Wave Forms: A New Laser Tool

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Possible marks from new wave forms processing.

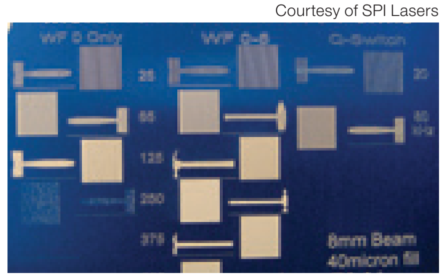
Courtesy of SPI Lasers

An innovative laser design provides pulsed energy differently than traditional mirror/Q-switch cavities. It offers optical engineers a new option for quick processing and fine pulse control.

In a new laser design that uses an arrangement of single-pass amplifiers, the single-pass master oscillator-pulse amplifier (MOPA) has no mirrors or Q-switch because the power is released in one single cascading pulse down a charged fiber gain media. This allows the laser pulses to form arrangements called wave forms—specially designed seed pulses combined with precise energy setting in the laser amplifiers.

This balance of pump energy and rapid discharge creates a maximized power pulse that is essentially equivalent to a large surge of energy striking a target in a shorter period than other laser designs. This means that more energy is available to do useful work at higher frequencies. The result is that galvo scanning markers are able to move faster without losing spot overlap. This benefit can be seen easily by comparing six of the main categories of wave form against lasers with only one pulse shape. While similar at low kHz rates to other laser designs, wave forms show startling differences at frequencies above 100 kHz.

Courtesy of SPI Lasers



A test plate compares surface markings achieved via MOPA wave form marking to those formed via Q-switch laser marking. MOPA can process anodized aluminum at scan speeds of 5 m/s.

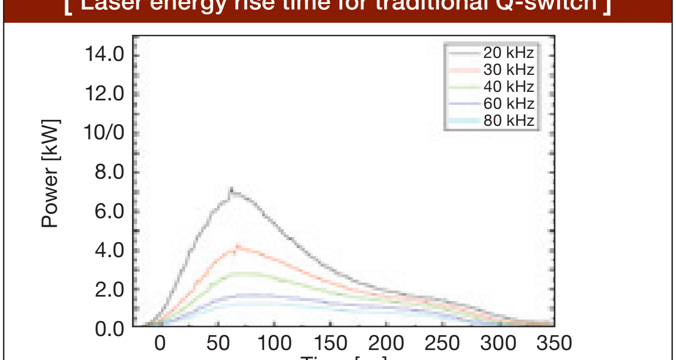
Duty cycles vs. laser pulsing vs. wave forms

Continuous-wave (CW) lasers use pulse-width modulation, which essentially provides a duty cycle of laser-on to laser-off times. Studies performed by SPI on high-brightness CW lasers show brief gains in power spiking up to five times the average power at the beginning of each modulation cycle. Pulsing a laser is more complex than chopping the output on and off. It offers higher power outputs by allowing the laser gain medium to release stored energy in factors 1,000 times the average power.

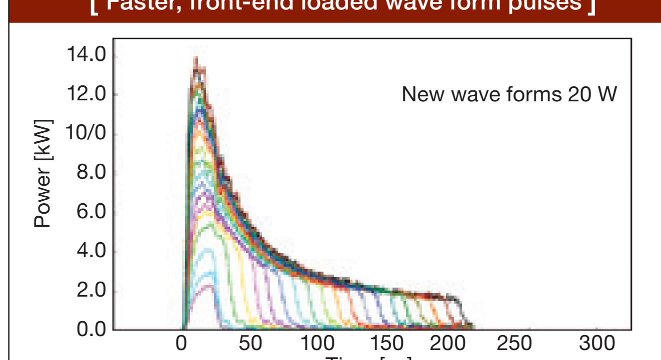
Traditionally, this has been achieved by vibrating an acoustical quartz switch inside the laser cavity. These vibrations prevent photons from being reflected back into the cavity until the moment the Q-switch is turned off. When "fired," the gain media discharges in a gently rising curve with a longer tail at the end of the pulse.

The single-pass MOPA seed-based design is different. Once the gain media

[Laser energy rise time for traditional Q-switch]



[Faster, front-end loaded wave form pulses]



in both the pre- and post- amplifiers are fully charged, a brief seed pulse is introduced into the system.

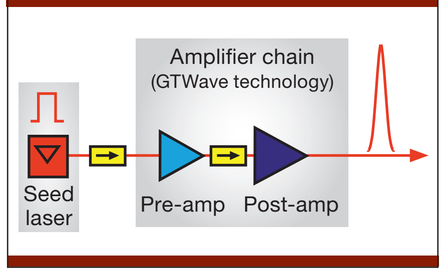
This seed causes a rapid release of energy that is very front loaded. A spike in energy strikes the target in the first 10 ns.

Wave form pulses work rapidly

Wave forms can whiten anodized aluminum at much higher scan speeds than Q-switch systems. Keeping all conditions constant, we configured a scanner system with an 8-mm input beam into a scanhead using a 163-mm f-theta lens with both a 20-watt single-pass MOPA and Q-switch fiber. Patterns were engraved at 5 m/s and at different pulse frequencies. Wave forms 0 through 5 were used on the single-pass MOPA laser, while the Q-switch fiber could only change its frequency.

At 5 m/s, lasers that did not utilize wave forms were unable to even partially

Single-pass MOPA seed-based design



remove the anodized surface at high kHz rates—there was just not enough energy per pulse. The whitest mark was achieved at frequencies above 375 kHz utilizing wave forms 4 and 5. While the Q-switch fiber laser did improve its level of whiteness from 20 to 80 kHz, it did not compare to the white of the SPI logo graphic made using WF4 at 375 kHz.

If one considers the laser pulse as a tool hammering the surface of any target material, there are far more hammers in the MOPA tool kit. Just as boosting the frequency of strokes does not change the property of a mallet strike, increasing kHz alone cannot improve the performance of a Q-switch fiber. Eventually, fixed-length pulses lose their ability to do work at higher repetitions.

For a carpenter to become a fine craftsman, he or she must have access to a wide array of specialized hammers, from claw to ball peen, all the way to the precision tack hammer. In the same sense, wave forms add a new piece of equipment to the optical engineer's tool kit, providing a broader spectrum of ways to apply energy with much higher granularity.

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