Nanosecond fibre lasers - versatile manufacturing tools

Fibre laser offer users a compact, low cost, reliable and highly efficient source with no maintenance requirement delivering a low total cost of ownership and, after process optimisation, a fit and forget solution. The latest generation of nanosecond pulsed fibre lasers offer a range of pulse options and are available with tailored beam quality giving users great scope for process enhancement. Recent increases in peak powers and pulse energies are opening up new applications in micro-machining.

The majority of solid-state pulsed laser sources rely on q-switch technology. This often limits the lower and upper limits of operating pulse repetition rates and a fixed pulse length. Many fibre lasers use this same pulse generating technology and suffer the same limitations. However, more refined fibre lasers exploit a MOPA (Master Oscillator Power Amplifier) design with a directly modulated semiconductor seed, which allows greater control of pulse parameters. Such lasers can offer pulse repetition rates in the range 1Hz – 1MHz and can even operate in CW mode.

SPI's current MOPA design offers fast rise pulses with high peak powers. Recently models give peak powers > 20 kW and pulse energies > 1.25 mJ with 40 W average power at 30 kHz. Using its proprietary PulseTune technology the pulse length can be varied from 10-200 ns helping maintain peak powers as the repetition rate is changed.

Process optimisation with pulsed lasers is much more difficult than with CW lasers. Average power and beam quality are common, but for pulsed lasers there is also peak power (kW), pulse energy (mJ), pulse duration (ns) and pulse frequency (kHz) to optimise.

In marking applications the pulse repetition rate is often the prime driver for marking speed. Marking relies on overlapping spots to create the continuous line and this becomes a particular problem for applications that require a high

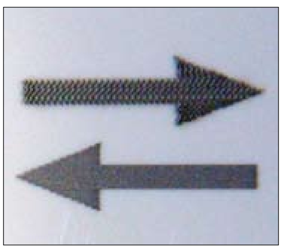

Figure 1: (top) 25 kHz 0.8 mJ mark showing material damage and mottled mark, (bottom) 375 kHz 0.05 mJ showing even fill and a smooth high contrast mark at 5m/s

Figure 2: Black anneal marking using a a combination of high repetition rate, pulse width control and a tailored mode.

pulse energy and peak power because the laser must typically be operated at low repetition rates, typically in the 20-30kHz range, resulting in a slow marking speeds (<2 m/s). However, if the marking process is more temperature sensitive (e.g. marking polymers) then there is particular benefit in processing with shorter pulses to maintain high peak powers while limiting overall heat input to prevent melting (see Figure 1).

Other applications where >100 kHz pulse repetition rate specifically benefit marking include:

- Black anneal marking on stainless steel
- Colour marking
- IC marking
- Night and Day (paint removal)
- Thin film patterning

Figure 2 above is an example of optimised black anneal marking is an application where surface melting had to be avoided at all cost.

Figure 3: Rolls created by ns pulsed fibre micromachining. Courtesy Applied Laser Engineering

Another key property of the beam is its beam quality (M^2). Lower M^2 (higher beam quality), which gives a smaller focused spot and a greater depth of field, is ideal for fine marking but the resulting peaked beam profile can be problematic for applications where large area processing is required (large logo marking) or where substrate damage can be an issue such as in thin film patterning and some laser cleaning applications. For such applications a higher M^2, which gives a broader beam profile, is preferable: but not a multimode or "flat top" beam for which there is generally insufficient peak power for the majority of the ns pulsed laser applications. A very modest change in M^2 from 1 to 4 can be significant. SPI has a range of tailored beam qualities in this range to cover a wide range of applications.

Other pulse characteristics such as pulse energy and peak power can significantly impact applications. High quality precision engraving is a good example where control of pulse characteristics can be critical. Companies specialising in intricate 3D engraving vary these parameters to optimise material removal regime for any given application. An example is ALE who specialise in engraving rolls in a range of materials including brass which is considered a difficult material to laser processing (see figure 3). Only a few microns per pulse are removed but with exceptional quality.

Figure 4: Engraving on copper tube with a 40 W HM (1.25 mJ, 20 kW, 30 kHz) and a 254 mm F-Theta lens: (top) 1m/s; (bottom) 6m/s

Deep engraving has conventionally been an application for a lamp pumped YAG laser, since to date the smaller ns pulsed fibre lasers have lacked both pulse energy and peak power. However, SPI's 40 W HM laser with >20 kW peak power and >1.25 mJ has proven itself in this application, achieving material removal rates >3 mm^3/min. The engineering industry has a growing need for the alphanumeric and 2D data matrix codes which typify this application and an example of marking in copper with this laser is shown in figure 4.

In addition to marking and micro-machining these lasers can be used for fine metallic cutting, low heat input soldering and even micro welding.

No longer limited to marking applications, nanosecond fibre lasers have become versatile micro-machining tools capable of performing multiple operations. Whatever your micro-machining or marking application, fibre lasers are seriously worth considering.

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