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# QCW Fiber Lasers Come of Age

## Wall-plug efficiency, high PPR are just two benefits of new laser technology

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Many reasons exist for companies to use quasi-continuous wave (QCW) fiber lasers, including the fact that a fiber laser combines the drilling and welding advantages of a pulsed Nd:YAG laser with the cutting capabilities of a $CO_2$ laser.

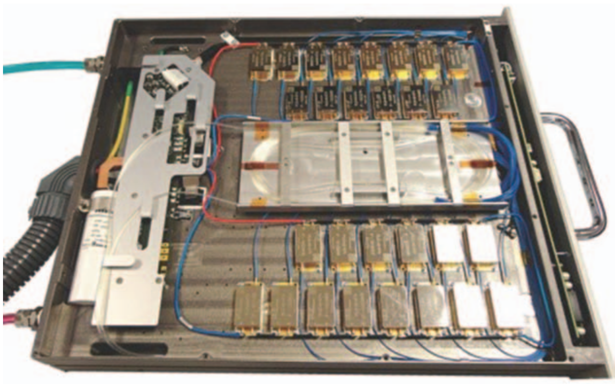
This combination of processing performance is not possible with the older technology, so in the past many companies owned both $CO_2$ and Nd:YAG lasers to handle a wider range of applications. Because QCW fiber lasers can be operated in both pulsed and continuous wave (CW) modes, a single laser can handle the spectrum of applications that used to require two different lasers.

Today tens of thousands of fiber lasers are being used 24/7 in numerous industries and applications. These laser systems are rapidly replacing both Nd:YAG lasers and $CO_2$ for many material processing applications. In addition, companies are replacing older lasers on existing production lines while keeping their current motion equipment with minimum loss in production.

## Why QCW?

Quasi-continuous wave fiber lasers are now part of the equation for modern fabrication shops.

They can operate in both CW and high-peak-power pulsed modes. Unlike traditional CW lasers, for



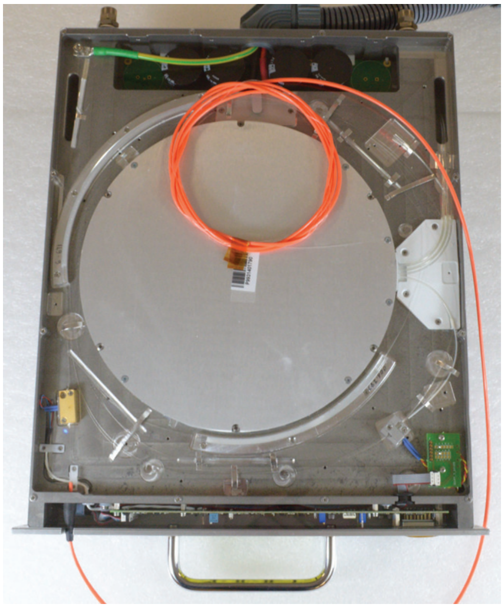


**Figure 1**
A fiber laser is a solid-state device with a continuous piece of fiber permanently sealed against dust and dirt, with no moving parts.

which peak and average power are always the same in CW and CW/modulated regimes, QCW lasers' peak power in pulsed mode is increased by a factor of 10 over the average power.

This allows generation of microsecond and millisecond pulses with many joules of energy at repetition rates from tens of hertz to many kilohertz, with multiple kilowatts of average and peak power.

## Consumables and Maintenance Requirements

**Figure 1** shows a typical fiber laser resonator. It is a solid-state device with a continuous piece of fiber permanently sealed against dust and dirt and no moving parts or free-space mirrors. The resonator does not require any adjustments, has no consumables, and requires no maintenance.

These features help ensure the laser's performance, resulting in stable and consistent processing for years of operation. With no consumable parts, there is no degradation in output power, the quality of the laser output does not change, and regular adjustments by skilled technicians are no longer needed to keep the laser processing system working as expected.

## Wall-Plug Efficiency

Wall-plug efficiency (WPE) is the metric for efficiency with which a laser converts consumed electricity into optical output power.

The solid-state fiber resonator of a QCW fiber laser efficiently cools itself because of its large surface-to-volume ratio, allowing it to achieve a WPE of greater than 30 percent with passive cooling schemes. Because QCW fiber lasers offer a tenfold WPE increase when compared to other laser systems, it is easy to understand why their acceptance has expanded so rapidly in the last few years.

> **The combination of single-mode high-power density, high pulse energy, high peak power, and high repetition rates allows for high-throughput micromachining of a variety of materials, including metals, silicon, alumina, sapphire, and glass.**

The drastically reduced electrical costs, combined with no consumables, no spare parts, lower maintenance, and no warm-up period, result in considerable savings, and, in some cases, the cost of the new laser can be justified on these savings alone.

## Typical Specifications and Throughput

QCW fiber lasers generate trains of pulses with multiple joules to tens of joules of energy at microsecond to millisecond pulse durations. They also offer several times higher maximum average powers (from 150 W to over 2 kW) with a maximum pulse repetition rate (PRR) up to 50 kHz. QCW lasers are also capable of operation in CW/modulated mode with a duty cycle up to 100 percent.

For example, a 20-kW-peak-power QCW laser can be operated at 2 kW in CW or pulsed mode, generating 200-joule pulses at 100 Hz, 20-joule pulses at 1 kHz, or 4-joule pulses at 5 kHz.

Because of their higher average powers and PRRs, QCW fiber lasers offer a significant increase in process speed and thus productivity. For example, when cutting dilution holes or windows on an aerospace component, the cutting feed rate for most lasers is between 5 and 10 IPM, depending on the part configuration and the material thickness. When a QCW fiber laser is used to cut the same holes on the same component, the feed rate is 20 to 30 IPM or higher.

## Modes of Operation, Pulse Modulation and Shaping

An advantage of QCW fiber lasers is their ability to rapidly increase and decrease the power level and switch from pulsed to CW operation mode on-the-fly. This is possible due to the absence of thermal lensing in the fiber resonator and to the fast response of the pump diodes, which is impossible to achieve with flash lamp-pumped lasers.

Individual QCW fiber laser pulses can be modulated with analog control or internal pulse generator to achieve the optimal temporal pulse shape for any particular application. The operator can also pre-program the desired pulse trains with customized repetition rates and power modulation.

The operator has full control over pulse duration, duty cycle, frequency, pulse energy, and average power in real time when processing intricate parts (such as sharp corners and narrow holes) or highly reflective and sensitive materials. QCW lasers offer superior pulse-shaping capabilities for production of structured pulses, exceeding modulation capabilities of other technology.

## Chiller Maintenance

Most non-fiber-based lasers must be water-cooled with large chillers that require regular routine maintenance. The deionization (DI) cartridge, particle filters, and DI water must be changed regularly (normally every six months) to prevent water contamination. If the quality of the cooling water is not maintained, the laser efficiency is reduced and the optical elements may become damaged. Companies must keep in stock flash lamps, DI cartridges, particle filters, and DI water and schedule periodic downtime to maintain the laser. These consumable and maintenance issues have been eliminated on fiber lasers; there are no lamps or optics to change, and all of the maintenance and the downtime associated with these items are eliminated.

**Because QCW fiber lasers can be operated in both pulsed and continuous wave (CW) modes, a single laser can handle the spectrum of applications that used to require two different lasers.**

Many fiber lasers are air-cooled, and no water chiller is required. QCW fiber lasers up to 4.5-kW peak power can be supplied with air cooling, eliminating the need for the water chiller. With higher-power lasers, chillers are required, but they are small because of the high WPE of the systems.

## Uptime and Repeatability

Legacy technology lasers require a warm-up time to stabilize the resonator and ensure that the correct laser power is delivered to the workpiece consistently.

When the process is not active, these lasers are usually run in standby mode with the lamps constantly flashing to ensure stable performance of the resonator. With this being the case, the "clock" on the flash lamp life is always ticking away, even when the laser is not actually producing parts.

Fiber lasers are pumped by solid-state diodes that can be turned off completely when the laser is not in use, and the correct laser power is achieved instantaneously,

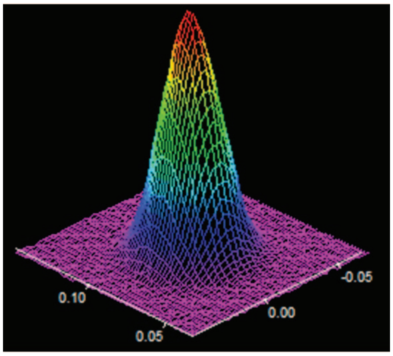
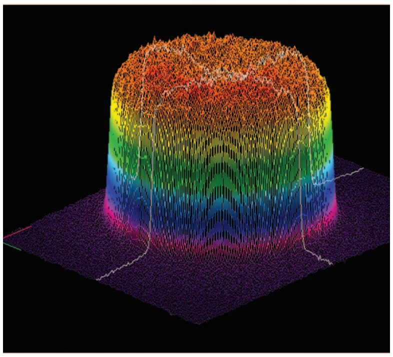



**Figure 2**
SM—Single-mode fiber laser beam profile.



FT—Top-hat, multimode beam profile.

with no warm-up time. Because the fiber laser is turned on only when the process is ready, higher uptime, electrical efficiency, and production volume are achieved.

## Beam Profile Flexibility

QCW fiber lasers are available with either single-mode diffraction limited or multimode output, with the choice depending upon the application. For cutting very thin materials or applications requiring micron spot sizes, the single mode would be the choice. However, the lion's share of high-power applications use the top-hat or multimode models (see **Figure 2**).

The aerospace industry has proven that holes drilled with fiber lasers achieve consistent flow characteristics. This is due both to the improved repeatability of the laser output and the top-hat beam profile.

The top-hat shape results in less taper in holes drilled with a QCW fiber laser.

Whether percussion drilling or trepanning, the top-hat beam profile usually results in less taper. Trepanned holes have the added benefit of a smaller recast layer than percussion-drilled holes. With a fiber laser, which creates no thermal lensing, the spot size remains constant as power is increased or decreased (the spot size is an image of the fiber core).

The combination of single-mode high-power density, high pulse energy, high peak power, and high repetition rates allows for high-throughput micromachining of a variety of materials, including metals, silicon, alumina, sapphire, and glass.

## Floor Space Requirements

Fiber laser technology allows very high power to be achieved in a very small package. This is attractive to most companies because the reduced footprint of the laser results in a reduction in the overall integrated system footprint required for a given laser process. Companies seem to always be looking for ways to jam more stuff into less space, and the smaller footprint of the fiber laser makes this possible.

## Fiber-Optic Delivery

Not only is the resonator on a fiber laser a long, continuous piece of fiber, the beam is also delivered to the workpiece via fiber-optic cable. There are no free-space optics or mirrors to align, maintain, and replace. The fiber delivery cable has quick-disconnect fittings, and no beam alignment is needed if a fiber change is ever required.

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