Burst Energy Breakthrough in Micromachining Lasers

Burst mode feature offers new way to control throughput and quality

Users of laser micromachining equipment are constantly striving to manage the balance between quality and throughput. The equipment provides a multitude of ways in which the user can configure its operation: in particular, laser beam delivery features such as focal spot size, and the speed and accuracy of the movement of the beam, provide a large degree of control over process efficiency.

But the scope of the user's control is fundamentally limited by the attributes of the laser itself: its maximum energy per pulse and power (pulse energy x pulse repetition frequency) are technical characteristics of the device, and are physically limited by the components from which a laser is made.

Now, however, this limitation has been eased by Lumentum PicoBlade® micromachining lasers. A new burst mode of operation increases the burst energy which the laser can deliver instantaneously to a single target location.

This new option for controlling energy at much higher levels means that PicoBlade users can achieve a unique and substantial improvement in micromachining performance.

Requirement for high fluence

In some applications, such as the modification of transparent materials, a laser beam with high fluence is desirable. Here, the use of high-energy bursts produces better results, taking advantage of the non-linear characteristics of the material.

An additional way to increase the amount of energy delivered to a single location on the workpiece is to tightly focus the power from consecutive pulses. When pulses are closely spaced, so that each one overlaps the previous pulse, the amount of energy delivered to a single location is higher than the energy in a single pulse.

An example illustrates the effect: in laser micromachining, a speed of 10 m/s would be classed as fast. At this speed, the distance between the pulses is just 2 μm in 200 ns. Two adjacent pulses delivered to the workpiece with an interval of 200 ns or less—requiring a PRF of 5 MHz—would for the purposes of many applications be hitting a single target area.

The user of laser micromachining equipment, then, has various settings under his or her control: these include the energy per pulse, the interval between these pulses, and the speed of motion. Users managing an application which requires high fluence would in an ideal world want to be able to deliver high-energy bursts with very short intervals between them (for high fluence and high power) while maintaining high velocity of the laser over the workpiece (for high throughput).

The real world, however, is subject to physical limitations imposed by the equipment.

The first limitation is illustrated in Figure 1: the average output power of seeded ultrafast lasers is fairly flat over the range of PRF settings. Above a PRF of 200 kHz, the increased frequency of pulses is more or less matched by the decreased energy per pulse, resulting in limited change in average power. To take the example above, of an interval between pulses of 200 ns: this interval is produced by a PRF of 5 MHz. As Figure 1 shows, the user of a conventional micromachining laser has to trade off a higher PRF against a lower energy-per-pulse.

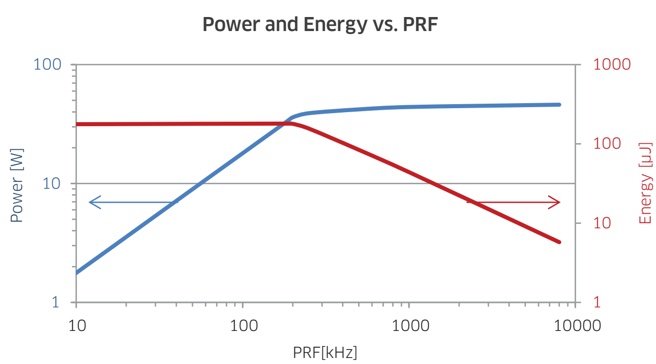

Figure 1: Plot of average power over the PRF range in a conventional single-pulse micromachining laser

The second limitation is the maximum pulse energy, a limitation which typically applies at PRF values of 200 kHz and below. Pulse energy is typically clamped by laser manufacturers at a maximum value. This is because of the inherent physical characteristics of the components of a laser emitter. At single-pulse energy levels above the rated maximum value, the laser's source and optics are exposed to the risk of damage. If allowed to operate at excessive pulse energy levels, the laser would, in effect, be micromachining itself.

Now, however, Lumentum has introduced a burst-mode technology which overcomes this maximum energy limitation and enables a significant increase in the maximum energy delivered to a single target location.

Breaking through the pulse energy ceiling

Advanced optical and electronics technology developed by Lumentum enables the controlled delivery of tightly spaced pulses, producing a 'burst' consisting of multiple (two or more) almost simultaneous pulses. This capability is offered in the PicoBlade micromachining lasers as the MegaBurst™ function that leverages our FlexBurst™ functionality.

Standard MegaBurst patterns are available, offering two or more pulses in a single burst. By default, the interval between each pulse in the burst is 12 ns. Optionally this can be increased by increments of 12 ns to optimize, for example, the time response of the material.

Within a burst, each pulse can deliver up to the maximum energy level. So a MegaBurst pattern consisting of four pulses, which lasts for 36 ns in total, can deliver up to four times greater than the maximum single pulse energy. Note that the burst energy is delivered to the same small target area as a single pulse, even when the laser beam is moving at a very high speed.

A PicoBlade laser operating in MegaBurst mode can therefore achieve much higher (burst) energy and fluence than the same product operating in conventional single-pulse mode.

This gives the user of laser micromachining equipment a dramatically increased range of options for developing a process and for matching its operation to the characteristics of the workpiece. With the ability to deliver burst energy levels far greater than the maximum energy per single pulse, the user can now adjust the pulse repetition rate, overlap, beam diameter and beam velocity to optimize results, in terms of quality and throughput, which might not have been possible before.

What this also means is that laser micromachining equipment can achieve increased levels of energy and output power at low PRF values below 200 kHz, without exceeding the pulse energy threshold at which the laser would be damaging itself (see Figure 2).

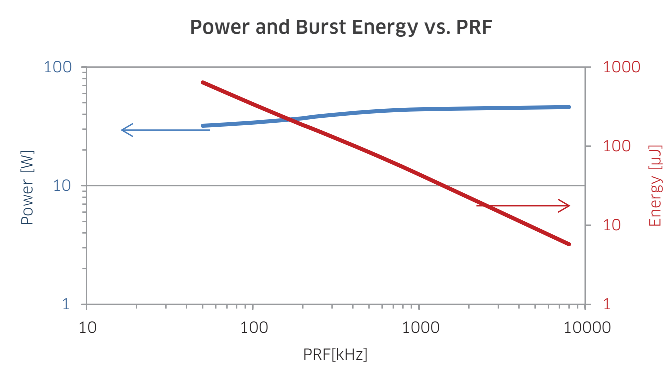

Figure 2: Plot of burst energy and average power over the permitted PRF range in a PicoBlade micromachining laser that features the MegaBurst function

Filamentation effect

There is another interesting benefit of MegaBurst operation in the atomic structure of the machined material. In a multipulse burst of the short duration generated by the MegaBurst function, the first pulse in the burst can serve to prepare the surface for subsequent pulses, opening a funnel in the surface material through which the energy of the second and subsequent pulses can pass. In general, the MegaBurst capability gives the user the freedom to configure operation so as to deliver multiple pulses which resonate with the relaxation state of the material. The first pulse or set of pulses may modify the surface, while subsequent pulses may perform the ablation.

PicoBlade support for MegaBurst operation

MegaBurst, an optional feature of both the PicoBlade and PicoBlade 2 micromachining lasers from Lumentum, is available with standard MegaBurst patterns. Other burst patterns at or above 200 kHz can be created by the user. The PicoBlade lasers may also be configured with custom MegaBurst patterns on request.

For more information about other PicoBlade options giving the operator enhanced control of the pulse format, pulse timing, and energy for optimum throughput—FlexBurst™, SYNC, and AccuTrig™ features—contact Lumentum.

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