Tube Cutting With Minimal Kerf Using Fibre Lasers

Laser cutting with minimal kerf is particularly important in micro-processing of materials. First and foremost, many of the components to be processed do not have much material to spare, medical stents being an obvious example. Similarly, an accurately cut line on the µm scale allows ever finer details to be realised, for example cutting masks for PCBs. In order to achieve very fine kerf widths, both the laser and optics, as well the mechanical handling of the component to be processed must exhibit the highest performance and stability.

Fibre lasers exhibit exceptional stability both in the output power and for the focussed spot size, and as a result are thus enjoy a growing acceptance within the laser manufacturing industry as a cost-effective alternative to conventional laser design. Fibre lasers have matured over the last few years into a robust industrial tool with a unique series of capabilities that enable a wide range of precision materials processing manufacturing methods, including low running costs, a fast ROI, a small footprint and exceptional reliability.

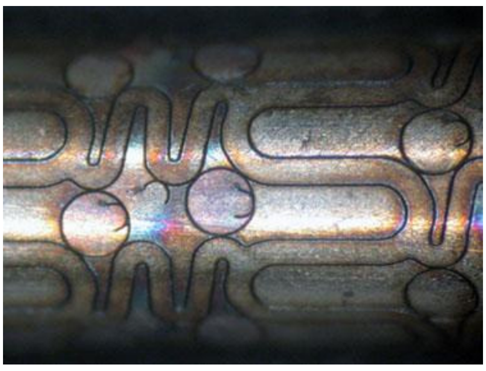
Micro-cutting with lasers

One of the major advances to occur in the field of micro-cutting is the use of a laser as the cutting tool. Small components with small wall thicknesses can not tolerate excessive vibration and do not lend themselves to practical motion control around a physical cutting tool. The laser obviates these problems by providing a vibration-free, stand-off cutting tool.

The use of a laser as the cutting tool does however require proper handling of other aspects of the cutting process – heat affected zone, the area around the cut which is subject to heating through diffusion, often has to optimised in order to minimise thermal damage to neighbouring materials or components (e.g. plastics or electrical components). Additionally, the cutting of very small wall thicknesses usually involves determining the best (laser) parameter space for the material in question, so that backwall finish is good and that dross and kerf are kept to a minimum. This parameter space places strict requirements on such aspects as laser output stability, proper motion control and proper beam delivery.

Despite these issues, lasers enjoy a growing popularity in general in the industry, but in particular in the field of cutting very small stent structures for medical applications. Bearing in mind that these stents are placed and expanded within blood vessels in order to improve blood flow and provide mechanical support for the vessel walls, they must be mechanically robust and reliable, and additionally exhibit high surface finish in order to avoid irritation in situ and to prevent rupture of the catheter balloons used to extend the stent within the blood vessel.

Fig 1 – generic pic of a stent or of a cut tube



Tube cutting with a fine kerf

Minimising the kerf width and improving the quality of the cut (correct tracking, good initial surface finish) requires special equipment, but opens up the possibilities for laser cutting in ever smaller regimes, at the same time maintaining robustness of the finished piece.

First and foremost the laser source itself must be universally reliable and flexible – aspects such as an instable power output, poor output control and a low output mode quality are all factors that can contribute to a poor quality cut with wide kerf. Secondly, the optics responsible for delivering the laser power to the workpiece and the final focussing optic must be of the highest standard to ensure the best focal spot. Thirdly, the motion system handling either the beam steering or moving the workpiece under the beam focus must maintain the intended beam path without introducing excess mechanical noise. And fourthly, the best cutting parameters must be determined for the material and thickness in question – the optimal cutting power at a given cutting speed, as well as factors such as wet or dry cutting and power delivery during complex cutting trajectories.

Wet cutting can be a beneficial factor for very small objects – small metal items heat up very quickly, although it is crucial to keep the heat affected zone to a minimum, especially as heat diffusivity increases with temperature. Wet cutting helps maintain better thermal management in the workpiece and also helps prevent backwall damage. Although it is not always practical to apply, tube cutting lends itself easily to its use, with water being pumped though the inner diameter.

As an alternative to using water, the gas used for improving the cutting process can also be applied in the same fashion *(is this dry cutting, or is dry cutting entirely without a cooling medium?)*.

swisstec AG of Schaan in Lichtenstein, a company with significant experience in manufacturing micro-processing workstations for cutting, welding, drilling and engraving, has successfully brought all of these requirements together in its cutting workstations. swisstec CEO Eduard Fassbind maintains that the kerf width is a reliable 10µm, the company having achieved this level of consistency by making use of some key components in the workstation assembly. These include a 50W or 100W fibre laser from SPI Lasers UK, high quality optics including a custom-designed optic for the final focussing and a state of the art motion system mounted on a solid granite base.

Fig 2 – stent cut.tif – courtesy of eucatech

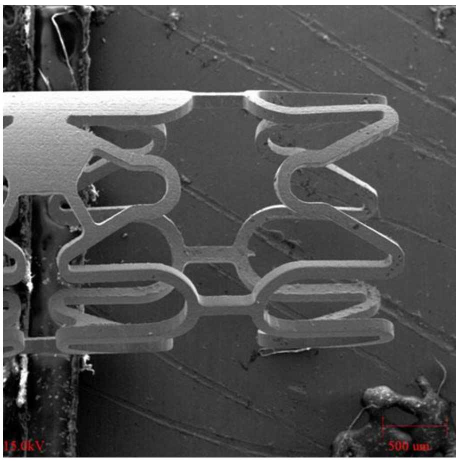


Fig. 2 shows a cut stent before the excess material has been removed. Analysis of the cut profile shows, in addition to the narrow kerf, that the entire contour of the cut is accurate to +/-3µm – achieved at a cutting speed of up to 700mm/min and with minimal thermal deformation.

The workstations from swisstech are capable of cleanly cutting 250µm thick cobalt chrome, stainless steel or Nitinol at speeds of 800mm/min. According to Fassbind, "Cutting speeds of up to 1000mm/min are realistic with the 50W laser, and we can also cut titanium at roughly half this speed, although we haven't finished optimising the process yet.

Above wall thicknesses of 250µm we will need to use SPI's 100W laser, and with even with the extra power we can still maintain identical kerf widths."

Such well cut tubing obviously simplifies the subsequent electro-polishing step needed to give blemish-free surface and edges – both being necessary to avoid irritation when in situ.

Advantages of fibre lasers

SPI Lasers UK Ltd., of Southampton, UK, has been developing fibre lasers for the industrial market for several years, primarily for materials processing applications such as microwelding and microcutting, but also for marking applications.

Specifically where maintaining narrow kerf and proper cut contour is important, fibre lasers excel through a combination of intrinsic performance related parameters. Power variation for example is below +/-0.5%, class-leading both for CW and in power modulation modes and despite additionally providing exceptional pulse flexibility (from microseconds to cw). Additionally, the consistent TEM_{00} beam (Gaussian beam profile) is critical to both achieving and maintaining a constant focal spot size in the cutting plane.

A further advantage is that the small spot size and high beam quality translate into high irradiance at the focus, enabling low power cutting of very thin wall thicknesses. Lastly, high quality precision cutting can be performed close (0.1 mm) to the most complicated and intricate component parts.

For these and other reasons, fibre lasers bring significant advantages for a host of industrial applications. Fibre lasers minimize operational costs with no lamp changes, alignment or calibration requirements, they reduce maintenance costs, exhibit longer up-times and improve production quality with less scrap. Fibre lasers are also exceptionally physically robust and stable and thus suitable for the most challenging of industrial environments.

These financial and performance advantages mean that fibre laser technology is now frequently chosen as an upgrade over conventional flash-lamp pumped solid state, or even DPSS laser technology in many other laser-assisted industrial manufacture segments.

Advantages for industrial manufacturing

While many different laser designs have found their way into materials processing applications, fibre lasers help minimize the critical balance that must be struck. As is typical of many manufacturing industries, materials processing is a complex mix of optical performance, system flexibility, high yield, high up-time and exceptional reliability.

By providing an extended performance envelope for the laser, SPI's technology opens up the performance envelope that workstation manufacturers can provide to their customers. In addition, the extended performance envelope enables applications that were previously out of reach.

Latly, fibre laser cutting workstations enjoy rapid ROI due to high yield, near 100% up-time and near-zero maintenance, meaning that the end-user can focus on his business demands rather than having to become a laser maintenance expert.

Acknowledgements

The authors acknowledge useful discussions and contributions from Dr. Micahael Giese of eucatech AG, Rheinfelden, Germany (www.eucatech.de).

Authors:

Eduard Fassbind, CEO
swisstec AG, Schaan, Lichtenstein
Tel: +41 41 790 3385
eMail: e.fassbind@swisstecag.com
web: www.swisstecag.com

John Tinson, Vice President Sales
SPI Lasers UK Ltd., Southampton, UK
Tel. +44 1489 779668
eMail: john.tinson@spilasers.com
web: www.spilasers.com

Gregory Flinn
Putting Photonics into Context, Munich, Germany
Tel. +49 89 95420457
eMail: gregory.flinn@gmx.net
web: www.gregoryflinn.net