Cut it out

Lasers are now more versatile in cutting, welding and drilling.
Image courtesy of IPG

Stephen Mounsey looks at some of the latest developments in laser technology's staple application areas: cutting, welding, and drilling

The majority of lasers with power outputs of a kW or more are produced for materials processing applications, although the term means different things to different people. While steel cutting remains the bread and butter of industrial laser use, more diverse applications with other materials are finding their way out of the laboratory and into everyday use.

Whether because of its relatively large budget, demanding specifications, or safety-critical nature, the aerospace industry has traditionally been a driver and early adopter of novel materials. In the case of carbon fibre composites, which were first developed in the 1960s for use in jet engines, cost-effective methods of processing the materials are only just being developed. The need for lighter, more fuel-efficient aircraft, driven by rising fuel prices and environmental considerations, has led to the use of composite materials in new aircraft such as the Airbus A380, the airframe of which is composed of 20 per cent composite materials. Innovative, laser-based processing methods are being developed to meet the industry's demand for these new materials.

Currently, composite materials are cut using saws, which can leave damage along the cut surface that can weaken the component unpredictably. Mo Naeem, an applications expert at GSI, explains that laser cutting of composite materials presents a better alternative: 'Composites have been around for a long time, and many industrial players have historically already tried to use lasers to cut and drill holes in them, but they've been unsuccessful so far,' says Naeem. 'We've been working with a team at Liverpool John Moores University to find ways of using fibre lasers to cut, drill, and perform surface modifications on these composite materials.'

Naeem explains that, when cutting composites, the beam quality produced by fibre lasers has proved important. 'The processing techniques we're developing use our fibre lasers, whereas many of the other companies trying to work with composites have been using CO_2 or Nd:YAG lasers. Although these technologies can achieve results, they do tend to result in thermal degradation of the fibres at the interface [between individual fibres and the resin matrix material].'

The small spot size and relatively low power of the fibre lasers used by GSI mean that the substrate is not significantly heated during the process, avoiding thermal damage. 'In the past we used lasers with a higher power, and the only variable when making a cut was the cutting speed. Sometimes that cutting speed wasn't fast enough for the power level used, and so it caused thermal damage. Now we're using only 50 to 100W of power, and rather than doing very slow cuts we're doing multiple very fast passes for each cut, to reduce the thermal damage. This approach gives us more control over cut quality,' he says. 'With a fast scanning head, we can do maybe 10 to 20 passes depending on the thickness of the workpiece. The most important thing is not the speed, but the quality of the cut, and with more passes there is very little damage done to the fibres or the resin, or the interface between them.'

In the safety-critical aerospace market in particular, the quality of the finished product is of greater importance than the speed of the process. 'Speed does come into it, but the quality is the number one consideration,' says Naeem.

Elsewhere, GSI has applied its lamp-pumped solid state lasers to drilling holes in turbine blades designed to operate in the hottest parts of gas turbines, both in the aircraft engines and in the power-generating turbines on the ground. These components have a ceramic thermal barrier coating (TBC) applied in order to allow them to operate at temperatures above the melting point of the nickel superalloys used, and networks

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of holes are drilled into them, through which cooling air flows. 'We've been using our lasers to drill holes through both the TBC and the alloy. It's a challenging thing to achieve because, although the alloy is quite easy to drill, the TBC itself is a ceramic and tends to crack when heated. It needs a combination of designing a good laser and also having a very sophisticated software system to control the laser input for each pulse.'

Lamp-pumped lasers may seem a little old fashioned, but such percussion drilling applications require a pulsed laser with high peak power, and lamp-pumped Nd:YAG lasers remain the most common way of achieving this. 'When we're drilling we are trying to evaporate the material rather than melting it, and so we need that high peak power,' explains Naeem.

Bill Shiner, VP of marketing at fibre laser specialist IPG Photonics, reveals that the company's recently introduced quasi-continuous wave (QCW) laser was developed specifically to compete with lamp-pumped pulsed lasers in these high peak power applications. 'Typically these lasers might offer 3kW peak pulsed power, but their average power is low, because they're pulsed. Prior to the QCW laser, if you required a laser with a 3kW peak power I would have to sell you a 3kW fibre laser, but it would be constantly at 3kW, and it would certainly be more expensive than a lamp-pumped equivalent.' The company's new QCW lasers change this, Shiner says, by offering high peak and low average power. 'For example, a QCW fibre laser with a peak power of 1.5kW has an average power of just 250W. We've also reached a price point at which we can actively compete with a lamp-pumped pulsed YAG laser, with the advantage of attractive pricing and all the benefits of fibre lasers.'

Among the most important of these benefits, he says, is efficiency: 'Fibre lasers offer a high wall-plug efficiency of up to 30 per cent, whereas this could be as low as 2 to 3 per cent on lamp-pumped Nd:YAG lasers.' Greater efficiency means the laser itself can be seen as a more green solution, but Shiner adds that environmental considerations are a significant driving force

across the whole range of materials processing applications: 'One area that is generating a lot of business for us is the so-called energy sector, which gets us into welding automotive batteries, working on wind tower projects, and even being involved in the automotive switch to high strength steel.' The automotive industry is beginning a transition from mild steels to high strength steels in cars, as less steel can be used for a given component, minimising weight and creating more efficient vehicles. 'We've seen a lot of demand for cutting this material at very high speed, and the only other way to do it [apart from high-power lasers] is to use plasma cutting. We've enjoyed an increase in business as the automotive industry has been ramping up to switch over to these high strength steels, which are not as easy to cut as the materials they were using before.'

Happy shopping

High peak power is also a parameter that the latest generation of sealed CO_2 lasers from Coherent also offers. The company has recently pushed the power of its slab-format lasers to more than 1kW, allowing the company to compete with lamp-pumped lasers. 'Our 150W Diamond E-Series laser puts out 375W of peak power, and our 400W laser puts out 1kW of peak power, and the 1kw laser puts out greater than 2.5kW of peak power,' says Frank Gaebler, senior product marketing manager for CO_2

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lasers at Coherent. The high peak power offered by the slab architecture sealed lasers leads to performance advantages over flowing-gas CO_2 lasers, particularly in metal cutting applications: 'High peak power allows more efficient coupling of light into reflective materials,' says Gaebler. 'The cutting speed of our 1kW [sealed] laser is equivalent to that of a 2kW conventional laser.'

According to Gaebler, CO_2 lasers are a superior product to fibre lasers for many applications, particularly in job shops where steels of more than 4mm thickness may need to be cut. 'The coupling efficiency of fibre lasers is, in theory better than that of CO_2 lasers, and they're particularly good for cutting thinner metal materials, but it's not a cut and dried comparison,' he says. CO_2 lasers offer the job shop user versatility, particularly where good cut speed and quality are required in thick steels, or where organic (wood, polymer) materials may also need to be processed.

The airframe of the Airbus A380 is composed of approximately 20 per cent composite materials. Laser-based techniques are being developed to process composite materials more effectively.

A new kind of collaboration

When designing cutting or welding systems for industrial and job shop users, GSI's Naeem says that process optimisation is as important as the laser used. 'To a certain extent, laser technology is the easy bit. When one of our customers says "I want to weld 50µm foil to 50µm foil" the laser itself is a cheap component, but the customer then needs to invest in equipment that can clamp 50µm foil without damaging it. If they want to weld a 10-15µm spot on the workpiece, the laser can achieve that easily, but they will need to invest money in vision and control systems capable of working to the same accuracy,' he says, adding that this can present more of a challenge.

California-based JDSU has been working with Amada Corporation, a Japanese developer of industrial systems, in order to develop a turnkey kW-class cutting system based around a JDSU's fibre lasers. Here, too, the process parameters must be as innovative as the laser used, and both are being developed alongside each other. According to Werner Wiechmann, product line management director for commercial lasers at JDSU, the expertise of the two teams is complementary. Amada, he says, has a history in the machine tool industry, and as such the company is able to contribute much to the machine interface and the mechanical design of the system, whereas JDSU's history of producing high-reliability laser diodes and fibre lasers will allow it to produce a reliable and well suited laser.

The Amada cutting system will be aimed at job shop users. 'In general we're competing against CO_2 lasers in this market,' says Wiechmann. 'In principle the fibre laser has many advantages over CO_2 lasers, including zero warm-up time (it can be tens of minutes for some CO_2 lasers), low running costs, and a higher wall-plug efficiency (30 per cent compared to 7 to 8 per cent or less for CO_2). Fibre lasers are therefore a more ecologically sound solution,' he says, noting again that being green is an important selling point in current markets.

Wiechmann believes, however, that JDSU's main advantage over other manufacturers in the job shop market is its partnership with Amada: 'Amada is taking control of the interface and the whole package, but the system integrator is also working closely with us – the fibre laser designer – to match the cutting machine to the laser's performance. The customer will be able to look at the whole package and see how well it plays together.'

'You could have the best beam quality and the best performance possible in a fibre laser but, if the linear speed of the machine doesn't match that performance, then you haven't gained much,' says Wiechmann. 'We think it's very important to have the integrator involved in the overall design, from a performance perspective, but we're also very glad to have Amada in the partnership for the sales and support angle. High quality laser design is our skill, and while Amada hasn't got that skill they do have the channel to market.'

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JDSU believes its work with Amada represents the introduction of a relatively new partnership model. 'We're not really aware of anyone else with the same kind of partnership; there are firms in the market that have the ability to make both the laser and the cutting system, but end users are trying to break that tightly controlled market,' says Wiechmann. Collaborations like this might be just what are needed to open the market up to greater competition.