malcolm Gower Exitech

Response by the author

Dr. Gower is correct, I too have been concerned for several years that excimer laser sales are not reported to the depth of carbon dioxide or solid state. He is also correct about the growth of excimers in the marketplace. And I appreciate his perspective on this market. I would be pleased to present more information on excimers in my market analysis if I can get verifiable and reliable numbers from the industry suppliers. I can only base my analysis on information provided by these suppliers, tempered by input from end users and other industry sources. I don't make-up the numbers, I report them in edited form. For his information, I am the one who develops the industrial laser market numbers published in both Industrial Laser Solutions and Laser Focus World and their associated seminars, so any slight to the excimer market would show up in these publications.

Another factor, which I am currently trying to correct, is that for years applications such as laser lithography and laser graphics, were not included in my economic analysis for industrial lasers. Because these applications were associated more with the semiconductor and printing industry, and reported in those industries publications, I chose to only report on excimer sales for applications such as ablation, via drilling, etc.

Usually total excimer sales, including the lithography and graphics applications were included in the materials processing category reported in Laser Focus World. Now, with an expanded editorial base in Industrial Laser Solutions I am able to track activity in the formerly "gray area" of industrial laser processing.

If the excimer laser and system suppliers are willing to share their views on the market with me, as do the suppliers of carbon dioxide and solid state lasers, I in turn will be pleased to pass them on to the public.

David Belforte

KAIZENITH™

A novel approach to change management

Sean MacEntee

Laserform (IRL) Ltd

Greenhills, Drogheda, County Louth, Republic of Ireland

Laserform (IRL) Ltd was established in 1969, under a different name, as a steel rule die manufacturer. Eighteen years ago the company installed its first laser, which is still running 80 hours per week. In 1990 the Company diversified into laser profiling. In 1996 it set up a sheet metal fabrication operation. We are currently structured into 3 autonomous business units – steel rule dies, profiling and sheet metal fabrication. We are based in the ancient town of Drogheda, 30 miles north of Dublin, and employ a total of 64 people.

The company has always been customer service driven with an emphasis on best technology and good systems. For example, we were the first industrial laser user in Ireland and the first diemaking company in the world accredited to ISO 9002.

However, by the mid- 90's we began to realise that we had to make better use of the human 'software' in the company and so began the 'holy grail' which culminated in the creation of Kaizenith™ in 1998.

The Birth of Kaizenith™

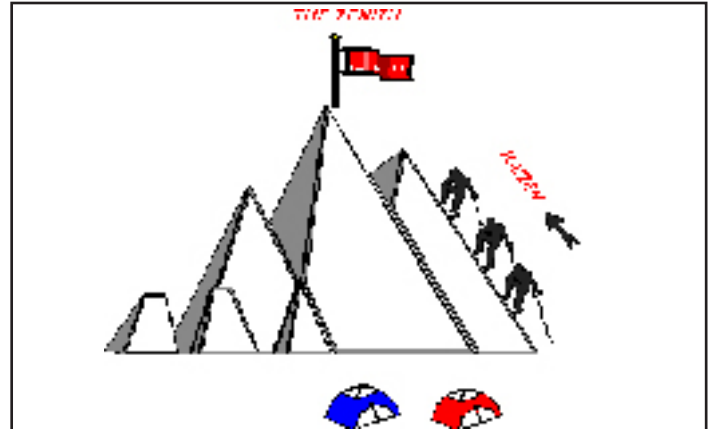
In April 1998, I participated in an EU sponsored visit to Japan. This was with a view to seeing at first hand how Japanese industry operated. There were 18 other participants on the mission from a total of eight countries. In total we visited six manufacturers, spending a full day with each one. The broad approaches by the companies we visited fell into one of two distinct categories: Total Productive Maintenance and Kaizen, and I immediately saw the potential in Laserform for the latter approach.

'Kaizen' is a Japanese word which describes any change or modification which:

- Improves output
- Eradicates waste
- Improves customer service
- Improves product design
- Improves the work environment

or any combination of the above.

The Japanese are also expert at summarising a concept or idea into one sentence or even one word. So on the long flight back from Tokyo to Amsterdam I set myself the challenge to come up with a unique word or slogan which best described the proposed Laserform approach, and so Kaizenith™ was born.



A pictorial representation of Kaizenith™ as a team effort to reach the summit by applying Kaizen principles

Kaizen describes the process of continuous improvement

Zenith is the attainment of a lofty goal

Kaizenith™ is achieving and maintaining peak performance through continuous improvement.

Key features of Kaizenith™

The following are some of the key features of Kaizenith™:


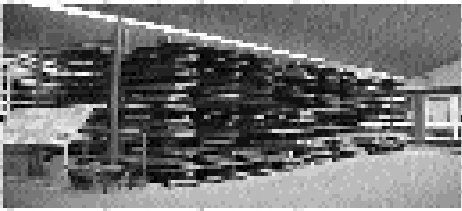





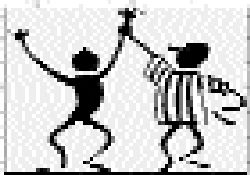
- Placing greater emphasis on the role of the employee as a problem solver. As is often said, when you hire a pair of hands you get a free brain.
- Training on problem solving and team working
- Working in groups or KITS (KIT = Kaizenith™

Unless you manage to convince the employee that you are serious about this new approach, which often means dealing with poor middle management, your attempts at change will be consigned to the scrap heap.

Improvement Team)

- Employing a full time 'internal consultant' as Kaizenith™ Facilitator
- Placing greater emphasis on good house-keeping
- Recognising that what gets measured gets attention
- Exploiting visualisation i.e. displaying information in a user friendly format
- Setting meaningful targets
- Achieving greater openness and transparencies by senior management

I will now give a little more information on some of these features.

KAIZENITH IMPROVEMENTS		
OBJECTIVE: 	To reduce downtime on Thrust machine	
PROBLEM: 	Downtime	
TEAM: 	Frank Hill Brian Coombs, Nigel Forster, Alan Atkinson, Noel Downey, John Baker, Roddy Campbell, David Cousins, The Head	
ACHIEVED ACTIONS / SOLUTIONS: 	Revised tool and place of tool used for changeovers Standardised work areas / change over standard	
BENEFITS / SAVINGS: 	Minimal time loss in picking out materials. Revised tool holders to suit the changed quantity of raw material. Early warning of material shortages, increasing lead (Material always prior to production) Less hassle for Operators / Material Handlers	
	Initiated April 1988 Congratulations to all!	

A KIT report, relying heavily of visualisation and stressing group involvement

The employee as a problem solver

If encouraged to do so, the employee will not only identify problems at an early stage but will be part of the solution. Work is growing in complexity and the day of a simple job description is long gone. The emphasis is now on Initiative, Flexibility, and Team Working. However, unless you manage to convince the employee that you are serious about this new approach, which often means dealing with poor middle management, your attempts at change will be consigned to the scrap heap as just another management fad!

And so to the most important question of all:

Are you as General Manager/Shareholder willing to make the changes to your management style/philosophy that are necessary to make this new approach work?

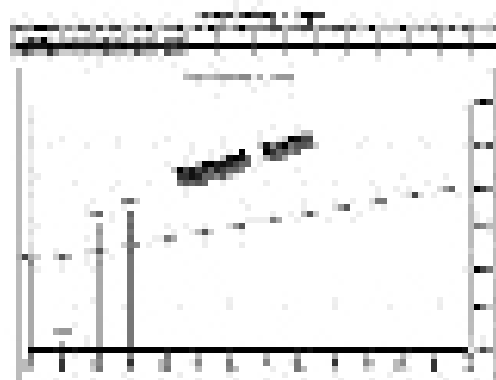
If the answer is 'no', then don't even begin the change process. It will be a dismal failure.

Kaizenith™ improvement teams

All improvements are carried out by a Kaizenith™ Improvement Team (KIT). The need or opportunity for the improvement is first identified by an individual or group of employees. A request to establish the KIT is approved by the Business Unit Manager in consultation with the Kaizenith™ Facilitator. Teams are usually made up of individuals from different departments, in order to bring to the problem as wide a range of disciplines as possible. Once the Team has achieved its goal, the results are displayed on a KIT report (see illustration above). In the future it is hoped to introduce some form of recognition scheme to reward those who actively participate in KIT Teams.

Kaizenith™ Facilitator

Change can often come slowly in an organisation, and it is therefore imperative that someone takes on the role of catalyst. The



The use of visuals to inform the workforce. It is important to keep visuals up-to-date and relevant

problem with using an employee exclusively from within the organisation is often twofold:

- Their experience base is too narrow and introspective
- They are often too easy on fellow managers

For these reasons Laserform decided to hire a full time internal consultant and we have given him the grand title of Kaizenith™ Facilitator. His job is to:

- Identify and where possible carry out training
- Work with Business Unit managers in identifying possible KIT Projects
- Facilitate KITs
- Introduce and monitor new measures of performance
- Project manage the Kaizenith™ Programme

The Kaizenith™ Facilitator has been in place at Laserform for almost a year. Much has been achieved in that time, but much remains to be done. The approach to be adopted must be one of quiet determination, while at the same time keeping the majority on side as often as possible.

Visualisation

Perhaps the most striking aspect about Japanese companies who have adopted the Kaizen or Total Productive Maintenance approach is their use of visuals to inform the workforce. Informing employees is critical and a picture paints a thousand words!

For some reason western companies are reluctant to adopt a highly visual approach. I simply don't know why. Some samples of visuals are shown above. It is important to keep visuals fresh and

COMMENT

Taking account of cultural differences

I have been working with Japanese material suppliers for nearly 20 years and have visited Japan on a number of occasions, and so the Laserform article is of considerable interest.

Many companies remain small because this is the wish of the proprietor and growth does not always yield greater rewards. However, in a world characterised now by continuous change and uncertainty, to grow business or even survive, more sophisticated tools are required to compete and to sustain business relationships particularly with Blue Chip companies.

Kaizen is a Japanese process and it has been highly successful for Japanese companies. Transferring Kaizenith to Europe has been successful in at least one company, but the methodology of the introduction is absolutely critical. The Japanese way of saying and doing things is totally different to ours. Culture differs significantly between countries, never mind continents, and for Kaizenith to be successful it must be applied with a different interpretation in each company, never mind each country.

Laserform has shown us the way and it is particularly valuable to compare their way with other ways currently in use in British Industry. Many of us will now be facing parts per million quality demands, and this is probably one of the best tools to use to achieve this.

Thanks to Laserform for their work.

Christopher Peace The Laser Cutting Company

relevant. They are like fresh vegetables. A board displaying machine output information which is out of date tells you something about the company's attitude to such matters.

Greater management openness and transparency

At Laserform all employees have had an opportunity to review our business plan for the next 3 years. Their feedback has been critical. The goals in the plan cannot be achieved without their support. When an employee knows why we wish to achieve something then it is much more likely that she/he will fully participate in achieving it. In addition, the employees produce an internal newsletter, *Laser Pulse*, each quarter. This helps to promote good communications which also benefits morale.

Conclusion

Kaizenith™ is like the quest for perfection, a never ending journey. It is more a way of life than a destination. Some might even call it a religion or philosophy. Either way, is it worth the effort you might ask?

I believe most definitely 'yes'. I see the last 12 months as being similar to the construction of foundations for a building. If not done properly, everything afterwards is pointless, no matter how much money and effort is expended. And once the job is done, like foundations, the initial work may not be that visible to the naked eye but it is still very much in existence. 'Bottom line' benefits are not expected until well into year 2 of the project. Leaving aside the financial gains, it is rewarding to see the enthusiastic involvement of employees throughout the company and the extent to which Kaizenith™ has become part of their way of life at work. And you know what they say about a happy workforce!!!

Continuous improvement

Laserform have embarked on a long journey. We at NG Bailey Manufacturing wish them every success and thank them for their willingness to share their experiences with us.

And we have good reason to thank them, for Sean led a team from Laserform to visit us in May of this year to benchmark themselves against us. In the process, we learned about Kaizenith. Their visit coincided with efforts within our business to develop Continuous Improvement Teams which are now operating throughout NG Bailey Manufacturing.

We are aware therefore both of the potential benefits of their journey, and the pains with which it begins. But we are more than persuaded that the investment and costs are worth it - indeed I fear for those businesses that think they can manage without it!

Cal Bailey NG Bailey Manufacturing

Steels for enhanced laser cutting performance

Alan Thompson

British Steel
Swinden Technology Centre Rotherham S60 3AR

With the continuing drive for greater efficiency and reduced costs, laser cutting is being introduced and/or extended in use, as technology advances permit. In response to this emerging demand, the role of the steelmakers, such as British Steel, is to develop steels that permit the advantages of this new technique to be maximised. Hence, the family of LASERSURE steels has been extended to greater thicknesses.

The enhanced accuracy, quality and speed of cutting and reduction of distortion on cutting which may be achieved by using laser-grade steels, can have a major beneficial effect on the quality and welding efficiency of subsequent fabrication processes.

Desired Attributes

The benefits obtained from laser cutting have been publicised widely. One example is summed up in the award to Vosper Thornycroft of the Make It With Lasers™ Innovation Award. It has generally been found that the quality and accuracy of a laser cut is far superior to the traditional oxy-fuel and plasma arc cutting methods, leading to improved productivity and efficiency.

In order to maximise these benefits, a new generation of plate steels specifically designed for laser cutting has been developed and is now available either as decoiled or reversing mill plate. Many of the benefits of these steels can also be obtained with plasma or oxy-fuel cutting:

- Ease and speed of cutting
- Good quality edge at increased cutting speed
- Uniformity of mechanical properties for predictability of response to forming operations
- Minimal distortion resulting from cutting operations
- Improved surface quality

Cutting Characteristics

It is well known that silicon levels less than 0.05% enable significantly faster plasma and laser cutting speeds to be achieved without loss of cut edge quality. Improvements in the range 5-20% have been quoted, according to plate thickness. British Steel's own experience as far back as 1992 is a cutting speed improvement of 10-20% on plasma cutting 15 mm AH36 type steel, with a low silicon content of 0.02/0.03%, compared with cutting conventional plate containing 0.30/0.35% silicon.

Silicon content also affects laser cutting properties of steel, through its effect on scale i.e. a low silicon content promotes the formation of a thin scale of a suitable composition.

Plate from cut coil is generally made with aluminium deoxidised steel with a typical maximum silicon level of 0.05%. Reversing mill plate, which is more commonly supplied in wider and thicker sizes, is traditionally made with silicon or silicon-aluminium

	C	Si	Mn	P	S	Al
Classification Society	0.21 max	0.50 max	2.5 x C min	0.040	0.04	-
Normal Conventional	0.07/0.19	0.15/0.35	0.55/1.1	0.022 max	0.020 max	-
Plasma/Laser Quality	0.14	0.022	1.27	0.015	0.005	0.03

Composition of laser/plasma cutting quality Grade A Steel

Typical compositions for conventional and laser/plasma cutting quality reversing mill Grade A plate, 15 mm thick together with Classification Society permitted limits.

deoxidised steel with a typical silicon content in the range 0.20 to 0.40%, according to grade. At this level, the silicon is also acting as a solid solution strengthening agent and as such is part of the steel composition design for achieving the specified strength level.

It follows that from a cutting point of view, there is a benefit in redesigning the chemistry of reversing mill plate in particular and plate from cut coil to a lesser extent, to minimise the silicon content. The loss of solid solution strengthening is compensated for by increasing the level of other elements such as manganese whilst deoxidation of reversing mill plate (and grain refinement where necessary) is achieved by using aluminium, as is already the case with plate from cut coil.

Low sulphur content is also known to be beneficial for cutting owing to its effect on the cleanliness and quality of the cut edge.

Uniformity of Mechanical Properties

Classification Society Rules for shipbuilding allow the chemistry and mechanical properties of plates to vary considerably within the requirements for a given grade. In other industries, such as earth moving equipment and general fabrication, there may be even greater variation or no limits at all. This can lead to plates of the same nominal quality and from the same batch behaving significantly differently during cutting and fabrication operations. For example, differential spring-back during bending owing to wide variations in yield strength.

This variation can be minimised by additional effort to control the chemistry within a narrow range. In the case of plates normally supplied in the as-rolled condition, a greater uniformity in mechanical properties can be achieved by applying more stringent temperature controls during reheating and rolling. This practice also helps to promote the formation of the thin scale layer necessary for optimum laser cutting.

Distortion on Cutting

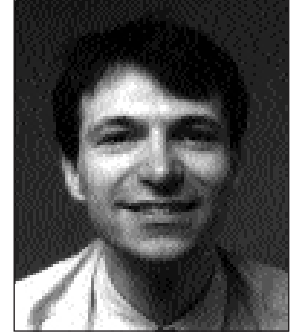
One of the major issues that causes fabricators extra work is distortion of plate during cutting and welding operations. This effect arises from the residual stresses in the plate which are unevenly distributed and are redistributed as a result of the heat input from the cutting or welding operation. These residual stress problems tend to be more severe as plate thickness decreases and plate width increases.

However, with modern cold levelling machines with individual roll adjustment and sophisticated computer control of set-up, it is possible to minimise and redistribute the stresses that occur during plate rolling and cooling. It has been proved that plates cold levelled by such machines will stay flat on subsequent cutting, even during stripping operations.

Condition of Steel for Cutting

It is well recognised that rusty or heavily painted steel will not cut well. It is therefore recommended that good supply/storage procedures are established or that steel is blasted immediately prior to cutting, with steel rather than sand. Some steel suppliers will deliver lightly painted product which should incur no noticeable cutting performance deterioration.

Alan Thompson EWE is Principal Laser Welding Engineer with British Steel, working on the new 25kW cutting and welding facility. Previously, he completed a Ph.D. on weld integrity at Cranfield.



COMMENT

Since 1992 Raex Laser steel has been developed and continuously improved to reduce costs through time savings and reduced scrap and energy. Cutting speed increases of up to 20% have been measured compared to cutting of normal grades of steel. This increase in speed is achieved without any loss in the quality of the cut edge, which is clean and burr free, due to the steel's low silicon (maximum 0.04%) and sulphur (maximum 0.015%) content. Cut sections separate easily and wastage is reduced, making laser-grade steel perfect for trouble free automated manufacturing. Since the chemical and mechanical properties of the steel are also highly uniform and consistent, this minimises the need to

regulate cutting machine parameters between batches. Laser grade steel has also enabled laser cutting machines to process heavier gauges than previously.

Precision Steel offers a wide range of materials in Raex 275 Laser in gauges from 3 mm up to 15 mm. 20 mm is delivered in the Raex 250 Laser grade. A new development is the introduction of Raex MC Laser, equivalent to high strength cold forming steels which meets the highest demands for both laser cutting and cold forming.

Erwin van der Heijden Precision Steel

QUESTION & ANSWER

Responsibility for providing a safe laser machine

Mike Barrett GSI Lumonics

As the manufacturer of laser processing machines, am I responsible for the safety risks which the change of the millennium (Y2K-problem) or other similar date-related problems may cause?

requirements or other production records are correctly produced by date-related controls within the machine. In this case, manufacturers may be required, by their Customers, to supply solutions or work-arounds to provide continuity of performance.

The brief answer is YES. The Machinery Directive clearly requires the manufacturer to carry out a risk assessment for all machines. In accordance to Clause 1.1.2 of Annex 1 of the Directive, the aim of the risk assessment is to eliminate any risk of accident throughout the foreseeable lifetime of the machine. This applies to situations where risks of accident may arise from abnormal but foreseeable situations. Clause 1.2.1 states that control systems must be designed and constructed so that they are safe and reliable, in a way that will prevent a dangerous situation arising. Similarly according to Clause 1.2.7, a fault in the control logic circuit or a failure or damage to the control circuit must not lead to dangerous situations. The change of the millennium or any date-related condition is undoubtedly a foreseeable situation and if the risk assessment shows that faulty operation can result in a dangerous condition, action must be taken.

We are an international company and have recently received a laser welding machine from our base in the USA. Do we need to CE mark the equipment before putting it into service, and if so, how do we go about meeting the EMC requirements?

Companies with premises outside Europe and importing machinery into their UK plant have to CE mark the equipment before putting it into service. The EMC directive can be a costly exercise. To get the machine tested is one thing, if it fails then the company is indeed in an expensive process. One solution is to look at what lies behind the directive. Is the machine affecting neighbouring equipment, is neighbouring equipment affecting it? If the answer to both is NO, then this is probably OK. Bear in mind, however, that this approach is context-specific, moving the equipment requires a fresh assessment. Also, the influence (either way) may be subtle and if an accident occurs the consequences can be serious.

The need for fume extraction in laser cutting and marking

Phil Mullins

Hi-Tech UK

Purex House Farfield Park Manvers Way Rotherham S63 5DB

Although perhaps not the first piece of equipment that springs to mind, fume extraction has a vital supporting role to play in laser materials processing applications. Health and safety issues aspects of fume extraction have been covered in recent articles ('The fume hazard in laser materials processing of organic materials' Issue 14 p 30, 'Dealing with plastic fume when laser cutting' Issue 15 p 12), but an effective fume extraction system also provides protection for focussing optics and eliminates a source of beam distortion.

Beam distortion caused by process fume can, we believe, be significant for high resolution laser marking and other processes involving features on a micron scale. The consequences of poor quality marking caused by distortion of the beam cannot be tolerated, and to eliminate this effect it is important to pull the fume from around the side of the laser beam, not through it.

To take an example where the sheer speed of laser marking is exploited, Hi-Tech UK installed fume extraction at a bottling plant in France that marks 64,000 PVC bottle tops an hour. If the extraction system failed to do its job effectively, thousands of pounds would be quickly wasted in badly marked product.

An efficient fume extraction system also prevents contamination of the final beamline optic. In the case of a lens, contamination can lead to breaking or cracking on contact. The large lens of a pre-objective scanning system alone costs several thousand pounds, not to mention the cost of down time.

Integrating the extraction system

The extraction system can be integrated with the laser and optics into a complete turnkey unit.

Fume is best captured as close to its source of production as possible, which in the case of laser marking where the fume comes up from the workpiece, can be achieved with a collar to draw the fumes away from the laser head. For example, on a CO₂ laser marking unit installed to mark 'best before' dates on the cardboard cartons of a breakfast cereal manufacturer, the fume extraction collar was positioned on the laser head approximately 20mm from the carton being marked. The laser selectively burns off the top (inked) surface to reveal the white cardboard beneath at an average speed of 100 cartons per minute.

Safety issues

COSHH legislation states that fume control systems must be appropriate to the hazard and the application, and must function correctly. Simply installing equipment is not necessarily enough. It is therefore important to ensure that the system chosen is up to the job and that it is properly installed.

Integrated fume extraction arranged around a marking head

As shown in the article by Haferkamp et al. (Issue 14, table on page 31) the main health hazard when processing most plastics, as with metals, is respirable dust. Of the respirable dust particles, most will be smaller than 1 µm diameter, so a HEPA filter is required. The filter's life can be extended by using it with one or more stages of pre-filtration, which exploit coarser filters to trap the larger dust particles.

The volume of dust and fume particles to be dealt with can vary large, particularly in the case of laser cutting. For example, a laser cut 1mm wide, 2mm deep and 1m long liberates 2000 mm³ of metal as fume particles into the workplace.

Fumes and dust can be a cause of fire and explosion if not extracted effectively. The particles are often hot, and finely divided they present a large surface area and can spontaneously combust in an oxygen-rich atmosphere, for example in oxygen cutting.

With efficient filtration, it may be possible in laser marking applications to recirculate purified air back into the workplace, instead of exhausting fumes outside. This provides environmental benefits as well as the cost savings of not having to heat or cool replacement air, and an assembly line can be easily moved without relocating external exhaust ductwork.

Conclusion

Laser cutting and marking is often used in a high volume production environment. When specifying or upgrading a laser system, it is important that fume extraction is taken seriously. By installing effective extraction, laser processing performance will be optimised, and employees' health and safety protected.

Thanks to Dr John Tyrer of Loughborough University and to Terry Nicklin of Domino UK Limited for help with this article.

COMMENTS over ...



courtesy Hi-Tech UK

COMMENTS on fume extraction

During my work at Exitech I have never observed the beam defocusing effect reported in Phil Mullins' article. We do a lot of high resolution imaging with excimer lasers and indeed if you don't extract the ablation products (smoke) you can get very bad results, but this effect occurs primarily because the smoke absorbs the pulsed radiation, creating excess hot plasma that can thermally damage the substrate, and producing a reduced and fluctuating machining depth per pulse.

When using short laser pulses (<100 ns, say) the pulse is over before the plume of vapourised material has developed, so focus and image quality is not affected. At the other extreme, it is well known that radiation from a CW or long-pulse CO₂ laser is strongly absorbed by water and organic vapours.

Jim Fieret Exitech

It is good to see that Hi-Tech are continuing to draw attention to the often neglected area of effective fume extraction when laser marking and cutting materials such as PVC. Laser Lines supply ultra low cost CO₂ laser marking systems as an alternative to inkjet and have recently incorporated a Hi-Tech system for a PVC Smart Card marking application. The economics of switching from inkjet to laser is extremely attractive in terms of higher reliability and fewer consumables; however, you must remember to cost in extraction for many applications.

Steve Knight Laser Lines

QUESTION & ANSWER

Frequently asked questions on laser gases

Jack Gabzdyl BOC Gases

Why do some lasers use premix while others use pure gases?

There are pros and cons on both sides. Using pure gases you need to stock three separate gases: helium, nitrogen and carbon dioxide and have spare cylinders available. This requires three gas lines and regulators. The gases are mixed internally in the laser, and the mixing panel adds significantly to the total cost of the laser. However, it does give the laser manufacturer the ability to tweak the lasing gas mixture to optimise performance or even to change the mix for different operating conditions e.g. to improve pulsing characteristics.

With premixed gas you only need one cylinder and regulator and there is no mixing panel on the laser, so there is no flexibility or means of changing the mixture. The filling tolerance that is commercially achievable for premixes is such that there is a detectable variation in laser performance over the premix tolerance band. In recent years the quality and availability of premixed gases has improved dramatically and so has our understanding of the importance of the mix quality and composition tolerance.

In general, Japanese manufacturers of high power CO₂ lasers use premixed gases while US and European manufacturers stick to pure gases. The reason for this may to some extent be historical as, in the early days of lasers, pure gases were more readily available while premixed gases at that time were expensive, on long lead times and sometimes of dubious quality.

Can my laser be converted to use premixed gases?

Only the manufacturer can address this question. Theoretically, there are no major obstacles to converting.

Why do CO₂ laser manufacturers specify different gas mix ratios?

In the laser gas mix, the nitrogen provides an energy transfer mechanism, the carbon dioxide gives out the laser light and the helium acts as a coolant. Optimising the laser performance requires matching the this complex energy in the gas mix to the detailed performance of the gas discharge and the laser resonator design. This optimisation sets the lasing gas mix and pressure.

The details of are therefore laser-specific. Models of the same general design will use the same mixture. It is also likely that the gas mix will remain the same throughout a series of models where the basic laser design remains the same, but is scaled in size to achieve higher laser outputs.

Why do CO₂ lasers have different lasing gas purity requirements?

To some extent the issue of gas purity is historic and geographic. In their infancy, lasers used commercially available grades with the purity specifications provided by the gas supplier i.e. He 99.995%, N₂ 99.99%, CO₂ 99.5%. Over the years, the deleterious effect of low levels of certain impurities on the laser performance became better appreciated, with moisture and hydrocarbons the worst contaminants, significantly affecting laser output power and the lifetime of internal optics. This led to laser manufacturers qualifying their purity specifications with maximum levels of specific impurities i.e. He 99.995% <5ppm H₂O, <1ppm THC (total hydrocarbons).

Adhering to the manufacturers' specifications generally gives problem-free operation. However, different manufacturers have different specifications so it is important to check the manual. Some manufacturers exploit this difference as a sales benefit, as some laser designs are more/less sensitive to gas purity. However, as manufacturers strive to reduce lasing gas consumption the issue of purity becomes more significant.

Why do some manufacturers specify hose material and regulator design?

The gas delivery system can be a greater source of impurities in the lasing gas stream than the gas in the cylinders. Most polymeric materials are permeable to atmospheric contaminants, and this can be quite significant, e.g. greater than 10ppm per 10m hose length. Regulators also have an intrinsic leak rate, but the leak rate specified for speciality gas regulators with stainless steel diaphragms is over a thousand times better than for welding grade regulators. The importance of contamination from the gas delivery system increases as manufacturers strive to reduce lasing gas consumption.

Minimising the Cost of Ownership: Can you have too much beam quality?

Keith Withnall

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High average power Nd:YAG lasers with power levels >500 W have been commercially available now for over 10 years. During this time a great deal of work has been done to improve understanding of the basic laser resonator technology, with the result that all the major suppliers have a good understanding of how to produce high power, high quality laser beams reliably. The majority of the YAG lasers produced in this power range have a continuous wave (CW) output as this is best suited to the most common welding and cutting applications, which tend to involve material 0.8 – 6 mm thick. These lasers, with the benefit of fibre optic beam delivery, have become well established as the first choice for a wide range of demanding production applications in the automotive and general fabrication industries.

As a general point, new laser technology tends to be adopted first in applications where there are performance problems with existing techniques and where the laser offers very clear advantages. Cost is not the main consideration. An example of this in the car industry is the welding of the roof retainer strip on the GM Aurora in the USA. Laser welding was introduced when problems were found with gluing, at a late stage in prototype assembly.

The next layer of applications are those where the laser enables new design features to be realised in the end users product, retaining a competitive advantage. Cost is more important here. For example the narrower pillar assemblies on Audi models are only made possible by laser welding and provide product differentiation for the manufacturer.

The third layer of applications are those where the primary driver for adopting laser technology is the reduction of cost of goods sold – so equipment purchase and operating costs are critical. Systems integrators and end users in this category need a good understanding of all of the factors affecting Cost Of Ownership (COO) to make an informed choice of laser source. Examples include tailored blank welding, hydroformed tube cutting and most on-line body welding applications.

High power CW applications are now well into the third level mentioned above, and this impacts the design and specification of the laser sources. Second generation products are emerging with the emphasis on ease of use and simplified diagnostics and maintenance procedures. The main factors affecting COO for YAG lasers have been reported previously (e.g. *The Industrial Laser User*; Issue 4, p19). As applications become more cost sensitive it becomes important to look at how some of these factors may be influenced by apparently unrelated characteristics of the laser.

Optimising beam quality

Laser sources of increasing beam quality and power are being made available. However, choosing the best laser for an application may not be a case of simply selecting the highest beam quality at the required power level. For example, let us look at the requirements for the growing application of cutting hydroformed tubing for automotive structures. A typical requirement might involve profiling the ends and cutting numerous apertures in shaped steel tubing of various thickness. Edge quality requirements are generally quite modest and tolerance and accuracy are within the range achievable by robots.

In figure 1, a typical plot of relative cutting speed against beam quality at fixed laser power, a beam quality of '1' equates to ~120 mm.mrad (diameter × full angle) at the work-piece. (see 'Comments' by Brooke Ward on units). Exact values vary with material type, beam delivery parameters etc., but will follow a similar profile. This graph applies to YAG lasers, the situation with CO₂ lasers has not been studied by the author and is likely to be different.

It is clear that as beam quality improves, leading to reduced spot size and improved depth of field, the maximum cutting speed increases.

The ultimate improvement is greater for thin materials (e.g. ~1 mm) than it is for thicker ones, since the minimum viable kerf width is greater for the thicker materials. It follows that you should select the laser with the best beam quality at a given power level for the most cost effective results.

However, there are at least two other factors that should be taken into account to optimise the COO. Figure 2 shows the general

Cost per metre of process is the best way to make a price comparison. It is surprising how many purchasers fail to do this, even on multi-million pound contracts.

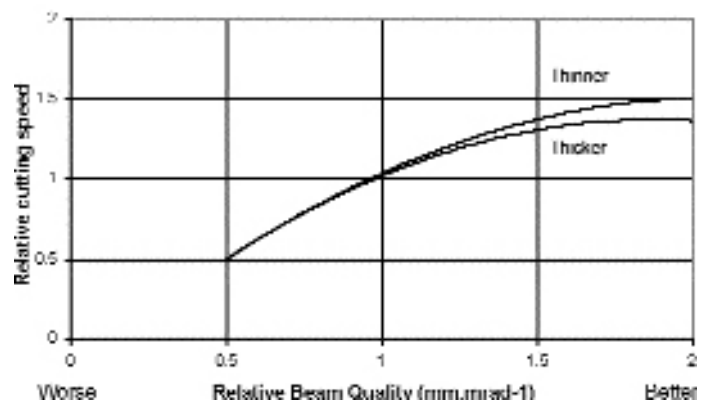


Figure 1 A typical plot of relative cutting speed against beam quality for a YAG laser at fixed laser power.

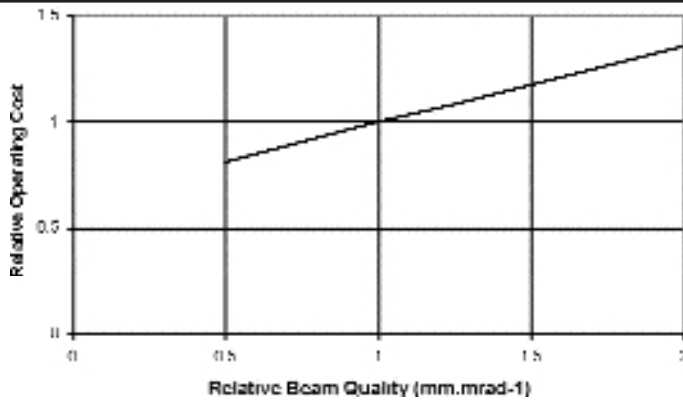


Figure 2. Trend for basic operating cost against beam quality.

trend for basic operating costs (electricity, cooling and lamps) against beam quality. Capital costs follows a similar trend; as beam quality improves the laser resonator efficiency reduces, so more laser rods and power modules are required to achieve the same output. Lower efficiency also means higher electrical and cooling costs, while the higher component count implies lower reliability, which again leads to increased operating costs.

The gain in cutting speed with improved beam quality is achieved mainly as a result of reduced spot size. However, as the kerf width reduces, a higher gas assist pressure is required at the surface of the cut to overcome the surface tension of the molten material, particularly on thicker materials. The cutting nozzle tip hole size can, of course, be reduced but not so much as to prevent higher gas consumption. Indeed, it is sometimes necessary to increase the nozzle size with higher feed rate to maintain the time the gas pressure is applied to the cut. As Figure 3 shows, the combined effect is to greatly increase, by up to 3 or more times, the rate of gas consumption as the cut kerf width is reduced. The impact of this is significant and can increase total running costs by more than 20% for cutting steel, compared to cutting with larger kerfs.

Figure 4 combines the trends in Figures 1 to 3, to produce a relationship between COO and beam quality. It is apparent that there is an optimum value for beam quality for a given cutting application. For example, the beam quality will optimise at a 'poorer' beam quality for thicker materials than for thin sheet applications.

Clearly, the optimisation process must take account of the effect on edge quality and accuracy. In our experience the optimum beam quality for typical hydroformed tube 3-5 mm thick is 100 - 130 mm.mrad at the workpiece (diameter \times full angle). The spot size is typically 0.6 mm and the gas pressure is below 1bar.

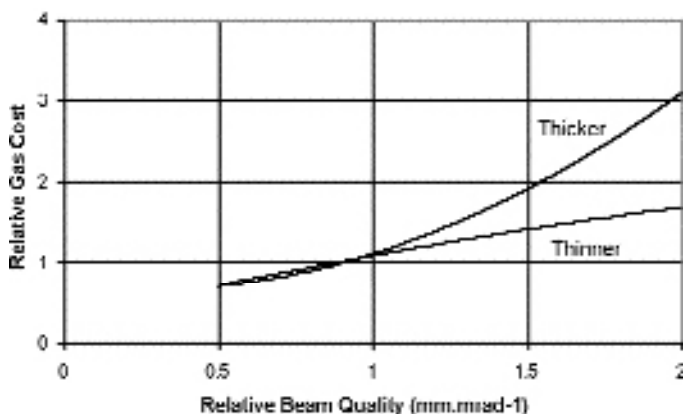


Figure 3. The increase in gas consumption with improved laser beam quality, a result of the higher pressure required at smaller kerf widths.

Similar trends are apparent for welding applications. Although the impact of assist gas no longer applies, the relative welding speed graph tends to plateau for the thicker materials as there is typically a requirement for a minimum weld width. This leads to a graph for COO against beam quality for welding which looks very similar to Figure 4, but slightly broader and flatter.

Laser source selection should be based on an estimate of the optimum beam quality for the application. This should be specified on the basis of beam quality measured at the workpiece – this makes factors such as the diameter of the fibre optic cable irrelevant. The source power level and beam delivery configuration are then selected to make best use of the investment in the system workhandling – aiming to achieve near 100% utilisation of both the laser source and the workhandling. It is easy to be mis-directed by curves of processing speed vs. beam quality and talk of higher 'process efficiency'. For a production application, as long as the process specification is fulfilled, the relevant measure is cost/unit length. Making the wrong choice can easily cost the user £50,000 or more in additional operating costs over the project life. At GSI Lumonics we use computerised cost estimating utilities in conjunction with processing trials to select the optimum laser from the range of beam qualities and power levels available in our new AM Series CW YAG lasers.

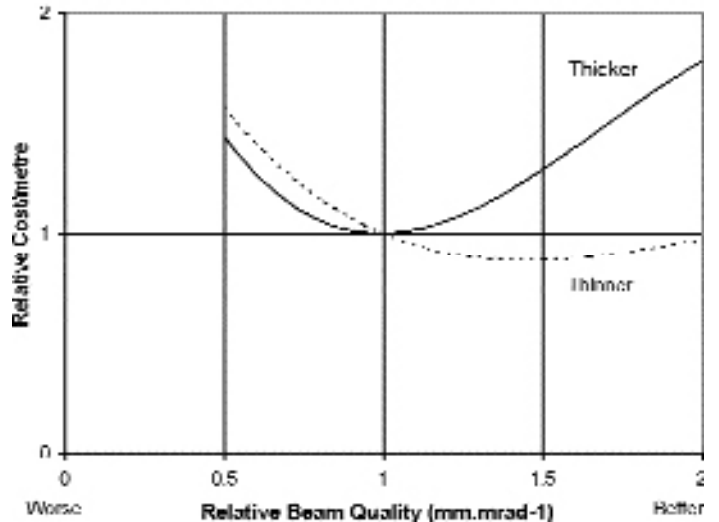


Figure 4 Overall relationship between Cost Of Ownership and beam quality. The optimum beam quality increases with decreasing with material thickness.

Cooling Configuration

YAG lasers are relatively inefficient - with conversion efficiencies typically in the 2-4% range for electrical power input to laser output. For a 4kW YAG laser the waste heat load can amount to ~145 kW with a maximum external coolant temperature of ~15°C. The large chiller required for this will consume around 50 kW of electricity and occupy ~ 5 m² of floor space.

Most production facilities have a centralised water cooling facility, typically based on low cost cooling towers, but the circulating water temperature of these towers ranges up to 30°C or more in the summer, making them unsuitable for most lasers. However, as shown in Figure 6, it is possible to split the cooling system so that the majority of the heat loss can take place at higher temperature, making direct use of existing factory cooling water at up to 40°C. To take the example given above, 115 kW can be disposed of

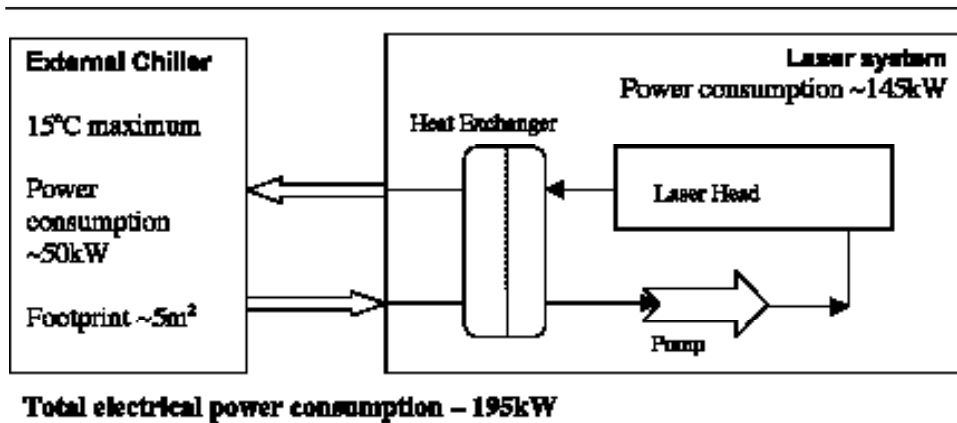


Figure 5. A typical cooling arrangement comprises a closed de-ionised water circuit and external heat exchanger.

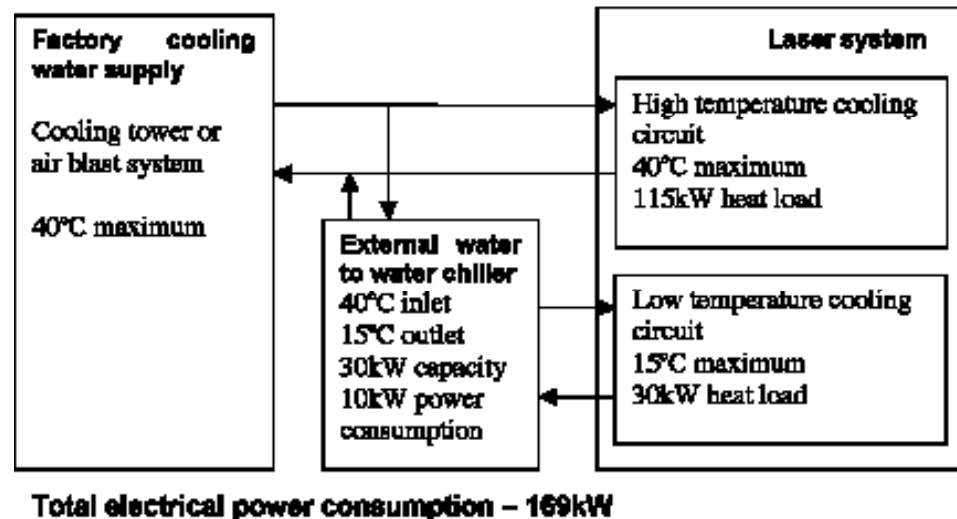


Figure 6. A split cooling system on the GSI Lumonics AM Series CW lasers. With this arrangement the majority of the heat loss can take place at higher temperature, making direct use of existing factory cooling water at up to 40°C. As a secondary benefit of this strategy, the risk of condensation on cooled surfaces is greatly reduced.

this way, leaving only 30 kW requiring the lower 15°C water. A small water-to-water chiller connected to the same factory water circuit can provide this. This reduces the chiller electrical consumption to ~10 kW and the chiller floor space to 1.2 m². This approach yields electricity savings over a 5 year period of up to £50,000 per laser for a three-shift operation, even after allowing for a 14 kW contribution to the operating cost of the cooling tower.

Future developments

The new features on the latest generation of high power CW lasers, such as the GSI Lumonics AM Series, are primarily aimed at reducing Cost Of Ownership. Examples include enhanced peak power modulation for improved processing performance; graphical diagnostics and plug-in modules for reduced downtime; split cooling systems and high efficiency pumping chambers for reduced power consumption. For many production applications the process speed is now limited by work-handling considerations and the laser is no longer limiting process performance. Future laser development for these applications is likely to target yet further improvements in COO, in the form of reduced capital and operating costs.

Diode pumped lasers will become viable for some of these applications but again the COO arguments need to be examined in detail to make a properly informed decision. Achievement of the required process speed using reduced laser power may be at the expense of weld/cut width, with adverse implications to the COO. At the present time there is insufficient data on long-term operating costs in real production applications to assess the true COO of high power diode pumped CW lasers.

New applications/markets may be opened up by further increases in laser average power. Trials are currently taking place at TWI, Cambridge using a GSI Lumonics combined laser system with an output power of up to 9 kW at the workpiece. The results of these trials will indicate if there will be a commercial market for YAG laser systems up to 10 kW average power, and will be used to identify the optimum specification for lowest COO in key applications. Early indications are that welding up to 15 mm thickness is realistically possible, but that significant plume and plasma control problems need to be addressed.

Summary

In this short article we have shown that cost savings may be achieved by paying careful attention to all of the factors affecting cost of ownership when selecting a laser source. Converting information into a cost per metre of process clarifies the true effect of different laser specifications for a particular application. This may seem obvious, but it is surprising how many purchasers fail to do this, even on multi-million pound contracts. Even laser features that appear to have little relevance to the processing performance, such as a split cooling system, can have significant impact on process cost per metre.

As the marketplace for high power YAG systems matures, and an increasing percentage of systems are used primarily, or entirely, for cost saving purposes, then an accurate understanding of COO will be vital. These issues will be a primary driver in the development of new laser features and technologies.

This article is extracted from a paper entitled "A Structured Approach to the Specification of Second Generation High Powered Nd:YAG Lasers" presented by the author at the High Energy Beams Conference, Tokyo in April 1999.

COMMENTS

‘Minimising the cost of ownership’

Diode pumping reduces costs

There is no doubt that buyers should look at running costs very carefully when purchasing things and lasers are no exception. Rofin have made a great effort to reduce the running costs of all their laser products, which is why we have developed the slab CO₂ laser and why we are developing diode lasers and diode pumped YAG lasers. We have been using the cost/metre method of calculating operating costs for a few years now as it does provide a fairly accurate comparison.

The slab CO₂ and diode pumped YAGs offer considerable operating cost savings over the fast flow CO₂ lasers and the lamp pumped YAGs respectively. For example: We have done calculations which show that using a 500 W diode pumped YAG laser instead of an 700 W lamp pumped laser saves about £50,000 over a 20,000 hour operating period. The savings occur in electrical consumption as the diode pumped laser is more efficient and so requires less energy and a smaller chiller. The processing capabilities of the 500 W diode pumped laser are equivalent to the 700 watt lamp pumped laser, which is why we compare the two. This saving increases to nearly £150,000 when you compare the 3 kW diode pumped YAG with a 4 kW lamp pumped YAG, which are, again, equivalent in performance. In my mind, the diode pumped YAGs are going to make a big impression on the market with their high reliability and low running costs.

There are many ways to present the cost data on lasers, and you have to be careful that you a) include all the relevant data and b) compare like with like. Properly calculated, the cost per metre approach is an excellent method.

Tim Holt Rofin-Sinar Laser

Hooray for Holistics!

At last, some support for the systems engineering approach to industrial laser applications. All aspects of the whole system must be designed to optimise the process AND to keep it optimised - although I suspect that Keith might have neglected this last aspect. If some process needs a small spot size and low order mode then not only must system stability and alignment be enhanced but there will be a need to monitor and manipulate the beam to maintain product quality within the process tolerance limits - and that costs even more money.

However, having congratulated Keith on his article, let me get down to some nit-picking. What’s all this about ‘Relative Beam Quality (mm.mrad)’. Why can’t we all start to speak the same language? Rofin appear to talk about beam quality as the half-width-half-divergence product. GSI Lumonics use the full-width-full-divergence product. The just-published ISO Standard (ISO 11146:1999) implies that both K and \mathcal{M}^2 can be used to indicate beam ‘quality’. Well, it’s all about to change!

I’ve just returned from the flesh-pots of Nice where ISO laser Standards folk met and finally came to their senses - and we are revising and extending ISO 11146. The Germans agreed to eliminate the beam propagation factor K from the Standard and to

rename it \mathcal{M}^2 . It is not longer the times-diffraction-limit-factor but the beam propagation ratio! We deliberately avoided using the word quality because, like Keith, we all know that a low-order-mode or small \mathcal{M}^2 beam does not necessarily produce the best quality product. (By the way, the extension of the Standard is to cover measurements of real beams with sharp edges and non-Gaussian profiles and beams suffering from General Astigmatism - but that’s another story.)

Some other nits that I feel I must pick at are the narrow smooth curves that Keith has drawn in his graphs. I do feel that we should have been given some idea of the uncertainty in those measurements. there must be considerable uncertainty in measuring both beam quality, cutting speed, operating and gas costs. My own experience in these matters with CO₂ lasers suggested that the relative cost curves should be drawn as quite broad swathes. I know that in addition to beam quality there are many other factors that can have a strong influence on cutting speed. These range from nozzle design/damage, stand-off and gas pressure of impurity condition to lens contamination/strain and alignment problems. The chance of holding all these factors reasonably constant while changing only the beam quality is rather remote.

There are two other factors that should be included in any holistic analysis - staff quality and monitoring instrumentation. A well trained and experienced operator or maintenance engineer can have an important effect on the productivity of an installation. On-line instruments that can monitor the quality of process input factors during production can give advance warning of deviation and allow pre-emptive maintenance. Both these factors can have dramatic influence on the profitability of a laser process - and, perhaps, swamp any smaller beam quality influences.

Brooke Ward Europtics

Author’s response to Tim Holt

It is good to see that we can achieve agreement between laser suppliers on the importance of using cost/metre as a consistent method of measurement. However, Tim's comments on the processing equivalence of lower powered diode pumped lasers leads me to believe that I haven't done a good enough job of conveying one of my points. Equivalent cutting performance using a lower powered laser comes at the expense of using higher gas pressures/flows and the cost of this needs to be taken into account. Likewise equivalent welding speed at lower laser powers comes from using narrower weld widths, and many customers’ processes will not tolerate the reduction in strength that this brings. Additionally, in order to make a fair comparison, the cost of diode replacement after 20,000 hrs has to be set against the electricity savings (and also the savings in flashlamp replacement).

I wouldn't want to give the impression that I am arguing against the benefits of diode pumped lasers, indeed GSI Lumonics have shipped almost 200 of them, it's simply that I am in favour of giving customers complete and accurate information to assess the available products.

Keith Withnall GSI Lumonics

Laser cutting with Dual Focus™ lenses

We asked V&S Scientific, the only supplier of Dual Focus™ lenses, to supply some test reports to substantiate the exciting claims for these optical components

Machine, beam Ø, conv. lens	Results with conventional lens	Results with Dual Focus™ lens
<p>Report 1 2500 W Bystronic, flat bed, moving optics</p> <p>18 mm 1/e² diameter, fairly constant</p> <p>1.5" dia, 7.5" FL, 6 mm ET</p>	<p>Laser power of 2.2 kW is delivered to the workpiece. The process is required to cut 100 parts from 8 mm stainless steel sheet, and is (conventionally) divided into 4 operations:</p> <ol style="list-style-type: none"> 1 The laser system is set to drill 100 'cut-initiation' holes at the start-points of each piece. Upper-surface erupted dross is formed by this operation. 2 Two men are employed to remove upper-surface dross (preventing collision with the nozzle). This takes about 45 minutes 3 The laser system cuts the parts at a maximum speed of 0.45 m/min. Lower-surface dross occurs. Gas pressure used in 12 bar at the nozzle* 4 Two men are employed to remove the lower surface dross from the cut parts 	<p>Using a Dual-Focus lens of basic FL 7.5", the cut initiation is immediate, with no upper surface eruption of material. Operations (1) and (2) are eliminated. Process speed was increased to 0.7 m/min (55% speed increase). In this trial, the upper Dual-Focus was set 2 mm into the material surface, and cutting was completely dross-free on all 100 parts. Operation (4) is eliminated. Gas pressure was 12 bar at the nozzle.</p> <p>Using same Dual-Focus lens, the cutting of 12 mm stainless steel was attempted. This material was successfully cut at 0.2 m/min. A limited amount of lower-surface dross was present. Cut initiation was immediate, with no upper surface dross from erupted material</p> <p><i>* Limited by virtue of the gas supply being in the form of liquid nitrogen</i></p>
<p>Report 2 'Old' 1200 W Bystronic, flat bed, moving optics, Flat bed size 4.0 m × 2.0 m (no beam expander)</p> <p>Varies over bed, 17 mm - 22 mm 1/e²</p> <p>1.5" dia, 7.5" FL, 6 mm ET</p>	<p>This customer can cut 2 mm stainless with good dross-free quality over the whole bed. When cutting 3 mm stainless, only half of the flat-bed area could be used and lower surface dross is formed. The process speed for 3 mm stainless is 800 mm/min, using a conventional lens. The gas pressure used is 12 bar at the nozzle*</p> <p>When processing 1 mm, 2 mm and 3 mm material, the focus must be changed for each thickness. Using conventional lenses, this system cannot cut 4 mm stainless.</p>	<p>Using Dual-Focus lens of basic FL 7.5", the process is insensitive to focus shifts caused by changing beam wavefront curvature over the bed. Accordingly, 3mm thickness could be cut at 1.2 m/min, completely dross-free, over the whole bed. This is a process speed increase of 50%. The gas pressure used was 12 Bar at the nozzle. the cutting of 4 mm thickness is possible. further results are pending.</p> <p>The customer found that 1 mm, 2 mm and 3 mm stainless steel could be cut without change of focus.</p>
<p>Report 3 Bystar 3015 (3.5 kW)</p> <p>19 mm 1/e² (see note)</p> <p>7.5" FL, 9 mm ET</p>	<p>The customer can cut 10 mm stainless steel dross-free at 400 mm/min @ 18 bar N₂ pressure and a nozzle aperture of 3mm. On 12 mm he conventionally cuts with some sub-surface dross problems at 350/min, again @ 18 bar N₂ pressure and with a 3 mm nozzle.</p> <p>The customer has tried to cut 15 mm but the cut quality was very poor with significant dross on the under-surface. This was achieved at a speed of 200 mm per minute with 18 bar N₂ pressure (3 mm nozzle aperture).</p> <p>In each case the nozzle stand-off during cut initiation (peck-through) is 2.5 mm with gas pressure set at 1.2 bar. During cutting the nozzle stand-off is 0.4 mm. The conventional lens focal point is usually set some 3 mm below the surface of the material to be cut.</p>	<p>The diameter of the beam proved to be less than the stated Ø19 mm 1/e² on which the Dual Focus lens was designed, and so the lens was not ideal for this system. Only approximately 25% of the laser power was incident on the material top surface and so peck-through was a problem on 12 mm and 15 mm materials.</p> <p>Despite this, the following results were achieved:</p> <p>a <u>10 mm thick stainless steel</u> Best ever peck-through hole, 100% speed improvement to 0.8 m/min, Dross-free sub-surface cut</p> <p>b <u>12 mm thick stainless steel</u> 50% speed improvement to 0.525 m/min, 50% assist-gas saving (2 mm Ø nozzle), Dross-free sub-surface cut</p> <p>c <u>15 mm thick stainless steel</u> Passable cut with virtually no sub-surface dross (dross removable by fingertip), 75% cutting process speed improvement to 0.35 m/min, 50% assist-gas saving (2 mm Ø nozzle)</p> <p>Further performance improvements possible with finer focusing adjustment and gas pressure optimisation.</p>
<p>Report 4 LVD 2 kW Fanuc</p> <p>Beam Ø 1/e² ≈ 17 mm</p>	<p>a) Conventional lens 7.5" F/L and 3 mm Ø nozzle with 16 bar pressure. 6mm stainless steel usually cut at 0.512 m/minute with good edge finish and no dross on star shaped 316.</p> <p>b) Conventional lens 5.0" F/L and 3 mm Ø nozzle with 13 bar. 2 mm stainless usually cut at 3 m/min with a good edge finish and only a very slightly serrated undersurface - (no dross on star shaped 316.)</p>	<p>a) Dual-Focus lens 15DFA 127-050-075. 2 mm nozzle aperture - 13 bar. 6 mm stainless steel was cut at 1000 mm/minute with an 'almost polished' looking edge and a dross-free finish on star shaped 316.</p> <p>b) Using same Dual-Focus lens the 2 mm thick 316 was also cut with a polished looking edge and dross free finish. The process speed was 4.6 m/minute. Gas pressure through the 2 mm aperture was 11-12 bar</p>

<p>Report 5 Amada system with 3000 W Fanuc laser</p> <p>13 mm $1/e^2$ power points</p>	<p><u>Process A (3 mm and 5 mm mild steel)</u> The customer cuts 3 mm mild steel using a conventional lens of 5" focal length. Using the 'Easicut' facility improves cutting of high-carbon mild steels. With conventional lenses, the cutting speed is 2 m/min, with near dross-free finish. Using a conventional lens and the 'Easicut' process, 5mm mild steel was cut at 1.1 mm/min. The quality was poor with a great deal of dross attachment.</p> <p><u>Process B (Cutting 6mm and 8mm stainless)</u> For cutting 6 mm and 8 mm stainless steel the customer uses a 7.5" focal length lens, a gas pressure of 15 bar (pure N₂), and a nozzle aperture of 2.5 mm. With the conventional lens the process results were: 6mm thickness - 1.2 m/min - low amount of dross 8mm thickness - 0.65 m/min - medium dross</p> <p><u>Process C (Cutting 10 mm stainless)</u> A conventional lens of 10" focal length is used for cutting stainless, using pure N₂ gas at 15 bar pressure and a nozzle aperture of 2.5 mm. Conventional process speed is 0.6 m/min, with considerable dross attachment (especially on longer cut lengths). It was noted that process optimisation/set-up time for the conventional lens was about 1.5 hours.</p> <p>NB Best results were obtained in 10 mm stainless using a 10" FL lens rather than a 7.5"FL lens. This may be due to the unusual laser mode.</p>	<p><u>Process A</u> Using a Dual-Focus lens of basic FL 5" the cutting speed increased by 60% to 3.2 m/min with a completely dross-free finish. The Dual-Focus lens of basic FL 5" gas a speed increased 45% to 1.6 m/min, with a dross-free finish.</p> <p><u>Process B</u> With a Dual-Focus lens of basic 7.5"FL, the cut speeds were increased, and dross removal improved: 6mm thickness - 1.5 m/min - no dross 8mm thickness - 0.875 m/min - small amount of dross NB The Dual-Focus specification was optimised for 6 mm thickness</p> <p><u>Process C (Cutting 10 mm stainless)</u> With a Dual-Focus lens of 10" FL, the process speed did not increase, remaining at 600 mm/min. Quality was improved, with a near dross-free finish. The process stability was greatly increased. Optimisation/set-up time was reduced to 5-10 minutes, and greater consistency was achieved in long cuts.</p> <p>Time and resources did not permit comparison trials with a range of Dual-Focus lenses of basic 7.5" FL to explore whether process speed could be increased.</p>
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COMMENT

Obvious benefits for cutting stainless steel

Bill O'Neill Liverpool University

I read with great interest the comparison between normal inert gas cutting of stainless steel and that achieved with Dual Focus™ lenses as provided by V&S Scientific and their industrial partners. The whole issue of dual focus lenses is not new. There have been many patent applications over the last thirty years regarding dual performance optics: Boeing, IHI Industries, and Hughes Aircraft to name a few. The main actions of these inventions are to re-distribute the laser energy over the whole length of the cut or selected areas like the top surface or kerf exit. Effective cutting is best achieved with a line source rather than a distributed point source (whose distribution is based on the Fresnel absorption relations and the geometry of the dynamic cutting front.). We have, of course, failed to produce a perfect line source in the free propagation of laser beams but have been helped significantly by the oxygen assist gas which provides a "chemical" line source through exothermal actions (another good "line" source is produced in the water jet-assisted laser cutting system which goes some way to providing the perfect laser source for cutting at low power levels). Inert gas cutting does not benefit from this chemical advantage and so suffers low rates and limited cutting depths. The provision of a dual focus arrangement has generated significant performance improvement as observed in the V&S data sets. The melt at the base of the cut is illuminated by a secondary source and suffers a dramatic viscosity reduction leading to melt ejection and dross free cutting within certain tolerances. Great news for job shops struggling to cut with lower quality cutting systems and even better news for those shops with the higher quality systems such as Bystronic or Trumpf which can be worked even harder !

What about the benefits of gas consumption? Many people have said "how can a lens design affect the volume of gas consumed ?" This is a difficult area since there are many interrelated issues that do not operate in isolation. Wide nozzles, such as those cited in the data set (3 mm Ø), are commonly used to allow beams to be focused at the base of the material and to prevent unwanted oxidation at the base of the cut due to entrainment effects, they of course consume more gas than narrower counterparts. The data sets do not mention the effect on cut quality caused by entrainment of oxidising gases into the jet, which will be significant for a 2 mm diameter nozzle compared to 3 mm. The dual focus lens will have no effect on this phenomenon, if anything it would make it worse due to the higher melt temperature at the base of the cut. It is not clear what the operating range is for the dual focus nozzles. As a job shop operator do I have to buy a different nozzle for every sheet thickness?

In general it is clear that dual focus optics can provide benefits to the operator when cutting stainless steel plates. The lack of performance increase when cutting mild steel with oxygen suggests that mild steel cutting has already received a re-distributed energy source with the exothermic effect of burning steel.

I hope that the dual focus products find their place in the market and improve the performance of cutting systems which are often operated with the built-in handicap of cutting technology that is essentially 30 years old. I applaud the work of V&S but would like to see cut samples that have been made with 2 mm and 3 mm wide nozzles so that the issue of "gas saving" can be both verified and understood in more detail than has so far been offered.

On-line quality monitoring for Nd:YAG laser welding: a look at opportunities

Chris Peters

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Industrial CW Nd:YAG lasers are now available over a wide range of average power, from 10 W to 4.5 kW, and are employed for a variety of uses, from small spot welding in the electronics industries to high speed welding and cutting on automotive production lines.

For these types of application the laser source is normally an integrated part of a fully automated production line where parts arrive, are laser welded and then passed onto the next process in the line without human intervention. Under such conditions there is the potential for faults in the welding process to go unnoticed until inspection further down the line. If the time between processing and inspection is long, a significant number of defective parts may be produced before the fault comes to light.

The ability to monitor process quality during laser processing has long been desirable and has stimulated a great deal of research over the years^{1,2,3}. This has borne fruit in recent years and there are now practical devices available commercially for on-line laser process monitoring. In this article we take a look at some of the opportunities that exist for on-line quality monitoring of Nd:YAG laser welding.

What signals are available?

On-line quality monitoring relies on obtaining signals from the process which are indicative of the process quality. In general, these signals fall into two categories⁴: process quality indicators, such as temperature or oscillation frequency within the keyhole, weld-pool and the plasma/plume, and operating parameter indicators such as power, focus position and welding speed.

Researchers have identified a number signal sources and investigated numerous methods of detection. Broadly speaking the signals available can be divide into three principle areas;

1. Acoustic signals⁵ i.e. the sound emitted by the vigorous activity within the keyhole and weldpool.
2. Electrical signals⁶ from the welding plasma/plume above the workpiece surface.
3. Optical signals⁷ emitted, reflected and scattered from the keyhole, plasma/plume and weldpool.

To date, methods employing the detection of optical signals seem to be the most favoured for practical application, possibly because of their inherent immunity to noise and the relative ease with which the signals can be collected.

What kinds of defect should we monitor?

Using optical signals, researchers have developed a number of methods for monitoring indicators of process and parameter qual-

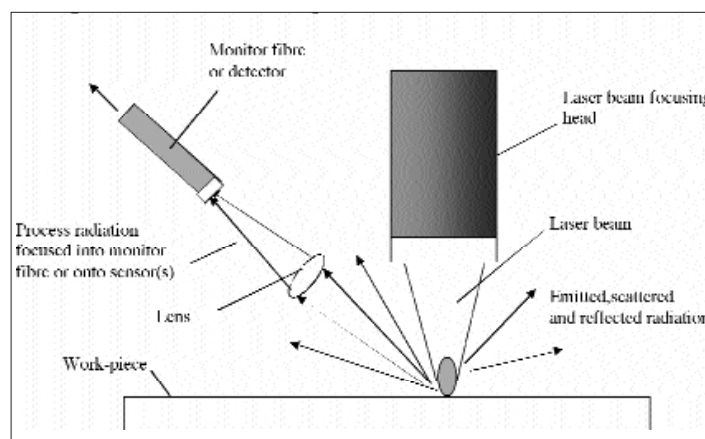


Figure 1 Off-axis optical radiation detection

ity. These include the detection of poor fit-up⁸, spatter detection⁹, degradation of gas shielding¹⁰ when welding critical materials such as titanium, variations in laser focus position, and loss of full penetration¹¹, to name but a few.

If a laser user is considering the application of process quality monitoring it is important to understand what defects need to be detected with the knowledge that some defects may be less easily detected than others.

It is implicit within the much used saying 'you can't inspect-in quality', that before it can be relied upon in production, a process must first undergo some optimisation and qualification. An essential first step is to ensure that the process has maximum tolerance to expected natural variations within the process. This is done by careful selection of materials, joint configuration, positioning accuracy, laser parameters etc.

Once optimum conditions have been selected, an on-line monitor should be used to detect defects which arise when unexpected or unforeseen events, such as damage to components or incorrect setting of parameters, cause the process to move away from its defined values. Such process monitoring will not in general detect defects directly, but indirectly e.g. the changing conditions will also influence optical signals.

Not all defects have the same significance from one application to another. For example, bead shape may be critical for a component used in a dynamic application but may have no significance for a component used in a static application. It follows that under certain circumstances there can be a mismatch between the sensitivity of the process and the sensitivity of the quality monitor which may lead to the rejection of otherwise sound components.

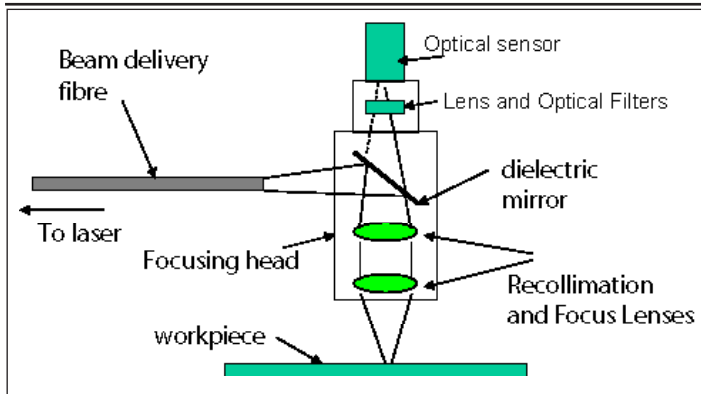


Figure 2. A sensor attached to a focusing head behind the turning mirror

Integrating the optical sensor with the process head

The relatively simple optical materials which are available for use with the Nd:YAG laser wavelength, such as fused silica, offer a number of benefits when considering where to position an optical sensor. Finding the best position for optical sensors depends on a number of factors, including what exactly is to be observed and the restrictions of space and alignment.

The simplest arrangement is to place the sensors adjacent to the laser focusing optics, away from the axis of the laser beam, using suitable fixturing. This arrangement is shown in figure 1. This arrangement, which is most suited to applications where the laser head remains stationary, has the attraction of keeping the monitoring and laser optics separate. For applications where space around the laser optics is restricted or where the laser beam is to be moved, as in a robotic application, such an off-axis arrangement may not be suitable.

With the Nd:YAG laser it is relatively simple to integrate sensors within the laser beam delivery system. One option is to place optical sensors behind an existing turning mirrors within the beam delivery. This approach is illustrated schematically in Figure 2, where the optical sensor is attached to a laser focusing head. With the appropriate selection of reflective coating on the turning mirror, the optical process radiation will pass through the mirror to the detector. In this position the detector has a large field of view of the process area and, once set, it can maintain alignment even when the laser beam is manipulated in three dimensions.

If fibre optic beam delivery is being used, full integration of the sensor can be achieved by placing the it further back along the beam delivery at the input end of the fibre within the laser source itself. This arrangement is shown in figure 3. In this position the

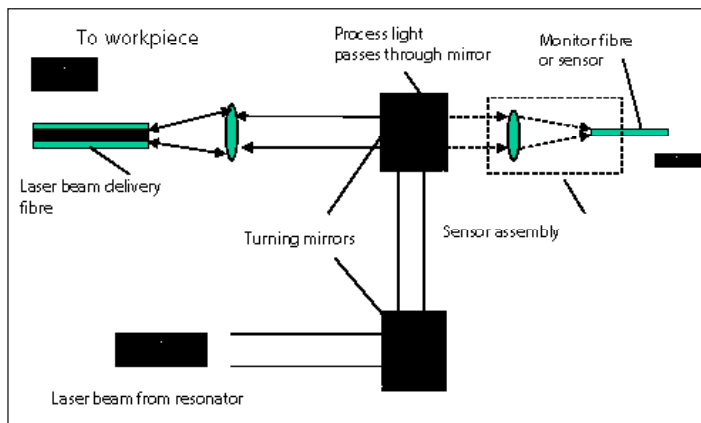


Figure 3 Fully integrated on-line sensor for Nd:YAG laser

sensor relies on optical process radiation travelling through the fibre, in the opposite sense to the laser beam. The benefits of this arrangement are that the sensor equipment is protected and does not add to the size or weight of the laser focusing optics, an important consideration for robotic applications.

What is available today?

A number of commercially available on-line monitoring systems exist for laser processing. These are based almost exclusively on the detection of optical signals from the laser beam interaction with the workpiece and they generally work by comparing a known 'good' reference signal with subsequent signals monitored during production. The user effectively teaches the monitor the signature for an acceptable weld by producing weld runs. The user can then construct a series of tolerance bands, normally above and below the reference, representing a signal amplitude which is unacceptable. In its simplest form, the monitoring system can be configured to reject the component the first time the monitored signal crosses the upper or lower boundary. Figure 4 illustrates how this might look.

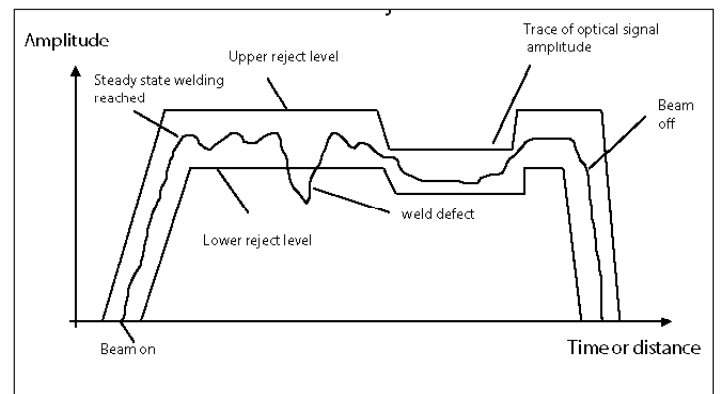


Figure 4 Schematic of signal output with upper and lower reject levels

At more advanced levels, the user can tailor his/her requirements by adding varying degrees of decision making. For example, components might only be rejected if the signal crosses a boundary more than once or for longer than a pre-defined time. Systems tend to vary by the number and types of sensors that can be used and the sophistication of the decision-making software.

Commercially available systems will typically generate an output signal indicating when a reject has occurred. As an example of the use of this reject signal, a robot handling the removal of components from the line might be instructed that on receipt of a reject signal it is to remove the defective component from the line and place it a reject stack isolated from the main production.

What does the future hold?

Imagine for a moment the possibility of not just quality monitoring but also on-line, real-time defect correction. Surely this must be the ultimate goal. A prerequisite to achieving this is the ability for monitoring systems to discriminate between different types of defect so that the appropriate remedial action can be applied. The possibility already exists to directly monitor weld penetration depth with the use of back-scattered laser light^{13,14}, so perhaps this goal is not so far away.

Development of techniques for closed loop control of operating parameters is almost certainly an easier task, and laser power 'cruise' control is now commonplace. Perhaps a more significant

development is an optically-based focus control system¹⁴ which employs the use of the same optical sensors as is used for process quality monitoring, to provide signals which are used to control the laser beam focus position relative to the workpiece.

Conclusion

Significant opportunities exist for the use of on-line quality monitoring and process parameter control for Nd:YAG laser welding.

Chris Peters has worked for GSI Lumonics for 10 years in a variety of roles including engineering and processing and is currently a project manager working in marketing. Over the past six years he has been working with Heriot-Watt and Liverpool University on the development of on-line monitoring and control techniques for Nd:YAG lasers.



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COMMENTS

Problem of overcrowding

Chris has outlined very succinctly the current situation with Nd:YAG based welding. On-line quality monitoring is also taking place with CO₂ based laser systems. The problem here, if the workpiece is not to be too crowded, is the 'outcoupling' of the process radiation. Such outcoupling is now being achieved with the use of 'sampling' fold mirrors, and setups have been tested at powers of 20 kW and upwards. The secret with these evaluation packages is not relying on the 'black-box' to make decisions, but to understand the significance of the signal variation.

Ian Johnstone Precision-Optical Engineering

The complexity of the monitoring problem

BS EN ISO 13919-1 1997 provides guidance on establishing quality levels for imperfections when laser (and electron beam welding). It is intended this standard be used within a quality system for the production of satisfactory welded joints. The standard considers: cracks, crater cracks, porosity and gas pores, localised clustered and linear porosity, shrinkage and crater pipe, solid inclusions, lack of penetration, lack of fusion, incomplete penetration, undercut, excess weld metal, excessive penetration, linear misalignment, deviation from specified joint line, and weld spatter. For each type of imperfection limits are given for three separate quality levels viz. moderate, intermediate and stringent.

It is clear from this list that on-line weld quality monitoring is a formidable undertaking! Chris points out that monitoring systems which detect optical signals arising from the weld region do not directly pick up weld imperfections, but register a change in UV or IR emitted radiation produced by the cause of the weld imperfection. The question to be asked is which of the above potential imperfections can any particular weld monitor detect?

In work conducted at TWI with a commercially available weld monitor, it proved remarkably easy to engineer a range of weld imperfections on a pair of steel plates and observe changes in either the UV or IR signals produced as the source of the 'imperfection' is encountered. Surface and edge contamination as well as edge gouges produced imperfections which were easy to detect, as did the effects of loss of process gas, introduction of a cracked focussing lens, change in focus position, or loss of laser power. The situation becomes more complicated however, when the possibility of asking the system to detect more than one imperfection is considered. This is because the sensitivity of the detected signals can vary from 'imperfection' to 'imperfection'.

The significance of this is clear when Figure 4 of Chris's article is considered. Process acceptance limits have been set at either side of a good weld. If the detected signal is outside these limits a 'failure' is signalled. However, if the sensitivity, for example to an edge fault, is very high, the limits must be set wide, and thus an imperfection arising from an effect monitored with less sensitivity, but which still might be considered a failure, would not be registered by the system.

As Chris also mentioned, it is possible to employ several detectors (which obviously increases complexity). In this case it might be possible to use separate detectors for various types of imperfection. In conclusion, it is clear that current weld monitors do have a part to play in production applications. Each of these applications should have its own weld quality criteria and levels for acceptance and failure, depending on the component service requirements, and weld monitoring systems can form part of a total quality control system.

Paul Hilton TWI

The Oxford Microengineering Cluster

Exitech Ltd, Oxford Lasers Ltd and the Central Microstructure Facility, all world class organisations in the increasingly important field of microengineering, are located in Oxfordshire within a few miles of each other.

Exitech

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<http://www.exitech.co.uk>

Back in 1984 when it was founded, Exitech became the first company in the world to commercially exploit laser micromachining for industrial applications. Since that time Exitech has grown to be a world-leading equipment supplier of laser materials micro-processing systems for industrial use and was the first to introduce such equipment onto the market. A very recent example of such technology leadership is the Exitech 157 nm Microstepper - the world's first VUV F₂ laser processing system. This will be used early next year by the silicon chip manufacturers consortium International SEMATECH (SEmiconductor MANufacturing TECHNOlogy) in Austin, Texas to print the 70-100 nm size features required for manufacturing 4 Gbit memory and 1 GHz processor chips in 2006. Capable of replicating such tiny circuits on silicon wafers with 25 nm focal precision, this tool far surpasses the optical imaging, metrology and automation performance of any laser microprocessing tool currently on the market.

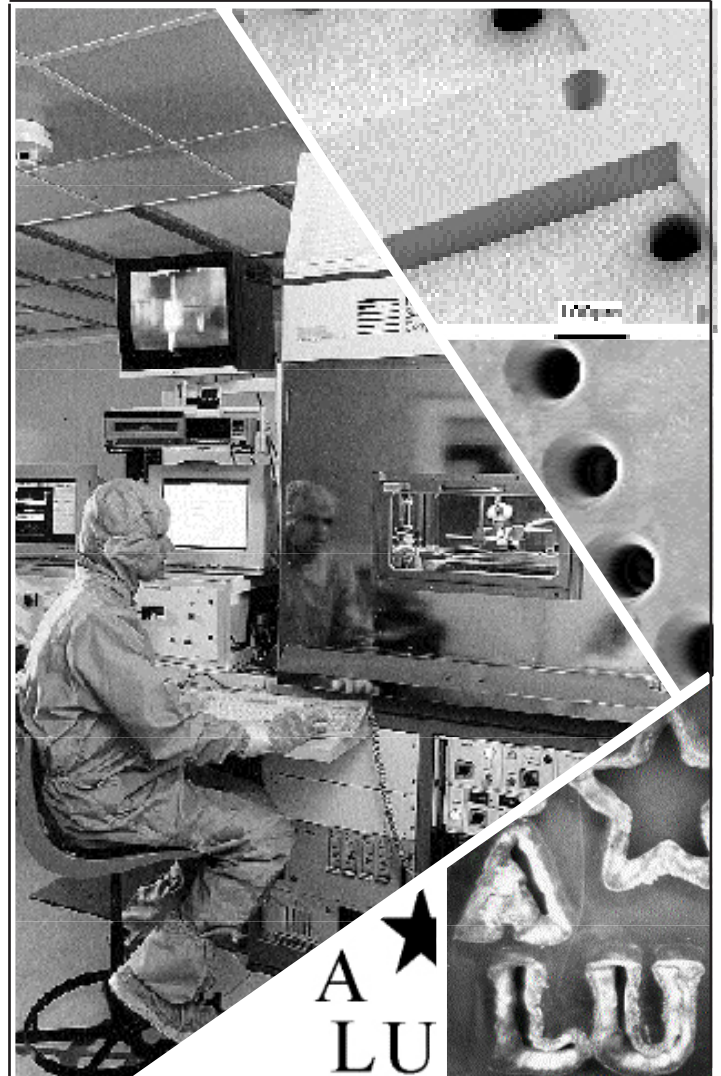
With a large well-equipped cleanroom dedicated to developing new applications of laser materials microprocessing, many industries now incorporating this technology did their developments with Exitech. Exitech continues to be an active participant in many UK and EU collaborative R&D programmes (more than 20 since 1987) that embrace a diverse range of industries: semiconductor, microelectronics, computer peripherals, display technologies, solar power generation, biomedicine and microsystems technologies (MST). Some such collaborations have been with other Oxfordshire-based companies and institutes active in 'Laser Microengineering' - for example, with Oxford Lasers in the EUREKA project: 'High power excimer laser and applications'; with Pro Laser and AEA Technology in the EUREKA project: 'Laser safety in the industrial workplace'; with the Rutherford Appleton Laboratory in the EU ESPRIT project: 'Excimer laser lithography for the sub-quarter-micron era' and the UK LINK project: 'Laser fabrication processing for microstructures'. Further afield in South East England, collaborations in LINK schemes with Nortel Networks, British Aerospace, Aston University, Centronic and UCL in the projects: 'Gratings in Fibre Transmission Systems' and 'Deep uv sensors for industrial applications' have also greatly benefited the technology developments made by the company. By locating two Exitech laser machines and permanently seconding staff to work at RAL, the collaboration with the Central Microstructure Facility continues in areas of developing excimer laser processing for micromachining in MST applications and for cleaning delicate substrates - primarily optics, photomasks and silicon wafers. The close geographic proximity and technology synergy between participants allows such collaborations and partnerships to proceed with minimal logistic disruption when attending meetings, transferring personnel and equipment.

Oxford Lasers

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Oxford Lasers Switchboard Tel: 01235 554211
<http://www.oxfordlasers.com>

Oxford Lasers was founded in 1977 by a group of physicists from Oxford University engaged in the research of new, yet practical, laser devices. The impetus to enter the commercial arena fully came from the group's innovative work on one of the world's first practical excimer laser devices. This led to the development of excimer gas processors and subsequently to the new copper vapour laser (CVL) technology.

In recent years, one of the areas on which the company has concentrated its efforts is micro-machining. Formed in the early



CW from top left: Exitech laser micro-cleaning tool situated at the Rutherford Laboratory, Laser-machined ink reservoirs behind ink jet nozzle (Exitech), Excimer machined nozzles in an ink jet print head, 30 μm diameter in polyimide (Exitech), A perspex beam print of a reconstructed image, size 11 x 14 mm, generated by reflecting a 500 W collimated CO₂ laser beam with a 32 levels.kinoform, Original pattern (CMF).

1990's the company's Industrial Division has since seen a huge growth in business year on year. Fuelled by the increasing demand for micro-machining in a wide range of applications throughout the aerospace, automotive and electronics industries, Oxford Lasers has been at the forefront of developments in this exciting industrial sector.

The company has been a key player in the European Community funded COMPALA consortium which was set up at the beginning of 1996 to develop industrial micro-machining systems based on CVL lasers. Amongst the COMPALA consortium partners were Philips CFT, Robert Bosch GmbH and TNO Industry. With a total budget of 4.2 million Euros, one of COMPALA's major objectives was to improve the precision of laser micro-machining of metallic parts for the electrical and automotive industries. Working with Clarendon Laboratory on the development of low emission diesel engines for the next century, Oxford Lasers has developed a copper laser capable of drilling precision holes with diameters well below the 100 micron limit of present techniques.

Inkjet printer production and development is another area in which Oxford Lasers is applying its CVL expertise. A single CVL system provides micro-drilling, cutting, milling, etching and high

resolution marking on a wide range of materials including metals, advanced alloys, ceramics and diamond.

Rutherford Laboratory Central Microstructure Facility

The Central Microstructure Facility (CMF) at the Rutherford

Contacts: CMF: Professor Ron Lawes, CLF (X-ray lab) Dr Graeme Hurst, CLF (other) Dr Colin Danson.

Rutherford Lab Switchboard Tel: 01235 821900

<http://www.ral.ac.uk>

Appleton Laboratory provides state-of-the-art microfabrication services and R & D facilities to universities and industry. A central well-founded research and prototype manufacturing service with access to advanced technology. The CMF is a neutral site where academic-industry and industry-industry collaborations offer good technology transfer opportunities.

One of the key CMF manufacturing specialities is in optical masks or reticles. CMF operates the most advanced R&D facility for mask-making in the UK, using the unique flexibility, resolution and placement accuracy of Leica vector scan e-beam machines and in-house resist processes and etching techniques.

In addition to e-beam processing, the CMF has a comprehensive range of optical lithography equipment, including an I-line wafer stepper, a wafer aligner and an extensive range of excimer laser tools developed in house.

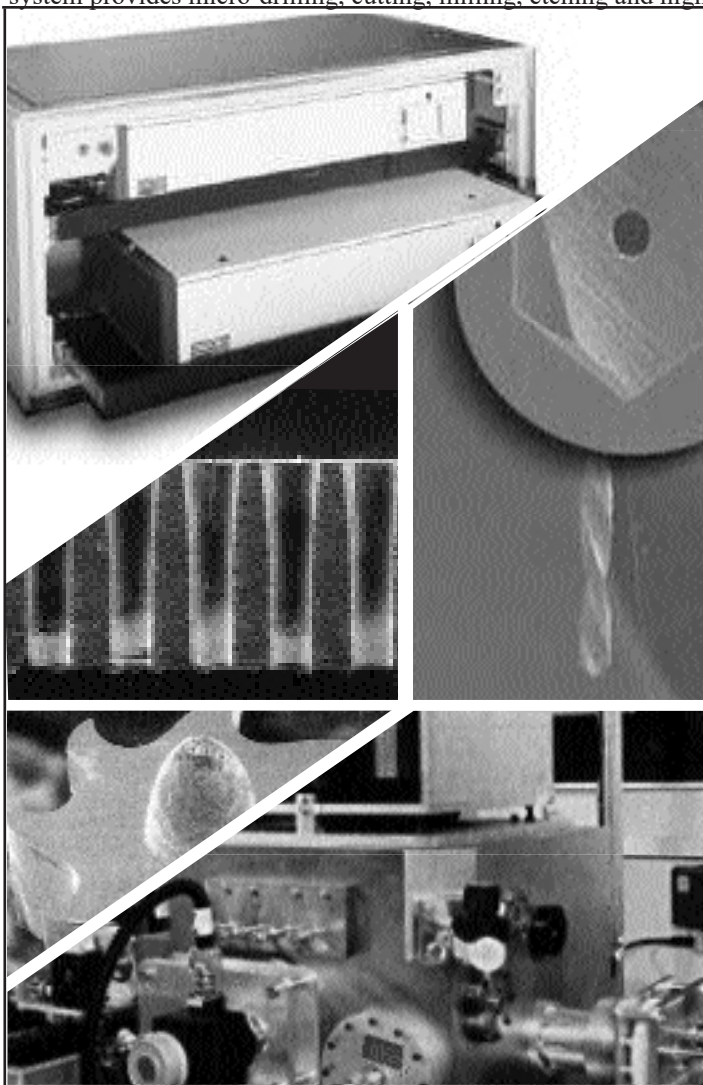
One of the many collaborative activities the CMF is currently involved in is the LINK Surface Engineering project 'Kinoform optics for laser materials processing', with Loughborough University, TWI and five industrial partners. To this end, CMF have developed a process for producing kinoforms with 32 quantised depth levels over a 0 - 5 μm range by direct write electron beam lithography. The process involves extremely careful control and multiple exposure in an electron beam microfabricator for accurate depth (level) control.

Central Laser Facility

The Laser-Plasma X-ray Laboratory in the Central Laser Facility houses a unique high-average-power picosecond excimer laser system which has been used both for direct microengineering (e.g. semiconductor thin-film annealing) and for soft X-ray generation. 1 nanometre X-rays are available with average powers up to 1 watt. These have been used for conventional lithography, producing FETs with $<0.2 \mu\text{m}$ features, and for LIGA, generating 50 μm deep 3-D structures. More recently 3 nm laser-plasma X-rays have enabled very effective lithography using novel high-resolution organometallic masks from the University of Dundee. The facility is available both for academic and for commercial contract use

CLF's ultraviolet short pulse lasers are being used to anneal miniature, high resolution electro luminescent flat screen displays to increase their light output. The short pulse laser enables just the right amount of energy to be delivered to the active region of the device, avoiding damage to other heat sensitive areas, and a whole wafer can be processed in a single shot. There are immediate commercial applications for head-up displays.

The CLF also provides state-of-the-art femtosecond lasers, which are available for laser materials processing.



courtesy: Exitech, Oxford Lasers, Rutherford Laboratory

CW from top left: Micromachining Copper Laser with amplifier module tray extended (Oxford Lasers), Miniature twist bit of human hair diameter (160 μm) with 20 μm hole laser machined in the tip (Oxford Lasers), CHEMI excimer laser chemical processing workstation (CMF), 470 μm dia. rotor microturbine (CMF), Optical fibre interconnect comprising an array of 130 μm dia. flared holes in Alumina (Oxford Lasers).

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Forthcoming Events

September

15 Members-only meeting

AILU

Loughborough University

Contact: AILU office (flyers already circulated)

30 Laser Surface Engineering

Make It With Lasers/ AILU supported

Culham Laboratory, Abingdon

Contact: Carol Fielding Tel: 01223 891162

October

6 So you want to join it properly!

IoM Awareness workshop/ AILU supported

Harwell Conference Centre, Didcot

Contact Keith Wakelam Tel: 0171 451 7357

12 Time-Compression Technologies '99 (12 - 13)

East Midlands Conference Centre, Nottingham

Contact Tel: 0171 924 5655

19 Job Shop of the Future

AILU Job shop launch

National Motorcycle Museum, Solihull

Contact: AILU office (invites to be dispatched)

20 Photonex '99 (20 - 21)

NAC Stoneleigh Park, Coventry

Contact: Mobilex Tel: 0171 924 5655

IoP courses (incl. diode lasers, optics design, FO sensors etc) during the exhibition:

Contact IoP events Tel: 0171 4704930

November

15 ICALEO (15 - 18)

Laser Materials Processing Conference

Laser Institute of America/ AILU supported

San Diego, California

Contact: AILU office

24 Tricks and secrets of design for laser manufacture

AILU workshop

GSI Lumonics, Rugby

Contact: AILU office (flyers yet to be circulated)

Further ahead

8 March 2000

Laser Materials Processing Conference

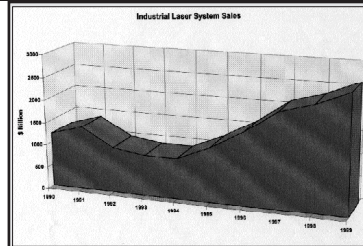
IoP/AILU supported

Contact: IoP events Tel: 0171 4704930

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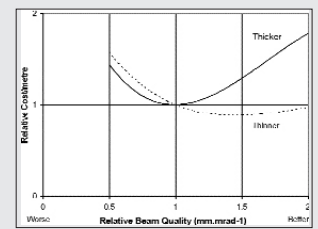
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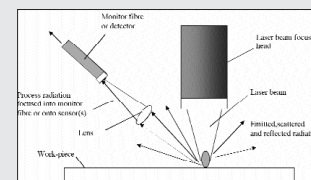
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Editorial Board for this issue

Cal Bailey, John Barker, Jim Fieret, Erwin van der Heijden,
Malcolm Gower, Tim Holt, Martyn Knowles, Bill O'Neill,
Chris Peace, Brooke Ward

Editorial Policy

The Industrial Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members.

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

Authors maintain the right to extract, in part or in whole, their material for future use.

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