Fiber Laser
WELDING GUIDE

IPG PHOTONICS®

FIBER LASER

Welding Introduction

Welding with fiber lasers offers unrivaled benefits as compared with traditional joining methods. Laser welding is a non-contact process with no tool wear or consumable usage and imparts minimal heat input resulting in small heat affected zones and minimal part distortion. Laser welding is the most reliable solution for high-speed, high-quality joining across a wide range of material combinations and thicknesses in nearly every industry.

Laser welding simply requires a laser source and fiber optic cable connected to a welding process head, each with options to best match desired welding results. Materials to be joined can be moved below a stationary process head or for higher precision joining of parts with more complex geometries, a multi-axis motion system can be employed. Industries such as electronics, medical and automotive rely on lasers to weld both normally challenging dissimilar and reflective materials consistently and efficiently.

IPG fiber laser innovations are on the forefront to further enhance the quality, speed and flexibility for welding applications while reducing overall costs. For high-speed spatter-free welding, adjustable mode beam lasers dramatically reduce the amount of rework and scrap. Real-time inline weld monitoring offers unmatched quality assurance of every part produced without the need for destructive testing. Wobble welding creates superior aesthetic finishes with no pits or cracking for normally challenging material combinations and poor part fit-up. These technologies are seamlessly integrated into scalable, automated welding systems enabling manufactures to increase part quality and overall productivity of their product lines to match the pace and needs of our leading manufacturers.

BENEFITS OF
Fiber Laser Welding

HIGHEST QUALITY & VERSATILITY

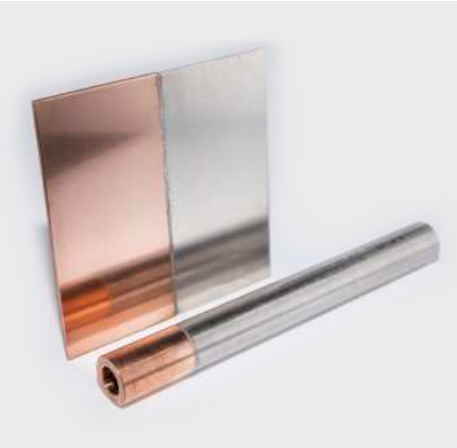
Laser welding provides high-quality joining across the widest range of material combinations for parts small and large. Minimal heat input creates small heat affected zones (HAZ) that result in minimal distortion. Normally challenging material combinations including those highly reflective are joined consistently and easily with high-strength results and minimal post processing required. When integrated into a system, parts with complex geometries that are impossible to process with traditional methods are precisely joined safely and repeatedly, enabling manufactures to benefit from new part design that takes advantage of laser welding versatility.

HIGHEST PRODUCTIVITY & FLEXIBILITY

Laser welding offers unmatched productivity for high-volume joining applications. Laser sources of varying powers and modes are matched with welding heads to maximize throughput while meeting exacting part specifications. Robotic automation and manufacturing system integration further increase processing speeds and provide connectivity and intelligence for smart manufacturing. Real-time inline weld process monitoring and control provides traceable part data and unmatched quality assurance of every weld before, during and after the welding process. Ensuring that only good parts are shipped and eliminating the need for costly and time consuming traditional destructive testing increases overall throughput and decreases the overall cost per part.

HIGHEST RETURN ON INVESTMENT

IPG fiber lasers are the most energy efficient and offer the highest powers in the smallest footprints. Less power consumption and less floor space required add up to dramatic cost savings while freeing up room on your shop floor. IPG fiber lasers are also the most reliable in the market, more uptime means more productivity and less worry of costly downtime. Spatter-free laser welding reduces costs associated with rework and scrapped parts. Further savings are realized through no consumable usage and minimal required manual labor.



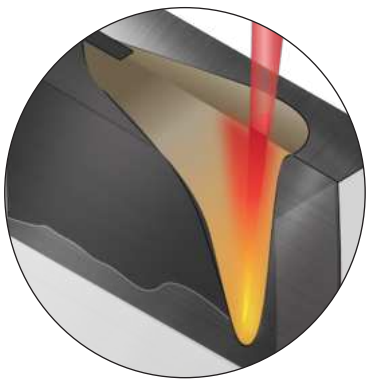
WIDEST RANGE OF MATERIALS

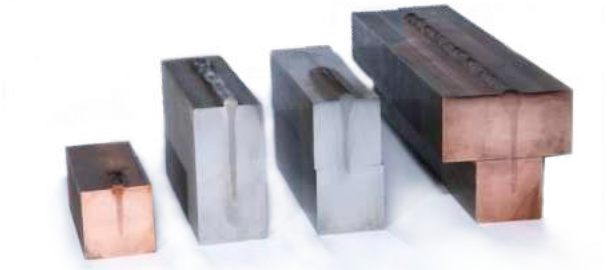
Laser welding is not just for typical applications such as in shipbuilding, construction, automotive or aerospace, it is also being used more complex components found in electronics, medical devices and electric vehicles. Modern components call for modern joining technologies capable of processing materials ranging from thin films to thicker dissimilar and reflective materials requiring high-precision welds without distortion or damage. As components become increasingly smaller and more complex, continuous innovation of IPG laser welding solutions ensure the most reliable and proven material joining in the industry.

MULTIPLE WELD TECHNIQUES FROM A SINGLE SOURCE

Traditional welders are highly accustomed to the basic types of joints such as overlap, butt and fillet; however, it is uncommon that a single operator or tool is capable of creating these joints reliably and consistently. The flexibility of laser welding provides manufacturers with a single source solution to create multiple joint types across a wide range of materials and thicknesses. The majority of laser welds are keyhole where an intense spot produces deep and narrow high-quality welds at high-speeds. For joining of materials at the surface level, conduction welding utilizes a wider spot for shallow welds with a resulting smooth finish.

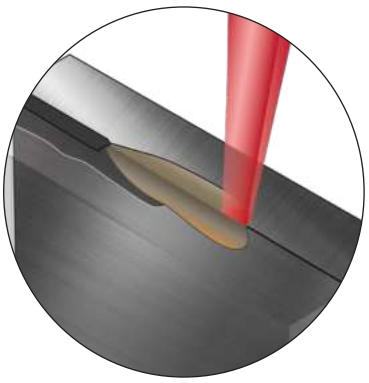
Laser Keyhole Welding





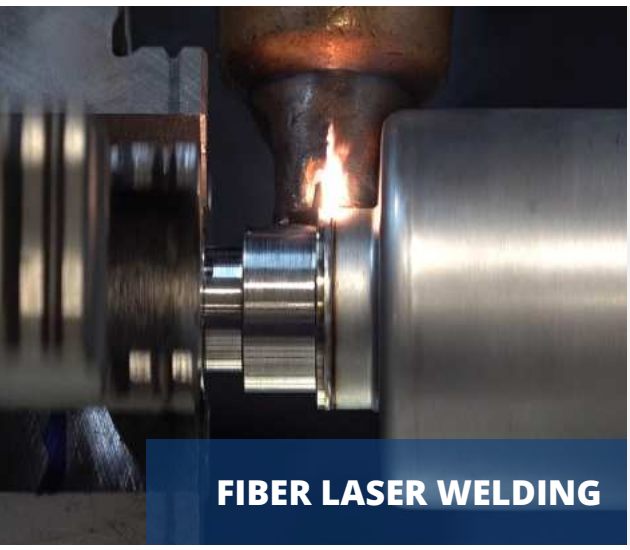
Up to 100 mm penetration with multi-pass two sided welding

Laser Conduction Welding



Fast, spatter-free, shallow welds

FIBER LASER WELDING vs.
Conventional Methods



FIBER LASER WELDING

Electron beam welding provides excellent weld quality, but produces x-rays and requires a vacuum chamber which is costly and limits the size of the work piece.

Fiber laser welding:
- Faster cycle times
- More cost effective
- No part size restriction
- Much lower energy consumption
- Does not require precise part fit-up or constant system calibration

ELECTRON BEAM WELDING

FIBER LASER WELDING

PAW is faster than TIG, but much slower than laser welding. Having a large melt pool, PAW is good for badly aligned parts, but creates too much heat for many applications.

Fiber laser welding:
- Provides higher precision with lower heat input; process is faster and non-contact
- Wobble welding is as effective on misaligned parts with no daily maintenance required

PLASMA ARC WELDING (PAW)

Why are more manufacturers turning to welding with fiber lasers as opposed to traditional and more conventional methods?

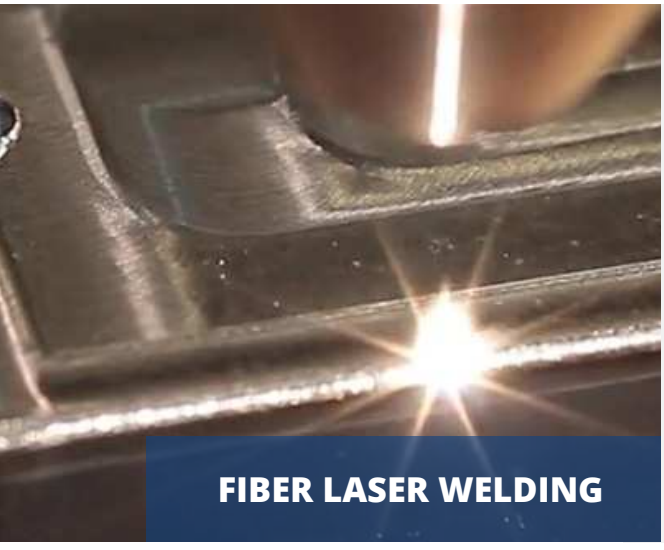
Manufacturers have several material joining methods to choose from, each having their own benefits and advantages. Worldwide, more manufacturers are welding with fiber lasers due to their increased uptime and throughput, lower operating costs and overall improved quality.

RSW requires high power, electrodes to be touching both sides of the materials and is limited to generally thinner materials

Fiber laser welding:

- Only needs single-side access
- **4X** higher process speeds
- Produces higher-strength welds
- Eliminates the time and cost for electrode replacement
- Less heat input
- Repeatable results

RESISTANCE SPOT WELDING (RSW)



MIG and TIG manual welding requires skilled operators that are limited by part access resulting in low precision, low throughput welding.

Fiber laser welding:

- Up to **10X** faster
- Provides more precision with lower heat input
- No consumables and less edge preparation
- Better handles dissimilar metals
- Easily automated and access for hard to reach areas

MIG & TIG MANUAL WELDING

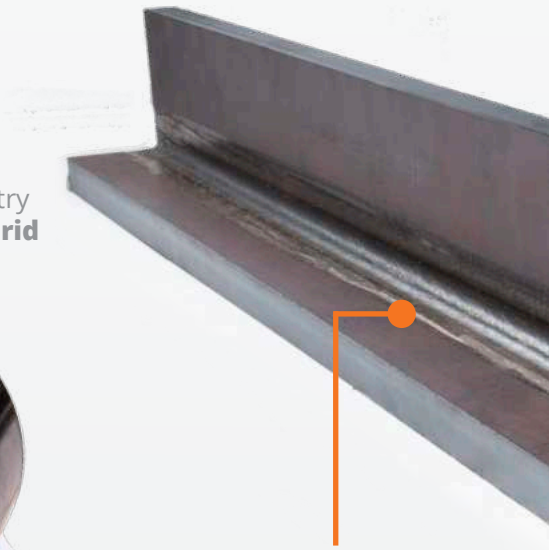
IPG FIBER LASER Welding Samples

Precision Welding of Small
Parts & Electronic Components

Copper & A
Busbar
Battery Ma
0.5 mm

Copper & Titanium
Plate Welding
Titanlum up to **68 mm**
Copper up to **10 mm**

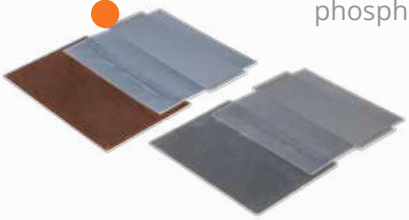
Oil and Gas Industry
Orbital Pipe Hybrid
Laser Welding



Construction Steel ½" to ¾"
1-20 kW fiber lasers
No edge preparation
Faster than conventional methods

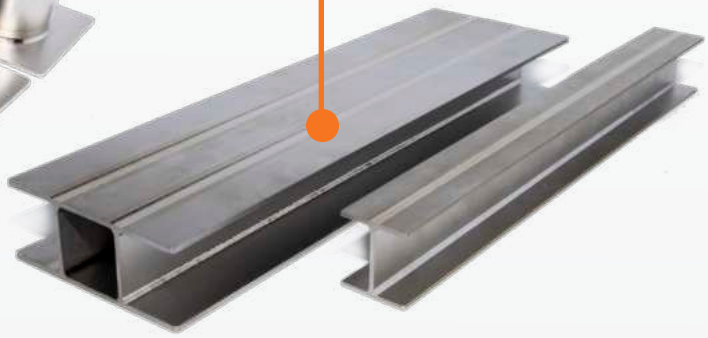
Aluminum Welding
nufacturing
to 4 mm

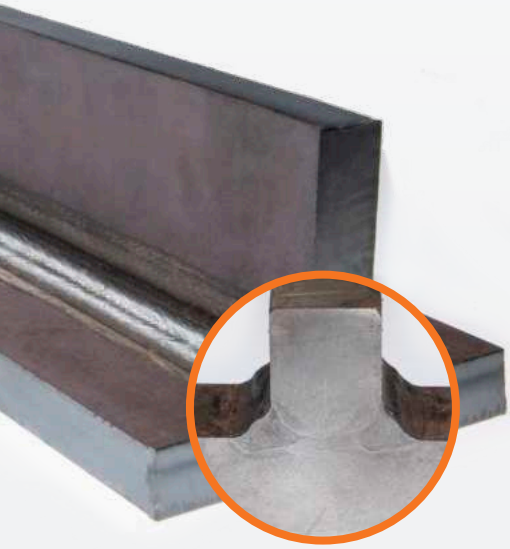
Dissimilar Material Joining
Micro Keyhole Welding
Cu, Al, stainless steel, carbon steel, Ni plated Cu, nitrinol, phosphor bronze



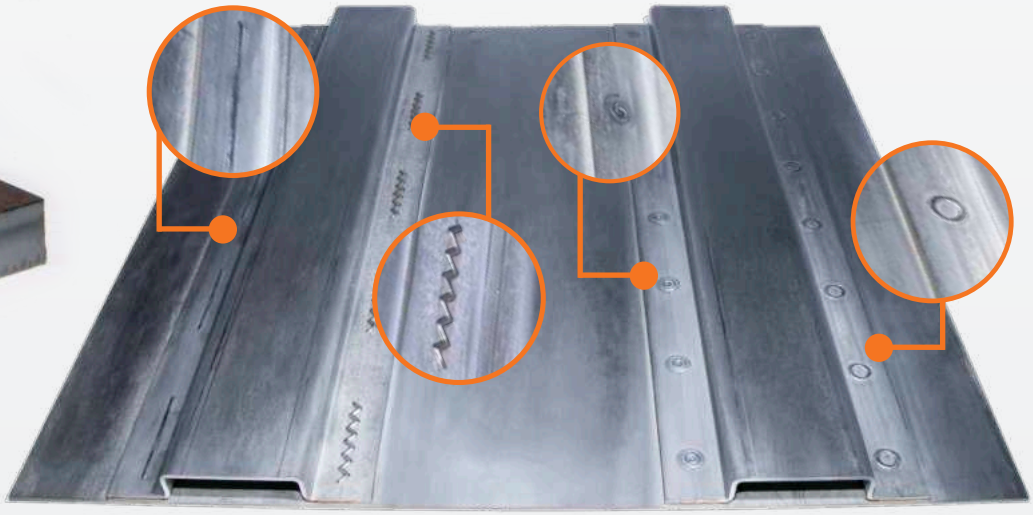
Polymer Laser Welding
White & Clear Polymers

Titanium Laser Welding
Aerospace Industry
Replacement of Electron Beam Welding





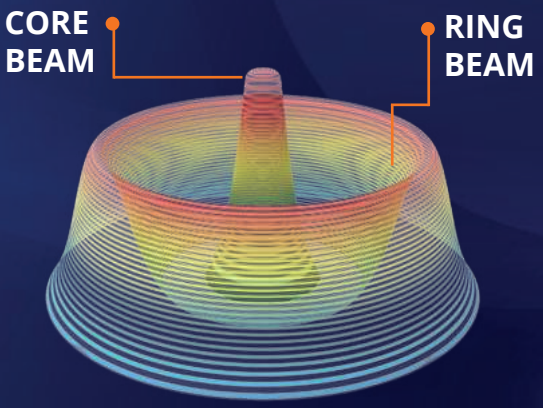
Welding of Railway Car Walls
with **2D High Power Remote Scanner**
6X faster than resistance spot welding
Low distortion, porosity free, fully automated



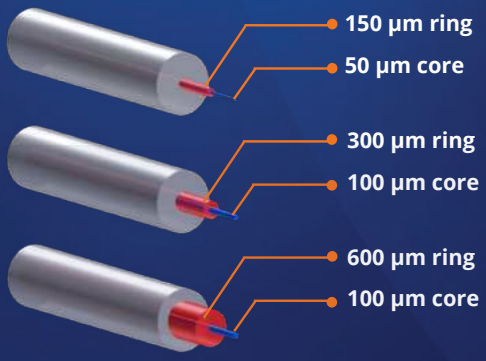
FIBER LASER Technologies

ADJUSTABLE MODE BEAM (AMB) LASERS

Adjustable Mode Beam (AMB) fiber lasers offer new levels of quality and flexibility for material processing. Laser power is delivered to the workpiece through a dual-core fiber comprised of an independent core and ring beam that can be adjusted on-the-fly for cutting and welding applications for thick, thin and highly reflective materials.



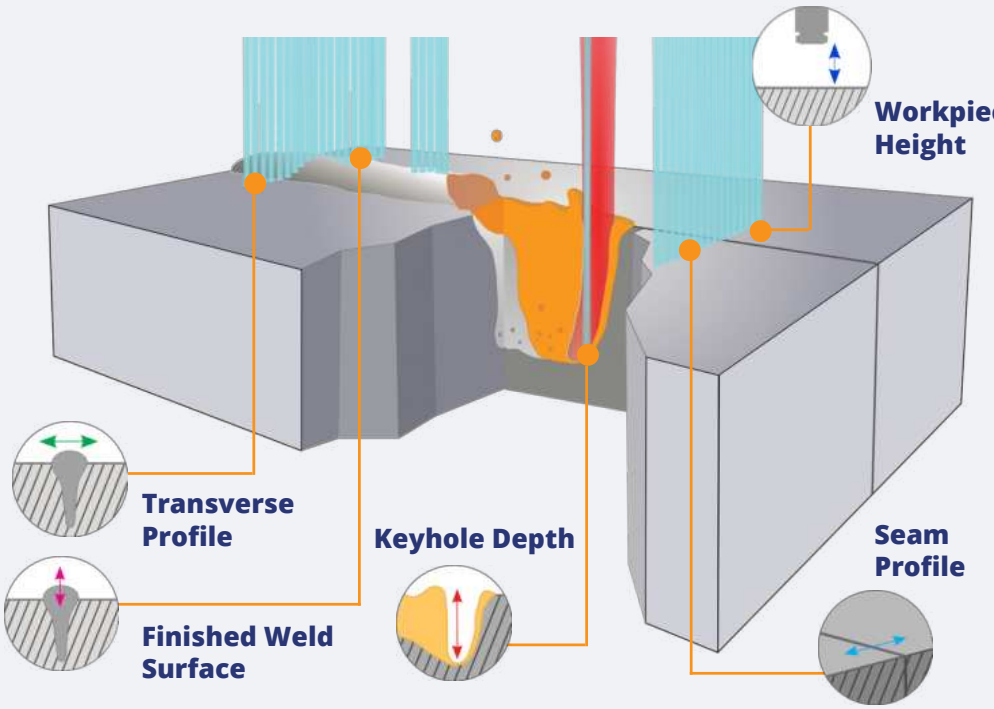
AMB Fiber Examples



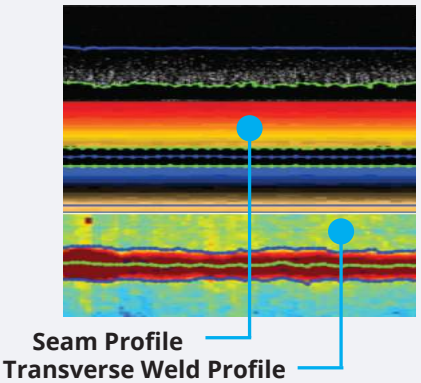
AMB fiber lasers provide independent and dynamic control of the size and intensity of the core and ring beams. Any combination of a small-spot high intensity bright core and a larger ring-shaped beam can be configured to and improve welding results. The core, for example, can be used independently during cutting while the addition of the ring beam provides significant benefits for welding.

INLINE WELD MONITORING & CONTROL

The IPG LDD-700 records and communicates real-time data for every part: before, during and after each weld. When degradation and weld failures occur, the acclaimed LDD-700 alerts operators and systems to take corrective action ensuring that normal operations resume quickly and only good parts are sent to customers.



LDD-700 enables manufacturers to reduce scrap and facilitates early detection of defective sub-assemblies by providing more complete and accurate records for safety-critical applications than was previously possible.

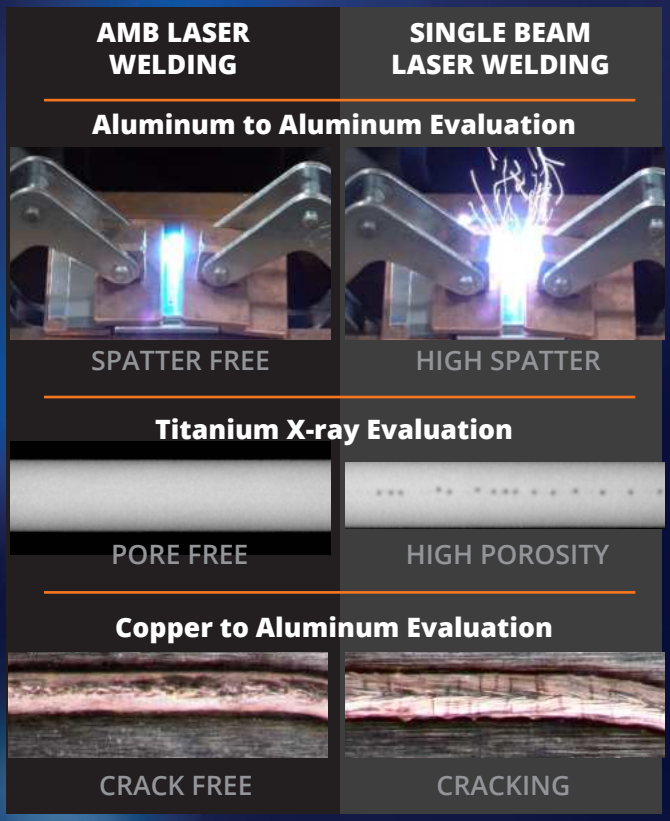


FAST, SPATTER-FREE WELDING
HIGH-QUALITY & HIGHLY PRODUCTIVE

AMB REDUCES SPATTER BY 90% OR MORE
By adjusting the power of the core and ring beams in real-time, AMB technology provides virtually spatter free welding across a wide variety of materials and thicknesses.

AMB ENABLES PORE FREE WELDING
Porosity in the weld material is caused by freezing of vapor released from the weld pool as it solidifies. AMB creates a larger and more stable keyhole allowing metal vapor to escape more easily.

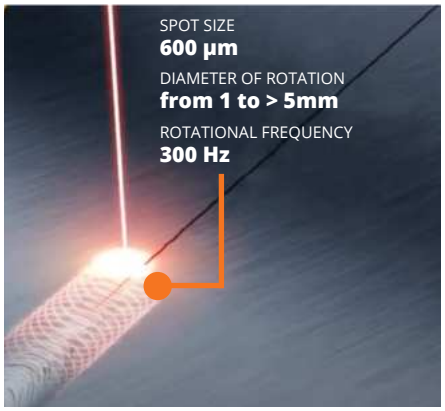
AMB ELIMINATES MATERIAL CRACKING
Cracks are severe defects caused by internal stress to welded materials. AMB stabilizes the weld pool and controls the cooling to overcome shrinkage stresses enabling repeatable crack free welding.



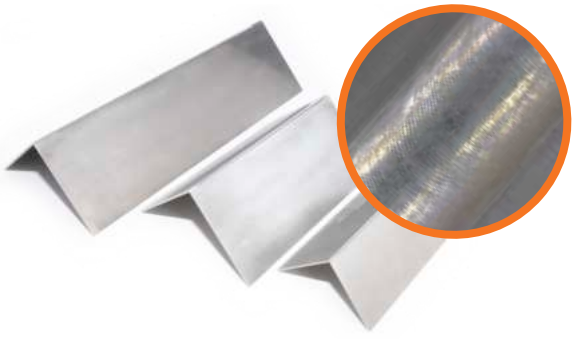
WOBBLE WELDING & SEAM TRACKING

Designed to provide the highest power handling in the industry in a completely sealed and lightweight package, wobble welding heads offer improved weld quality, wider process parameters for part gaps and offsets, and better visual finishes across a wide range of material combination and thicknesses.

D50 Wobble Welding Head



WOBBLE WELDING
High frequency wobbling rotation of the laser lens creates a circular beam pattern across the workpiece for improved welding of dissimilar metals and those prone to cracking and porosity.

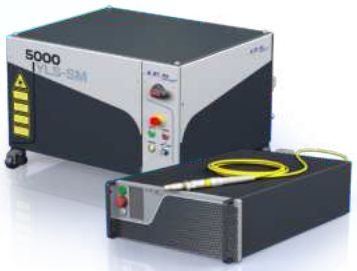


SEAM TRACKING OPTION
Increases productivity through automated adjustment of weld location to match varying seam positions with < 10 µm accuracy

FIBER LASER Welding Sources

High power fiber lasers from IPG provide high quality and reliable welding for thick, thin and highly reflective material combinations. Available as rack units (YLR) or as cabinets (YLS), these lasers present flexible manufacturing solutions as they not only operate at peak powers, but can also be used at lower powers for precision applications with ease. Their modular redundant design ensures maximum uptime as the unlikely failure of any one module is compensated by others, decreasing service time and significantly increasing productivity.

Factors to best select a laser source for welding:	
Laser Power	• From 100 W for thin materials to over 100 kW for deep penetration welding
Operation Mode	• Continuous wave (CW) - highest laser power with the lowest cost of ownership • Quasi-continuous wave (QCW) - up to 10X peak power long pulses • Short pulse – microsecond to picosecond pulses for micro-welding applications
Wavelength	• 1 micron ytterbium for nearly all metal welding applications • 355 nm UV or 2 micron thulium for non-metals and polymers
Beam mode quality	• Single-mode provides small spot sizes with very high powers typically for micro-welding applications • Multi-mode provides wider spots for the most common welding applications • Adjustable beam mode with a core and ring beam for high-speed, spatter-free welding applications • Trifocal welding utilizes three beams in a single cable with independent power control



SINGLE-MODE CW FIBER LASERS

High Precision and Controlled Welding

Highest brightness and intensity output

- High speed lap and close part fit-up welding
- Focal spot sizes from 20 microns
- Dissimilar and reflective metal joining

Laser Power, kW	0.1 to 10
Operation Mode	CW or Modulated
Wavelength	1 micron
Beam Mode	Single

MULTI-MODE CW FIBER LASERS

High Power Lasers up to 120 kW

Reliable and Efficient High Power Welding Sources

- Consistent high strength welds for thick and thin materials
- Fast, high-quality welding for common applications
- Beam switching and sharing options

Laser Power, kW	1 to 120
Operation Mode	CW or Modulated
Wavelength	1 micron
Beam Mode	Multi

AMB SERIES FIBER LASERS

Adjustable Mode Beam Lasers

Broadest Range of Beam Profile Tunability

- Spatter-free high-speed welding maximizes throughput
- Significantly reduces rework and scrap
- High-quality weld seams, pore and crack free

Core Beam Power, kW	Up to 12
Total Output Power, kW	Up to 25
Operation Mode	CW or Modulated
Wavelength	1 Micron
Beam Mode	Adjustable Core & Ring

THULIUM CW FIBER LASERS

Direct and Transmission Polymer Welding

Welding Without Absorbing Additives

- Welding of Clear and White Polymers
- Welding of Polymer Composites
- Welding of Polymers to Metals

Laser Power, W	10-200
Operation Mode	CW or Modulated
Wavelength	2 Micron
Beam Mode	Single or Multi

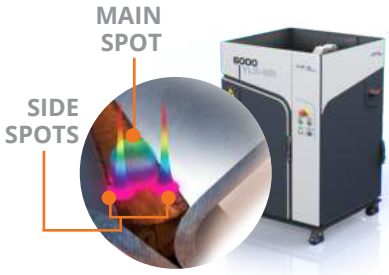
QCW AND PULSED FIBER LASERS

Versatile Lasers with High Pulse Energy

Advanced Welding for Sensitive Materials

- Minimal heat affected zone
- Minimal part distortion
- Microelectronics and medical devices

Laser Power, kW	0.1 to 2
Pulse Energy	microjoules to Joules
Pulse Duration	milliseconds to picoseconds
Beam Mode	Single or Multi



BRAZING FIBER LASERS

Trifocal Laser Brazing and Welding

Clean and Join Materials in a Single Step

- Excellent joint surface quality that can be painted immediately
- Two ablation spots clean base materials and improve filler flow
- High-quality, high-speed brazing with low heat input

Laser Power, kW	Up to 8
Operation Mode	CW or Modulated
Wavelength	1 micron
Beam Mode	Trifocal

BLUE, GREEN AND UV FIBER LASERS ARE ALSO AVAILABLE FOR SPECIALIZED WELDING APPLICATIONS

FIBER LASER Welding Heads

The **HIGHEST LASER POWER HANDLING** in the Industry for **MAXIMUM PRODUCTIVITY**

Laser welding heads are designed to deliver reliable, repeatable high-quality welds across a wide range of material combinations. Fixed optic heads deliver the highest power handling for deep penetration welding, while wobble heads provide superb visual finishes and enhanced capability for parts with gaps or poor fit-up. Scan heads weld across wide fields for high-productivity remote welding. Collimator and focus options customize spot sizes and working distances to best match applications and heads paired with inline weld monitoring provide unmatched real-time weld quality assurance to reduce scrap, provide part traceability and increase throughput.

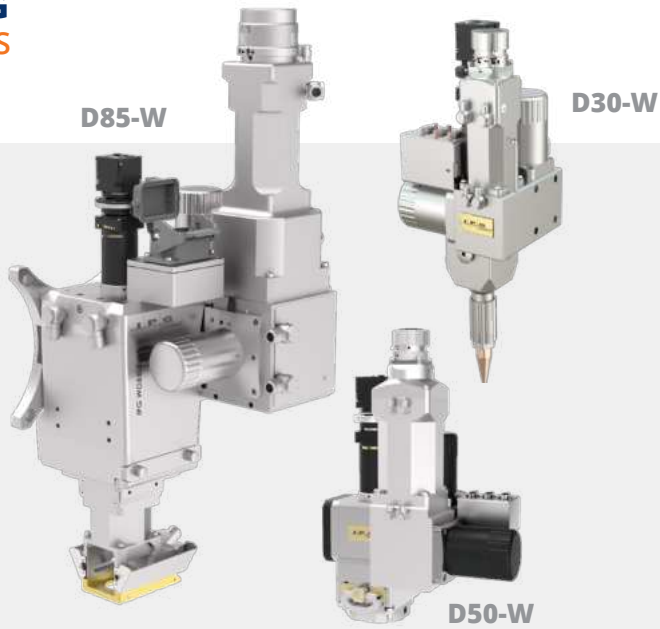
FIXED OPTIC WELDING HEADS

Highest Power Handling for Deep Penetration

POWER HANDLING	
D30-L	6 kW
D50-L **D50-S** **D50-HP**	10 kW 30 kW 50 kW
D85-HP	100 kW

REAL-TIME WELD MONITORING
AVAILABLE ON ALL WELDING HEADS

WOBBLE WELDING



WOBBLE WELDING HEADS

Enhanced Capabilities with Superb Finishes

POWER HANDLING	
D30-W	6 kW
D50-W	12 kW
D85-W	50 kW

Mid-Power

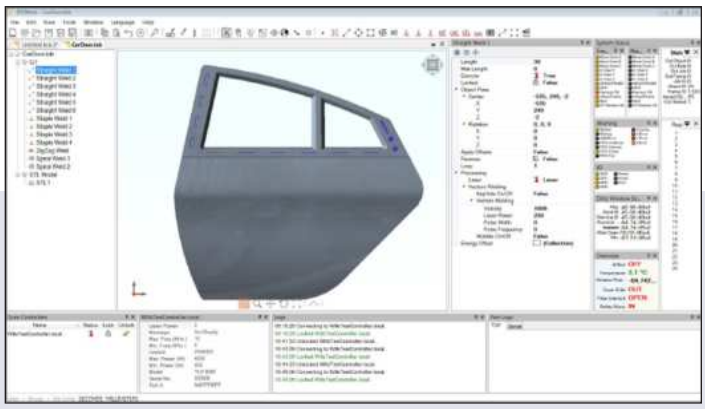
2D High-Power

REMOTE SCANNER WELDING HEADS

Wide Scan Fields for High Productivity

	POWER HANDLING	SCAN FIELD
Mid-Power	2 kW	Up to 300 X 300 mm
2D High-Power	12 kW	Up to 250 x 250 mm

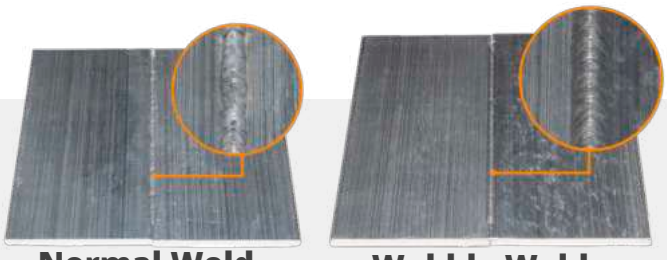
SOFTWARE IPG*Weld*



- Comprehensive welding software
- Basic shapes and DXF file import
- Optimized laser & comprehensive weld parameters
- Embedded camera

SPOTLIGHT

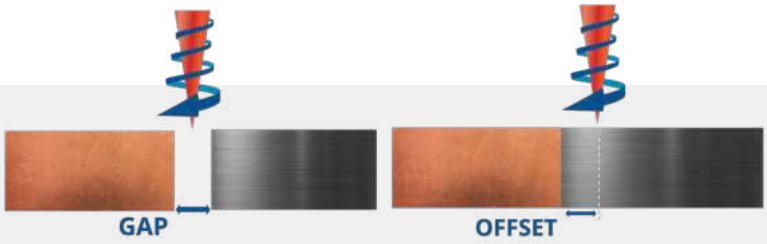
INCREASED QUALITY



Normal Weld **Wobble Weld**

Unmatched results with highly reflective materials such as Aluminum and Copper

INCREASED CAPABILITY



High-quality welding of parts with gaps or offsets increases productivity

Melting behavior of dissimilar materials can be balanced by adjusting wobble parameters

Optimized wobble parameters minimize cracking and porosity in sensitive materials

FIBER LASER Welding Systems

Laser welding systems provide high-speed automation for high-quality, repeatable welding of common and complex parts and components across industries such as medical and aerospace, automotive and electronics, and for specially designed R&D projects. Powered by the most reliable and efficient fiber lasers in the world, IPG fiber laser welding systems are easily configured and customized with a wide range of laser sources and welding heads to best match applications, high precision motion platforms and robotic systems, custom optics and beam switches, and software for high-productivity, low cost-per-part laser welding.

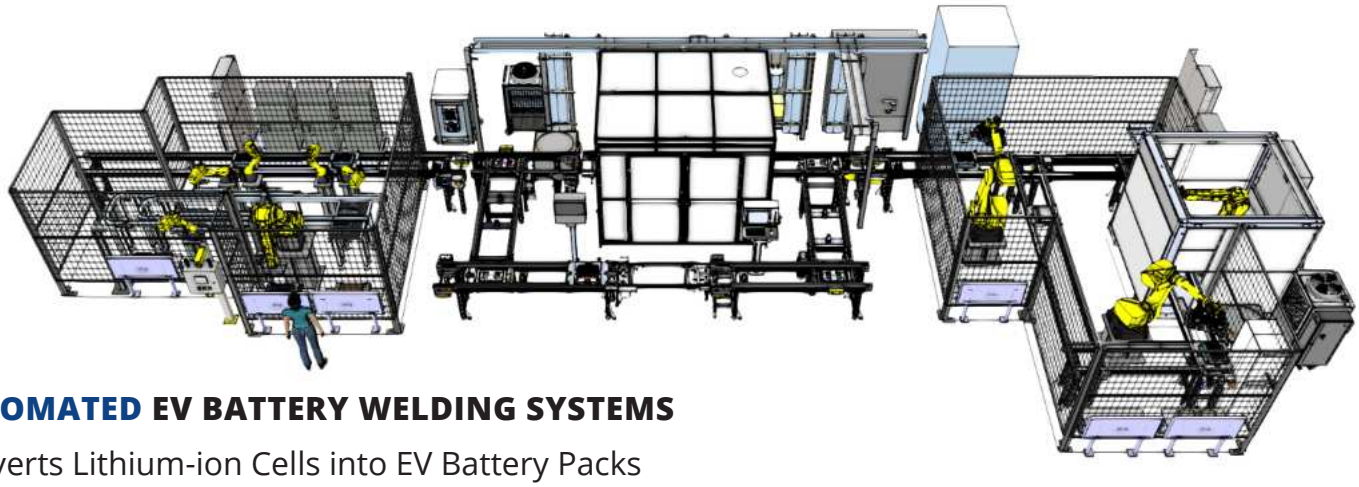
HIGH PRECISION HIGH PRECISION WELDING SYSTEMS

Compact, Configurable and Cost-effective

Versatile Welding Systems for R&D and Volume Manufacturing

- High-precision, high-speed motion systems
- Wide range of lasers and process heads to best match applications
- Reliable systems for medical devices, aerospace, electronics and other small part applications

Small Footprints	from 0.54 to 1.11 m^2
Work Envelopes	Up to 500 x 300 x 300 mm
Control Software	HMI-2200 and IPGWeld
Laser Power	Up to 2 kW

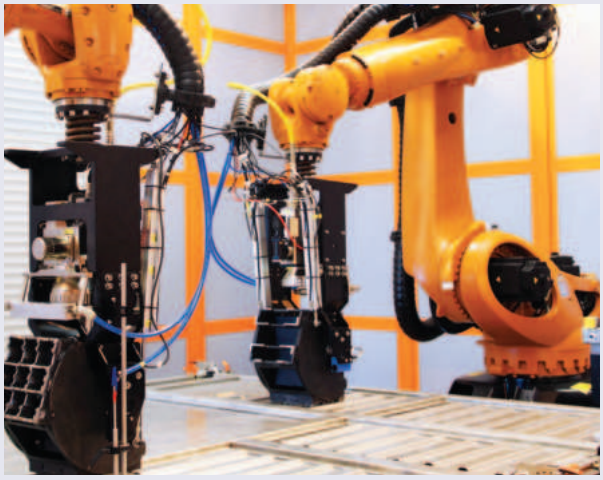


AUTOMATED EV BATTERY WELDING SYSTEMS

Converts Lithium-ion Cells into EV Battery Packs

Scalable and Flexible for All Battery Types

- 10X faster and more reliable than traditional production methods
- Integrated process monitoring, traceability and non-destructive testing
- 100% tested welds guarantees safety and quality



ROBOTIC WELDING SYSTEMS

Standardized & Customizable Systems that Maximize Welding Productivity

- Precise and repeatable positioning for consistent laser welding
- High-speed remote processing
- Easily integrated into production lines
- MES connectivity for monitoring and control
- Customized with IPG laser sources, beam delivery & technologies for high-reliability, high-efficiency welding
- Turn-key systems available

SEAM STEPPER WELDING SYSTEM

Optimized Overlap Welding for Automotive Applications

Superior Zero Gap Welding with Single Sided Part Access

- Robotic clamping and welding for high-speed processing
- Adjustable part clamping force with process monitoring
- Repeatable, low distortion multi-layer material joining

Laser Power, kW	Up to 3.5
Controller Footprint	800 x 600 mm
Weld Length	Up to 40 mm
Weld Speed	Up to 60 mm/s

TUBE AND PROFILE WELDING SYSTEMS

Precise and Continuous Tube Welding

Fully integrated production system

- Seam welding of stainless and carbon steel tubes with wall thicknesses up to 4.0 mm
- Turnkey welding system including laser, welding head, chiller and control system with industry standard interfaces
- 3-Axis precision control system with automated weld seam tracker

Laser Power, kW	Up to 12
Motion System (X-Y-Z)	300 x 100 x 750 mm
Tube Thickness	0.7 – 4.0 mm

IPG Applications Labs

Equipped with the latest fiber laser sources, technologies, motion systems and beam delivery components, IPG state-of-the-art applications labs are developed to demonstrate the reliability, productivity and high-quality results you can expect from your welding solution. Submitting your sample for evaluation ensures that the exact equipment and process variables are determined to best match your specific welding application. Our industry leading knowledge of fiber laser welding accelerates and optimizes your welding process deployment.

DISCOVERING YOUR NEXT WELDING SOLUTION IS EASY

Send us your welding project requirements and our experienced application engineers will deliver welded samples of your parts for inspection.

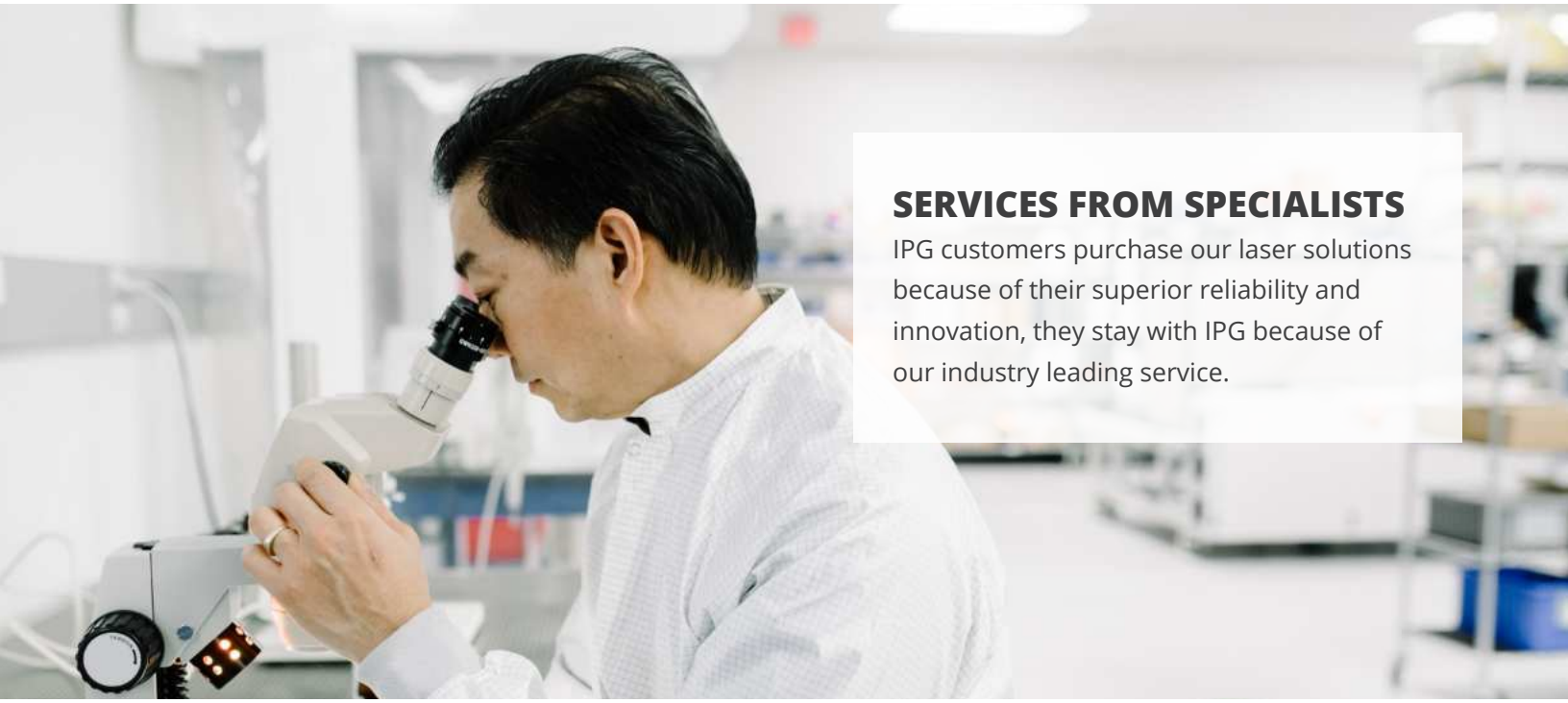
IPG operates **25 applications labs** worldwide that are available for you to visit and experience a live customized welding solution demonstration.

From there we help with process development to fully scaled production and installation through welding application optimization to maximize the throughput and quality of your parts.

Tensile Strength & Bend Tests
Verify Laser Weld Quality

PREMIERE **APPLICATIONS LABS**

IPG applications labs provide you the opportunity to investigate the benefits that laser systems can bring to your product development and manufacturing lines.

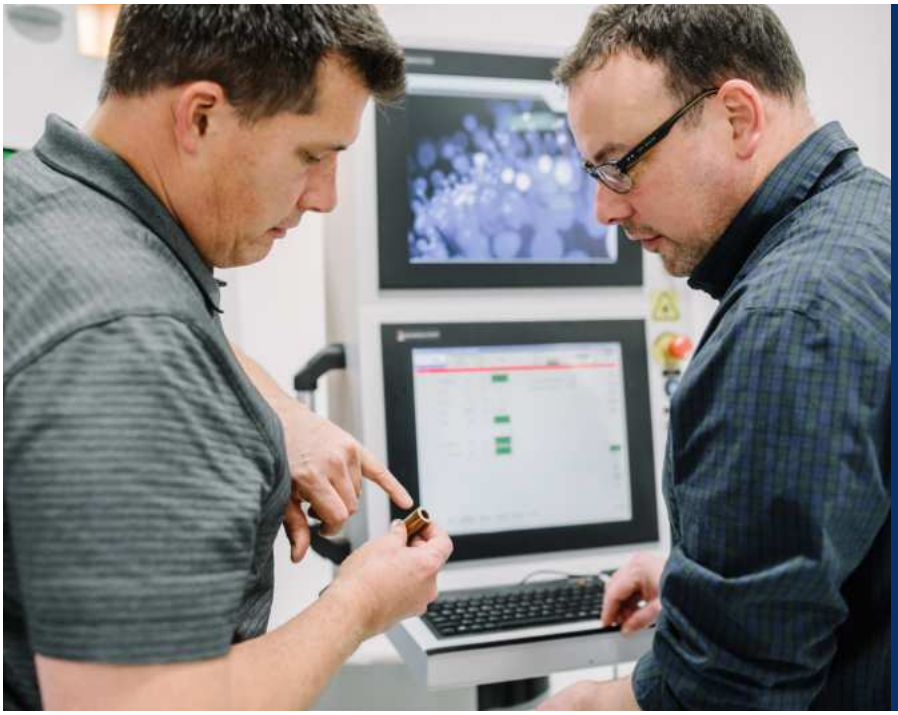


SERVICES FROM SPECIALISTS

IPG customers purchase our laser solutions because of their superior reliability and innovation, they stay with IPG because of our industry leading service.

IPG application specialists have experience in materials science, metallurgy and physics across many different industries and understand what it takes to meet production targets and deadlines. These experts are here to provide you the best and most complete answers to your laser welding questions.

Customer satisfaction is our goal at IPG. Teams of dedicated service professionals and technical support specialists are available worldwide whenever are wherever you need assistance. We strive to make the best fiber lasers and amplifiers in the world and back it up with our commitment to service.



SUPPORTING YOUR SUCCESS

IPG support teams are in your corner every step of the way. No other company has the depth and breadth of fiber laser experts committed to guiding and supporting our customers.

THE WORLD LEADER
IN FIBER LASERS

IPG Photonics is the inventor and world's leading producer of high-power fiber lasers, which enable greater precision, higher-speed processing, more flexible production methods and enhanced productivity. IPG fiber lasers combine the advantages of semiconductor diodes with the high amplification and precise beam qualities of unique optical fibers to deliver superior performance, reliability and usability.

IPG has continually pioneered the development and commercial production of numerous unique technologies related to fiber lasers combining deep materials science expertise and process know-how with a vertically-integrated business model. All key components of its fiber laser technology are produced in-house, enabling:

- **Faster product development**
- **More efficient production methods**
- **Industry leading product delivery times**
- **Better performing, higher quality solutions**
- **Highest wall-plug efficiencies that lower overall energy consumption and costs**

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FOUNDED 1990

40,000 DEVICES SHIPPED IN 2019

400 PATENTS
450 PENDING

+100K INSTALL BASE

40 BILLION POUNDS
LESS GLOBAL CO_2 EMISSIONS WHEN OPERATING IPG LASERS COMPARED TO OTHER LASERS (since 2011)

+66% OF FIBER LASERS MANUFACTURED WORLDWIDE