Over 50 Percent Wall-Plug Efficiency Fiber Laser

World record wall-plug efficiency for high power industrial lasers

High power laser performance is determined by output power, beam quality and stability. Other key factors are total cost of ownership, size and weight. At the moment, IPG's fiber lasers achieve single mode beam quality up to an output power of 10 kW. The first 100 kW fiber laser for material processing was delivered by IPG in 2013. High performance fiber lasers from IPG have been established in industry for more than 15 years in 24/7 production. Significant improvements in wall-plug efficiency occurred in recent years from 25 % in 2008 up to 50 % in 2015 (Fig. 1).

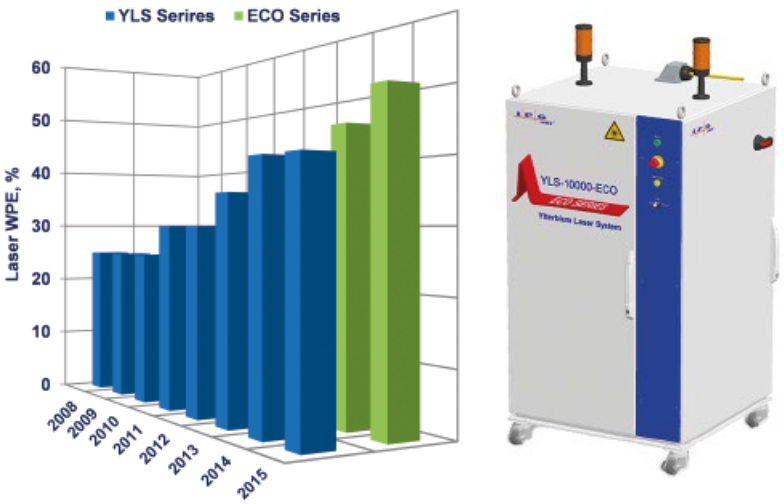

Fig. 1 The development of the wall-plug efficiency (WPE) in the last years

Reducing energy costs is a key theme in the manufacturing industry. Energy is a large factor of the total cost of the end product, driving demand for energy-efficient technology. Between December 2012 and December 2015, all non SMEs performed a so-called energy audit according to DIN EN 16247-1. Exceptions include companies that already work with an energy management system according to DIN EN ISO 50001. This new regulation helps show potential for improvement in energy-efficiency and environmental compliance.

The new ECO laser family represents all advantages of IPG industrial lasers with 50 % wall-plug efficiency. This new development demonstrates the advantage of vertically integrated industrial laser production. All the key components are developed and manufactured in-house. Each component has the potential for higher efficiency but the balanced optimization of each component part leads to the maximum possible total wall-plug efficiency. Examples are the pumping diodes. The single emitter diodes are manufactured using telecom-proven technology and processes. Each pump diode is qualified to telecommunication industry standards, which sets IPG apart from all alternative industrial pump diodes manufacturers.

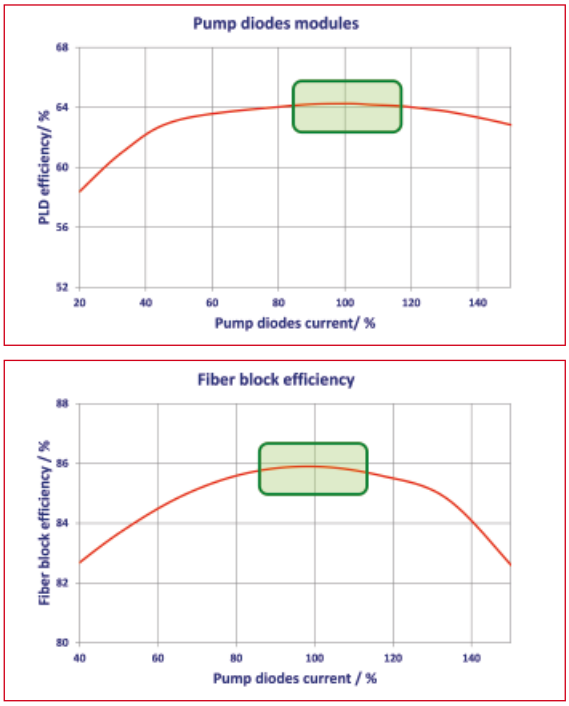

Fig. 2 Efficiency of pump diodes and fiber block

The path to 50 % wall-plug efficiency

The key reason for a higher efficiency is not a single component; instead the interaction of various components makes it possible to establish the highest efficiency in a fiber laser. The main components for optimization are categorized as follows:

- Diode modules design optimization
- Advanced design of fiber blocks
- Active and passive fibers; design optimization
- Small insertion losses of IPG components: a) feeding & process fibers, b) beam switches & fiber couplers
- Laser modules with digital electronics
- IPG's power supplies

The challenge is to optimize all individual components to a higher efficiency and to keep the best functionality with all components. For example, the efficiency of the laser pump diode design and optimisation are important. The wavelength is optimized that it has a maximum absorption at a current of 6 A (Fig. 2, top). Here, the pump diodes reach an efficiency of 64 %. This part of the optimization describes the conversion of the electrical current into the optical pump wavelength of 975 nm. Consequently, the efficiency of the fiber block was improved to a higher value. A key part of a fiber block is the active fiber. It introduces amplification by mixing the propagating light with pump laser light, in the presence of rare earth metal ions embedded in the fiber core. The active fiber transforms optical power at 975 nm into 1070 nm, the laser operating wavelength. The optical fiber's unique properties make it an ideal active gain medium for amplification to higher powers. It is flexible and easy to handle. The huge surface to volume aspect ratio facilitates heat removal and helps to avoid thermal lensing. Points of improvements to higher efficiency are splice points of the pump fiber and general heat management of the whole fiber block. All in all, the fiber block efficiency achieved today is around 86 % (Fig. 2, bottom).

The ECO lasers include new digital control electronics of laser modules, replacing the analog modules electronics. With additional optimization the conversion efficiency of input DC voltage into PLD's current goes up to

Fig. 3 Example of wall-plug efficiency (WPE) by a YLS-6000-ECO

98 %. A laser module includes a fiber block, pump diodes and an electronic controller. The entire laser module with all components achieves an efficiency of 54 %. In addition to module electronics, the power supply of the laser is critical to overall efficiency of the laser. The peak conversion efficiencs of input voltage from mains into the DC voltage that is required for laser modules is 96 %.

The optical efficency is influenced by losses in optical components. IPG manages the development and manufacturing of all optical components in our fiber laser system. Besides fibers, we make other critical optical components, including lenses for beam switches or couplers and optics for the fiber outlet. The coating plays a crucial role in optimizing these optical components. In contrast to conventional coatings, IPG uses multilayer coating. By optimizing the selection of raw materials, the composition of the coatings is controlled. Power losses from optical surface should be kept low as possible. For instance, insertion loss for fiber-to-fiber couplers and beam switches are under 1.5 %. The coatings of optical bulk elements contribute to high efficiency; we observe < 0.2 % losses of any optical bulk element.

In summary, the efficiency of the whole high power fiber laser system achieves over 50 % (Fig. 3). This is only possible because IPG is able to design and manufacture the whole product line and component parts of a fiber laser system.

Advantages of in-house chiller development

An additional factor that significantly contributes to energy efficiency is the corresponding chiller for each laser system (Fig. 4). To reach optimization between chiller and laser, their interdependence must be managed. For this reason IPG has its own laser chiller product line. One key challenge is the communication between laser and chiller to facilitate switch-on and switch-off timing. IPG's communication protocol optimizes the system so that the chiller only operates when it is really necessary. The following features are uniquely combined in the new chiller systems:

- Energy-efficient with scroll compressor by standby
- Well-spaced water cooled condenser
- Additional sub-cooling for higher efficiency
- Regulation of cooling water rate via CAN bus connection laser / chiller
- Closed cooling circuit for optics
- Special compact design for integration

In combination, the laser with optimized chiller wall-plug efficiency is up to 46 %.

There are two kinds of laser chillers available. Water-to-air and water-to-water chillers for fiber lasers with output power up to 6 kW. By using only a heat exchanger the efficiency can reach even higher compare to a chiller.

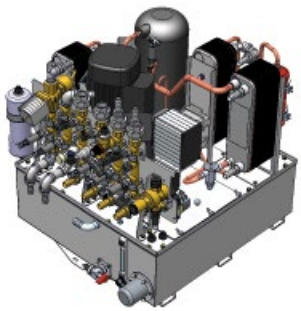

Fig. 4 IPG chiller layout

Fig. 5 YLS CUT laser

Innovation in fiber technology

Because of a higher efficiency, it is possible to generate more laser light in one laser module. This will allow manufacture much more compact laser products. One example is the new YLS CUT laser (Fig. 5). It is specifically designed for high performance in harsh cutting environments. Features are a compact design with a hermetically sealed cabinet. To optimize internal humidity a dehumidifier is installed as standard. The YLS CUT Series contains all the latest technical efficiency improvements for diode modules, fiber modules, digital electronics and power supplies.

Another new market innovation based on a compact design is the multicore fiber laser. There are multiple applications in the high power range where the multicore fiber laser has advantages against standard laser systems. Basically, a defined number of fibers from the laser can be used. Each fiber has independent power control, opening up a wide range of application possibilities. One current application in field is brazing of hot dip zinc coated steel with a tri-focal fiber laser (Fig. 6). In commercial laser brazing achieving a high quality seam with hot dipped coated steel remains a challenge, in comparison to electrolytically galvanized zinc coated steel. In tri-focal laser brazing, the main laser spot is accompanied by two smaller spots, with a defined separation. The two small spots are located on the edge of the brazing seam and ablate a part of the coating, immediately prior to brazing. The small spots actually clean the brazing path so that the filler material flow significantly improves. The result is a reproducible brazed joint with increased strength and better appearance.

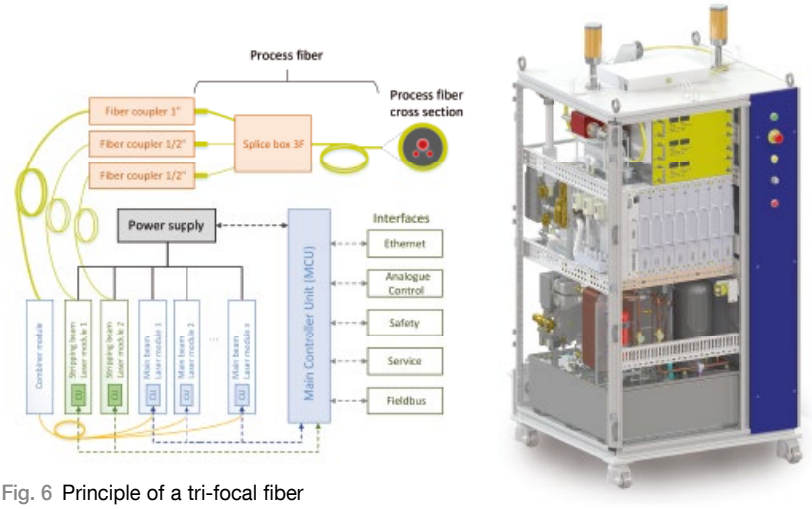

Fig. 6 Principle of a tri-focal fiber

Generally key effects are:

- Reliable brazing process
- Increased brazing speed
- High quality seam appearance
- Inline cleaning process
- Maximize joint strength

The continuous improvement of processes requires laser beam sources with adaptable properties. For many years, IPG has offered its customers a test fiber laser system, in the Burbach application center. The multicore fiber laser offers new ways to optimize a wide variety of process developments in various markets. The tri-focal fiber laser is, for now, ideally adapted to the brazing processes. However, in other applications a multicore fiber laser will realize significant benefits using more fiber cores, different fiber diameters or independently powered multi-cores.

Michael Stark
IPG Laser GmbH,
Tel.+49(0)2736 4420 8428,
mstark@ipgphotonics.com,
www.ipgphotonics.com

Laser Beam Shapes Under Control

When the application dictates the laser beam shape Industry 4.0 beckons

Since 2008, Limo has been supplying the Prague-based company Medicom with industrial laser systems that have proven effective in process-stable laser transmission welding for plastic fuel filter enclosures.

"Limo has been Medicom's key supplier of diode laser modules since the year 2000," says Michal Horáček, Project Manager Industrial Lasers Division at the Prague-based Medicom Inc., one of the world's leading manufacturers of laser systems for industrial production and medical technology. The use of these components in laser systems for the medical industry went so well that, after eight years, the two sides expanded their business relationship to include the industrial sector. Horáček notes: "When we started a new product line of welding lasers in 2008, Limo products were our first choice because of their high performance and excellent reliability."

Since then, Limo has supplied a large number of industrial laser systems (ILS) that Medicom integrates into its welding lasers. These systems comprise fiber-coupled 200 W diode laser modules that feature an intelligent laser processing head and a sensor for non-contact temperature measurement (pyrometer)

Fig. 1 The industrial laser systems from Limo are the "heart" of Medicoms welding lasers, which are used by well-known automotive suppliers for the reliable production of pressure- and liquid-tight plastic fuel filter enclosures. (Source: Medicom)