# Analyzing the potential of the solid-state laser

## Fiber laser technology begins to penetrate the market

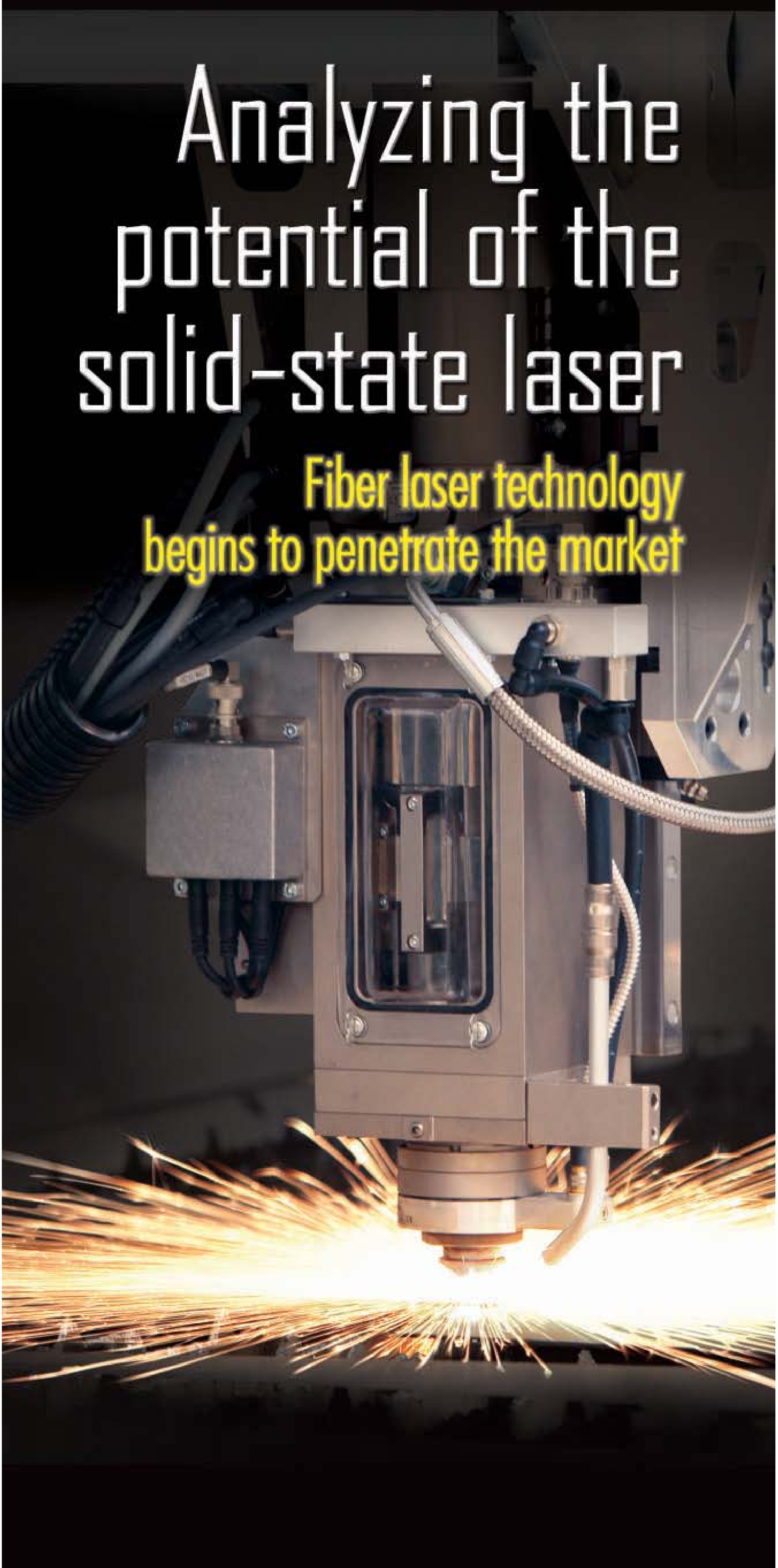


**Figure 1** The fiber laser is beginning to make its mark in sheet metal fabrication.

**By Tim Heston, Senior Editor**

Lasers unleash the power of nature's light packet, the photon. To make a laser, you basically energize, or "pump," electrons into a host medium so that they produce more photons, amplify that energy within an optical resonator (also called a pump chamber), and then send the resulting beam to where it can do work. Smart people have discovered various ways to accomplish this, and the more efficiently they can force these packets of light into a beam of their liking, the better.

And it just so happens that Carlo Dal Medico, sales and production manager for the Italian contract manufacturer Pres Metal S.p.A., works with one of the latest iterations of the technology in the metal fabrication arena. Last year Dal Medico's company became an early adopter of a fiber laser sheet metal cutting system.

### Small Spot, Big Opportunity

Midway between Milan and Venice, on the outskirts of the farming hamlet of Veronella, Pres Metal was launched in 1979 and has grown to specialize in thin sheet metal parts. Fiber laser technology has allowed the shop to cut a range of materials, including highly reflective ones such as aluminum, copper, and brass, all of which happen to make up a lot of Pres Metal's bread-and-butter work: electrical enclosures, oven components, and the like. Dal Medico explained that the fiber laser has allowed the company to take more orders in sectors where it had previously had only a limited presence or none at all.

He held up one component with a pattern of extremely small holes. "This is, for example, the case of a drilling application in the agricultural sector, where the reduction in kerf width achieved using a fiber laser means that we can make very small holes, which has allowed us to accept an order that we would otherwise have had to refuse."

Last year the shop bought Salvagnini's L1Xe-30 sheet metal cutting system, with a 2-kW fiber laser from IPG Photonics (see **Figure 1**). From a distance it looks similar to a conventional cutting laser, but there are important differences. It has a tinted glass enclosure designed specifically for fiber laser applications. The chiller is small, as is the laser power source. From that comes a laser capable of cutting mild steel from 0.028 to 0.40 inch thick without changing the lens in the focusing head, according to Dal Medico. Only a nozzle changeout is required.

As Steve Aleshin, applications manager at Salvagnini America, explained, "There is no need to change lenses when switching between material thicknesses, as the fiber laser's small spot size allows for high-speed cutting even with the use of long-focal-length lenses."

And it cuts fast, especially on thin sheet. On 20-gauge mild steel, it travels twice as fast as a 4-kW $CO_2$ laser. Overall, the machine can cut steel up to 0.709 in. thick, stainless to 0.394 in. thick, aluminum to 0.315 in., and copper and brass (yes—*copper* and *brass*) to 0.197 in.

### The Road to Fiber

In metal fabrication, no laser has penetrated the market as deeply as the $CO_2$ gas variety. To produce a laser, $CO_2$ molecules are pumped as they collide with nitrogen molecules, reflecting back and forth inside the resonator. Think of the $CO_2$ molecule as an elastic band, with oxygen atoms on the sides and one carbon atom in the center. Every time this band is stretched or deformed in a certain way, it produces a photon. Duplicate this action continuously, billions of times over, and you get a powerful laser, these days powerful enough to cut thick plate.

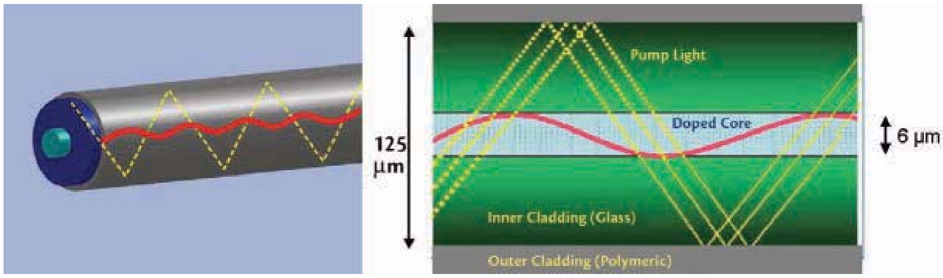
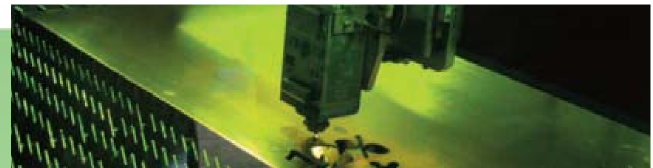



**Figure 2** In a fiber laser, a double-clad fiber, internal reflection serves to efficiently contain and transport energy within the fiber walls.

The $CO_2$ laser is the industry workhorse for a reason: It's inexpensive compared to other legacy technologies like Nd:YAG, and it offers a beam quality suited for cutting and welding metal. But it does have drawbacks. The $CO_2$ laser requires a hefty supply of lasing gas. To get the beam from the resonator to the metal takes careful alignment and maintenance of mirrors. And when it comes to power consumption, they aren't the most efficient systems. They draw a lot of power and produce extremely hot gas that requires cooling. That's basically why the $CO_2$ laser's wall plug efficiency—or the optical power from electricity consumed—is only 10 to 12 percent.

That's plenty high when considering the flash/arc-lamp Nd:YAG, with its 3 to 4 percent wall plug efficiency. In these systems, a lamp pumps a crystal rod to produce the beam. The Nd:YAG laser has several advantages the $CO_2$ doesn't. Being solid-state, Nd:YAG lasers don't need lasing gas, and the beam can be delivered via a fiber due to its lower wavelength—no more mirrors, no more alignment troubles.

## Answering questions about fiber lasers



The fiber laser is a unique animal. The beam is delivered via a fiber and has a beam quality suited for cutting metal. Laser power isn't generated in a gas pumping chamber (as with $CO_2$) or by a pumped crystal rod, as with an Nd:YAG; instead, the power comes from diodes pumping a coil of double-clad active fiber. The laser has a short wavelength, giving it the ability to penetrate some of the most reflective materials. Fiber laser machines can be spotted by their green-tinted glass enclosures, which provide eye protection.

Fiber lasers are expandable. Diode modules can be ganged together to produce more power; generally, the more modules there are, the greater the power and speed. In the sheet and plate metal cutting arena, some are integrating powers previously unheard of in most conventional metal fabrication operations—up to 10 kW in some cases.

As part of this month's coverage of the fiber laser, *The FABRICATOR* sat down with Jeff Cornell, director of sales at Laser Photonics, a Lake Mary, Fla., company that's building laser cutting systems using IPG Photonics' fiber laser source.

Fiber lasers can cut some material extremely quickly. They're solid-state and, according to machine suppliers, cost less to operate. Their short wavelength can be absorbed by reflective metals like copper, brass, and aluminum. They offer small spot sizes and kerf widths.

But they aren't a panacea. As with any laser, actual cutting performance depends on the material the fiber laser cuts. And there are other factors, such as the beam collimator, nozzle design, assist gas delivery, transport fiber between the power source and cutting head— the variables are many. As Cornell explained, a fiber laser shows enormous potential, but that potential can't be realized without weighing the options and knowing exactly what a fiber laser can accomplish on the shop floor.

**The FABRICATOR:** ***The fiber laser's expandability is unique. You add more diode modules and you get more power. How would a fabrication operation utilize, say, an extremely high-powered fiber laser, between 6 and 10 kW? Are we talking extreme thicknesses and cutting speeds?***

***Cornell:*** It's actually a bit complicated. For thin mild steel, around 20 gauge, you can get some very high speeds. And because it uses a short wavelength, it can penetrate reflective material. The fiber laser has an extremely small spot size and high power density, which is why you can cut faster on thin stock with less power. A 2-kW fiber laser can do the work of a 4-kW $CO_2$ laser for thin mild steel, and often cut twice as fast.

But it's not a linear relationship. A certain amount of cutting power does not give you a certain amount of added speed or thickness capability for every material. To cut 1-in. stainless steel, for instance, would require 6 kW from both a $CO_2$ and fiber, if you needed to attain a high-quality cut edge. On the other hand, to cut 0.375-in. aluminum, which is reflective, you'll need a 5-kW $CO_2$ laser, while a 2-kW fiber laser can cut such aluminum very well. So there are some extreme differences in cutting parameters from one material to the next.

When thinking about a $CO_2$ and fiber laser, it's not an apples-to-apples comparison, because they have different wavelengths. For mild steel, fiber lasers can cut faster with less power than a $CO_2$. Fiber lasers can cut brass, copper, and other materials that $CO_2$ lasers can't. Try to cut brass of any thickness on a $CO_2$ laser cutting table, and you may void the machine's warranty. But with stainless steel, you have roughly the same cutting performance on a fiber as on a $CO_2$ laser.

Currently you generally can cut metal 1 in. and less with any cutting laser, at least in most production environments. Unlike a laser, plasma and oxyfuel torches induce a chemical reaction that superheats the metal, and the heat carries on down through several inches of metal thickness. You get a wide kerf, but you get a smooth cut edge. With lasers, you cut with heat from a conical beam, and cut quality comes from the beam shape and position of that focal point.

Think of the beam edges coming down in the shape of an hourglass, converging to a focal point at the center, after which it diverges again. That X shape, the beam length, can be only so long before cut quality degrades. That's one reason that, when you're laser cutting 1 in. thick or more, you'll experience poor kerf and wider swaths of missing material at the top and bottom of the cut. It's following the actual profile of the beam.

In laser cutting, thicker cuts require wider beams. As you cut thicker material, more than 0.75 in., with the fiber laser, we need to defocus or have different optics on the system to make the cuts. If you're cutting thick metal with a narrow beam, the melted material won't be able to evacuate before resolidifying. With a laser, it's all about heat and focus from the beam. The better a metal absorbs the beam's energy and the less it reflects, the better a material generally will cut. With plasma and oxyfuel cutting, it's about a chemical reaction that starts in the plume and continues through the metal thickness.

So realistically, no laser beam can cut 2 in. with good edge quality, because no matter how much power you have, beam divergence will cause defects with such thick material. Yes, you can crank the assist gas up to 100 PSI and cut with oxygen alone to handle very thick plate, but at that point you've essentially turned your machine into an oxyfuel system. You're cutting with a chemical reaction, and on the laser that's usually not a production-ready process—at least not yet.

**The FABRICATOR:** ***That said, what would be an application for a 6- to 10-kW fiber laser cutting system?***

***Cornell:*** First is speed. You might need a 10-kW to cut material at a very high speed to meet customer demand and achieve an acceptable return on investment. This can apply even to challenging materials like stainless steel. On the extreme end, a 7-kW fiber laser could cut 0.5-in.-thick stainless at roughly a half-inch a second to attain good cut quality. To increase that speed, you could upgrade the fiber laser power to 8 or even 10 kW.

Or, you might be beam switching, where you can divert the power to run several cutting systems, a cladding system, or a welding system—at the same time. For instance, one 10-kW fiber laser power source essentially could turn into two separate 5-kW laser power sources. With a 7-kW system, 4 kW of power could go to one cutting system, while 3 kW could go to another. Or one laser source could feed both a cutting and a welding system.

Beam switching doesn't apply to everyone in manufacturing. It's very advanced, and it requires some finely tuned processes. Machine synchronization has to be just right. But it's something that can be offered with a fiber laser, and it's something that a $CO_2$ laser just can't do.

**The FABRICATOR:** ***Within metal fabrication, who do you feel will become the early adopters of this technology during the next several years?***

***Cornell:*** Again, the fiber laser can cut thin mild steel extremely quickly, faster than any alternative, unless you're blanking with a high-speed stamping press. Also, if a shop wants to build a niche cutting specialty reflective materials, a fiber laser would be attractive.

That said, large fabrication operations likely will experience the most dramatic benefits. Fiber lasers are more energy-efficient and have less maintenance. Modern laser diodes can last 200,000 hours. To maintain a $CO_2$, it might cost $20,000 to $40,000 to refill or refurbish a gas resonator, and it might cost $10,000 to $12,000 to get new mirrors. And this doesn't include associated downtimes while repairs are taking place. Those costs add up, particularly for large fabrication operations.

A small job shop with a modern $CO_2$ laser running six hours a day might not see dramatic operating-cost savings. But those who have many flat sheet metal cutting systems on the floor are taking a hard look at fiber technology. These companies have the most cost associated with their manufacturing. When you look at shops operating multiple systems over two or three shifts, you start to see enormous costs for maintenance and associated downtime. At least initially, those organizations may be the biggest users of fiber laser technology.

***Laser Photonics, a member of the Comvest Group, 400 Rinehart Road, #1000, Lake Mary, FL 32746, 407-829-2613, www.laserphotonics.com***

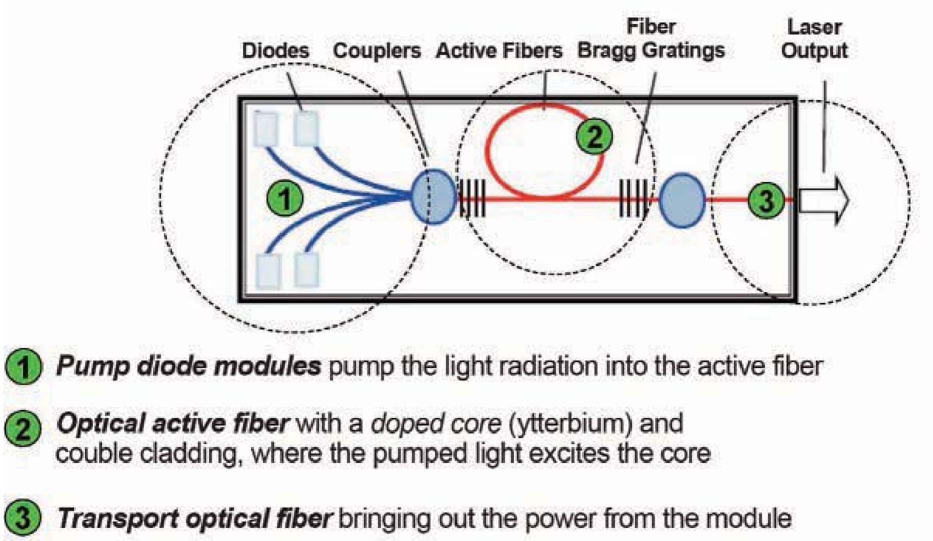



**Figure 3** The three major components of a fiber laser module are the laser diodes (1), a double-clad active fiber (2), and a transport optical fiber (3) that brings the power out of the module and to the laser focusing head for materials processing.

But these advantages *don't* make the system more energy-efficient or less expensive. The flash/arc lamp emits a variety of wavelengths, and only a few are absorbed by the crystal rod. The rod also isn't heated uniformly, with a hot skin and cooler middle, which contributes to poor beam quality, so often it isn't the best choice for cutting.

The first step in the right direction came by switching out the lamp with a diode laser, which uses a semiconductor as the lasing medium and boasts high wall plug efficiency. Diode lasers' low power and beam quality left something to be desired if you wanted to cut most metal. But these devices can be used to pump another, more powerful laser's active medium. For the Nd:YAG, these diode lasers can pump the rod with specific wavelengths, which means less energy is wasted. This increases Nd:YAG's wall plug efficiency, but it still doesn't bring beam quality close to the $CO_2$ laser's. To do that, you need, among other things, to remove that heat variation.

Researchers needed something with more surface area that could absorb heat uniformly and efficiently: technically speaking, something that would increase the so-called *surface-to-volume ratio*. Through the years they've found several ways to accomplish this, and one way led to the technology now sitting on Pres Metal's shop floor—the fiber laser.

Instead of using a crystal rod for the excitation medium, these lasers use double-clad fibers doped with rare elements, including ytterbium (a great Scrabble® word, by the way). These coiled fibers, initially developed in the telecom business, are long, have more surface area than the Nd:YAG's rod, and hence increase that all-important surface-to-volume ratio. Heat distributes evenly, and a high-quality beam is produced.

Multiple diode lasers emit specific electromagnetic wavelengths into a coupler, which in turn feeds into a coiled, double-clad fiber (see **Figure 2**). As Randy Paura, Canadian regional manager and processing consultant for IPG Photonics Corp., Oxford, Mass., explained, "Total internal reflection serves to contain and transport this energy efficiently within the fiber walls." He added that controlled release and reflection are accomplished at the fiber ends using Bragg gratings, named after the physicist who in the early 1900s developed the basic research that made these special refractory devices possible. The beam then exits the unit through a transport optical fiber, which brings the laser to the materials processing focusing optics designed for cutting, welding, cladding, or other processes (see **Figure 3**).

"The laser energy that starts in the fiber stays in the fiber until delivered to the work object," Paura said.

## Fiber Advantages

What makes the fiber laser unique is that the resonation actually happens inside a double-clad fiber—no crystal rod (Nd:YAG) or blazingly hot gas cavity ($CO_2$) required. This is why so much fiber laser power can be generated from so little space. Pres Metal's 2-kW source contains modules consisting of diodes that pump the double-clad fiber. Because the system generates less excess heat, fiber lasers require only small chillers. Overall wall plug efficiency is around 28 percent, more than twice that of $CO_2$.

The result is an efficient, solid-state (less maintenance), high-powered, short-wavelength, high-beam-quality laser delivered via a fiber. These days the diodes pumping the fiber last on the order of several hundred thousand hours. And because the beam is transported to the head through a fiber, the beam path length never changes, eliminating the need for complex and expensive compensation devices.

> "The laser energy that starts in the fiber stays in the fiber until delivered to the work object."
>
> —Randy Paura, IPG Photonics Corp.

Fiber laser cutting systems can be easily spotted by the tinted glass, designed so that operators can gaze safely at the work and be protected from the invisible scattered or diffuse reflected laser beam on the other side. And though the machines do not use lasing gas, they do use common assist gases, such as oxygen, nitrogen, argon, and compressed air.

Then there's the speed advantage. On thin stock, 20 to 22 gauge, the fiber can cut twice as fast as a 4-kW $CO_2$ laser. At the upper level of a laser's thickness range, though, the speed difference between a 2-kW fiber and 4-kW $CO_2$ becomes nil. "Between 7 and 12 gauge is where the crossover in speed occurs," explained Salvagnini's Aleshin. "As the materials get thicker, the speed advantage goes away as power becomes more important in the equation."

Achieving extreme power can be complicated, but the idea of the fiber laser's expandability still is elegantly modular. In general, the more diode modules you connect together, the more power you get, as long as the transport fiber has a diameter sufficient to handle all the energy feeding into it. In recent years IPG Photonics began producing fiber lasers of 50 kW (that's right, *five-zero*). Such high laser powers aren't needed for most fabricating operations, of course, but the fact these lasers even can be produced at such powers is impressive all the same.

Is machine cost an issue? According to Bill Bossard, president of Salvagnini America, not really. "Right now we're getting comparable performance from a 2-kW fiber laser to that of a 4-kW $CO_2$. The price difference between those two machines is essentially zero."

Bossard added, "So if I can cut twice as fast and it's six times less expensive to operate—well, that forms my opinion as to where fiber lasers are going in the market."

## All About Efficiency and Quality

Earlier this year the laser turned 50. On May 16, 1960, Theodore Maiman of Hughes Research Labs became the first person on the planet to build **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. (Thank goodness the acronym stuck.) Since the first commercial sheet metal cutting lasers emerged in the late 1970s, the technology has transformed many a metal fabrication operation.

According to sources, there's little doubt $CO_2$ laser systems will remain the industry workhorse for years to come. In Italy, for example, a combination $CO_2$ laser/punch system remains on Pres Metal's floor, and it likely won't be going anywhere soon. The job shop's fiber laser is another tool to help produce quality products as quickly and efficiently as possible. Like other shop floor systems at Pres Metal, the fiber laser machine has lights-out capabilities, with automated material handling. Since it was installed last year the company has been running the machine three shifts and over weekends, with 52 hours of continuous, unattended operation every week.

"During the day we produce samples and manufacture small batches, leaving longer production runs to the unattended night shift and weekends," Dal Medico said.

That kind of efficiency likely will remain a goal of fabricators everywhere, no matter what new machine tool technology reaches the shop floor. FAB

***Senior Editor Tim Heston can be reached at timh@thefabricator.com. Images courtesy of Salvagnini America.***

***Salvagnini America Inc., 27 Bicentennial Court, Hamilton, OH 45015, 513-874-8284, www.salvagnini.com***

***IPG Photonics Corp., 50 Old Webster Road, Oxford, MA 01540, 508-373-1100, www.ipgphotonics.com***

***Pres Metal S.p.A., Veronella, Italy, www.presmetalspa.it***