IPG Fiber Lasers:
What's New in Applications for Fabricators

ALAW Laser Applications Workshop
13-14 May 2009

Randolph Paura, P.Eng.
Regional Manager, Canada
Materials Processing Consultant

Agenda

- Introduction
- Company background
- Fiber laser basics (power supply review)
- Fiber laser adoption and growth
- Advantageous characteristics of fiber lasers
- Why fiber lasers are outpacing market growth
- Recent market statistics
- Fiber laser advantages
- Market drivers for growth, development and applications
- Fiber laser power sources (single mode versus multi-mode)
- Fiber laser cutting example
- Fiber laser applications: single mode (SM) and multi-mode (MM)
- Fiber laser applications: Laser Additive Materials
- Fiber laser applications: Welding
- New process regimes for fiber lasers
- Future: Outgrowth of continuous improvement
- Fiber laser summary and conclusions
- Thank you

Hybrid Laser Welding Images Courtesy of SMU: Center for Laser Aided Manufacturing

Introduction

Randolph Paura, P.Eng., IPG Photonics, Regional Manager Canada

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Lifetime Member, Laser Institute of America (LIA)
Lifetime Member, SPIE
Member FMA
Network Member, Materials & Manufacturing Ontario (O.C.E.)
Vice-Chair, ANSI Z136 SSC-9
Member ANSI Z136.1 ASC

ALAW 2008, "*Fiber Lasers for Fabricators*"
ALAW 2007, "*Doing more with less (Harnessing Fiber Lasers)*"
Co-Chair, ICALEO 2003 Laser Solutions Courses
ICALEO 2002, "*Orthotropic SUV Frame Design (LBW enabled)*"
ICALEO 2001,
  Laser Solutions Course Instructor, Weld Quality Monitoring
ICALEO 2001,
  Laser Solutions Course Instructor, Robotic Laser Cutting and Welding

IPG Photonics

IPG Fiber Lasers: The company

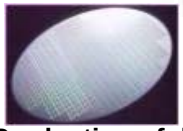
Modules

Amplifier block

Laser Fiber

Laser Fiber Preform

Laser diode Packaging

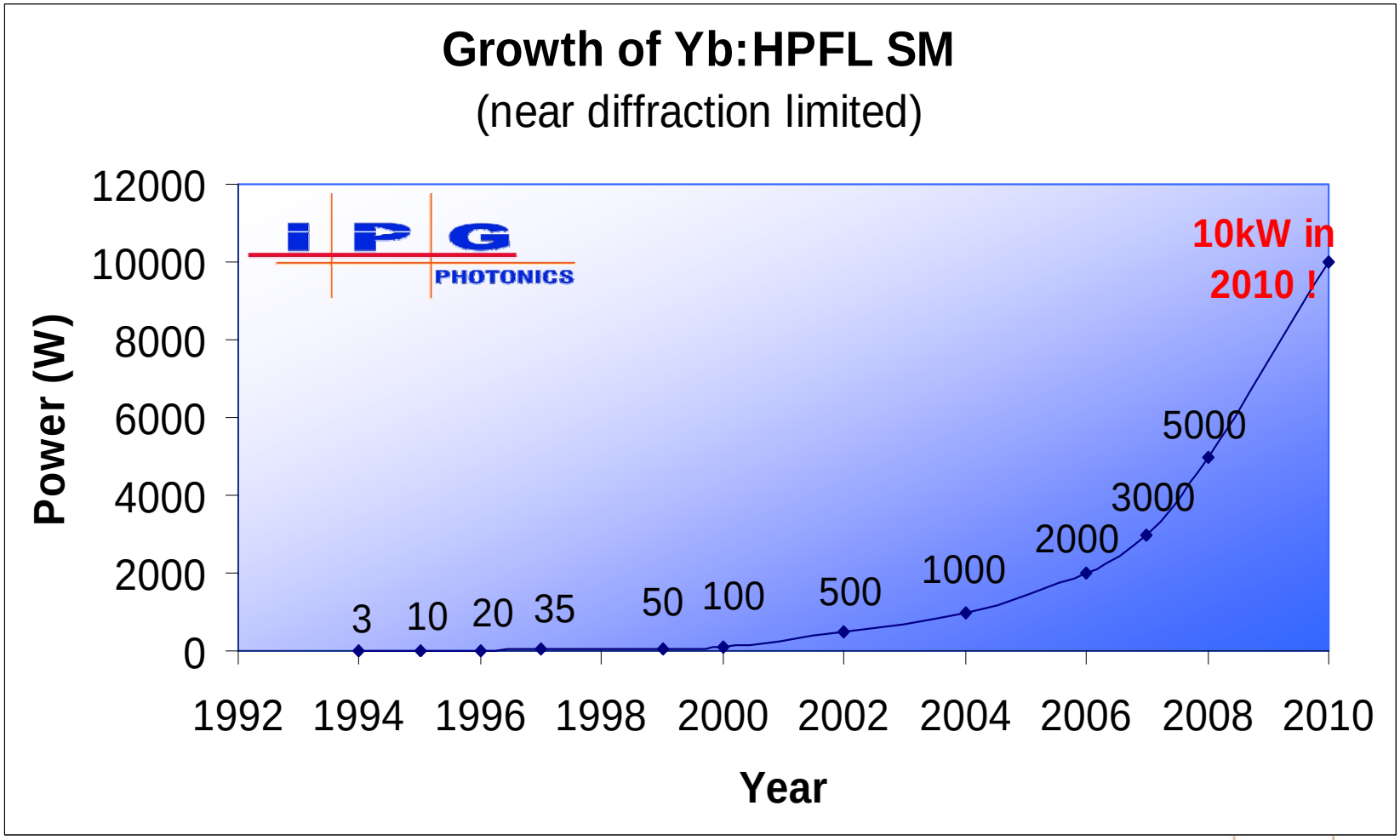


Production of diodes

Fully Integrated Laser

- Working Fibers
- Connectors
- Fiber Lasers
- Modules
- Gain Modules
- Active and Passive Fibers
- Diode Lasers

IPG Fiber Lasers



IPG Fiber Lasers

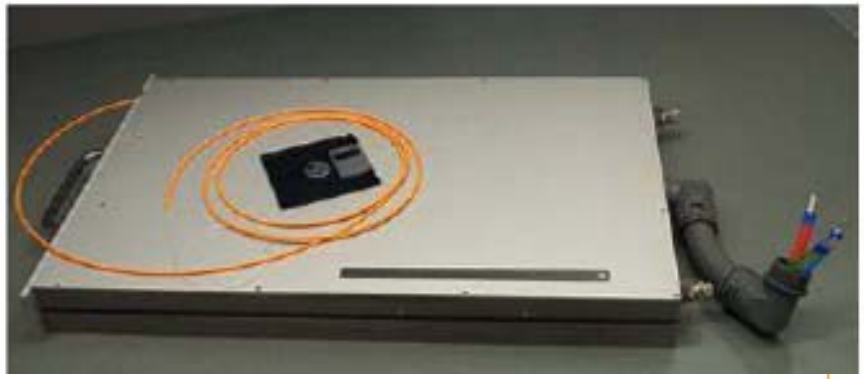
A single module can supply:

- 250, 400, 800, 1000+ W of laser power
- Wavelength of 1070nm (NIR)
- One 7 or 15 um fiber core
- 0.34-0.41mm*mrad beam divergence

T x H x D = 60 x 33 x 4.7 cm

Efficiency (DC) > 35%

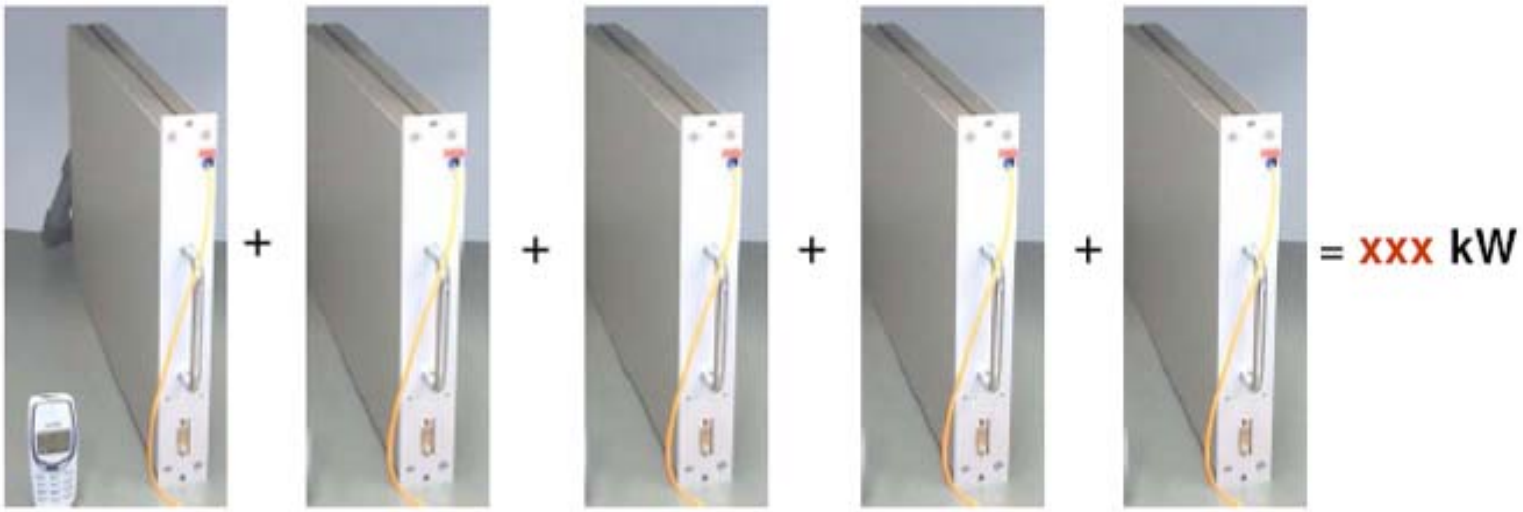
Building blocks (modules) for HPFLs



IPG Fiber Lasers

IPG Fiber Lasers: The technology

High power multi-mode fiber lasers



Modular multi-kW fiber laser

High beam quality

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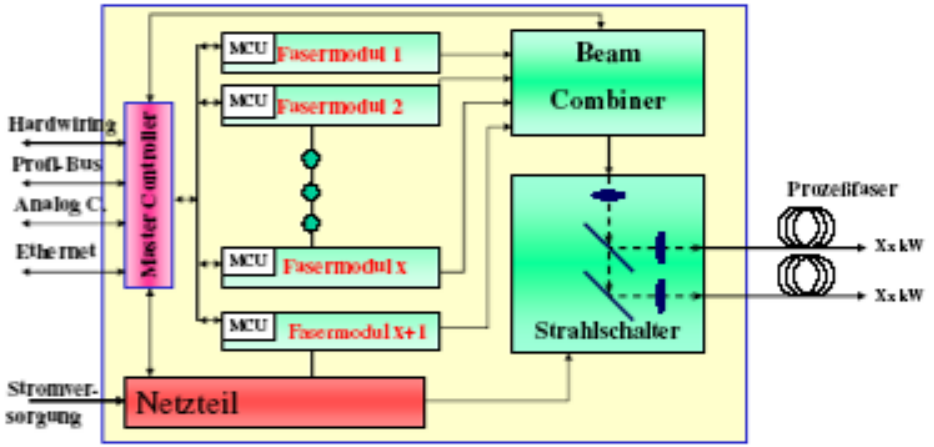
IPG Fiber Lasers

High Power Fiber Laser

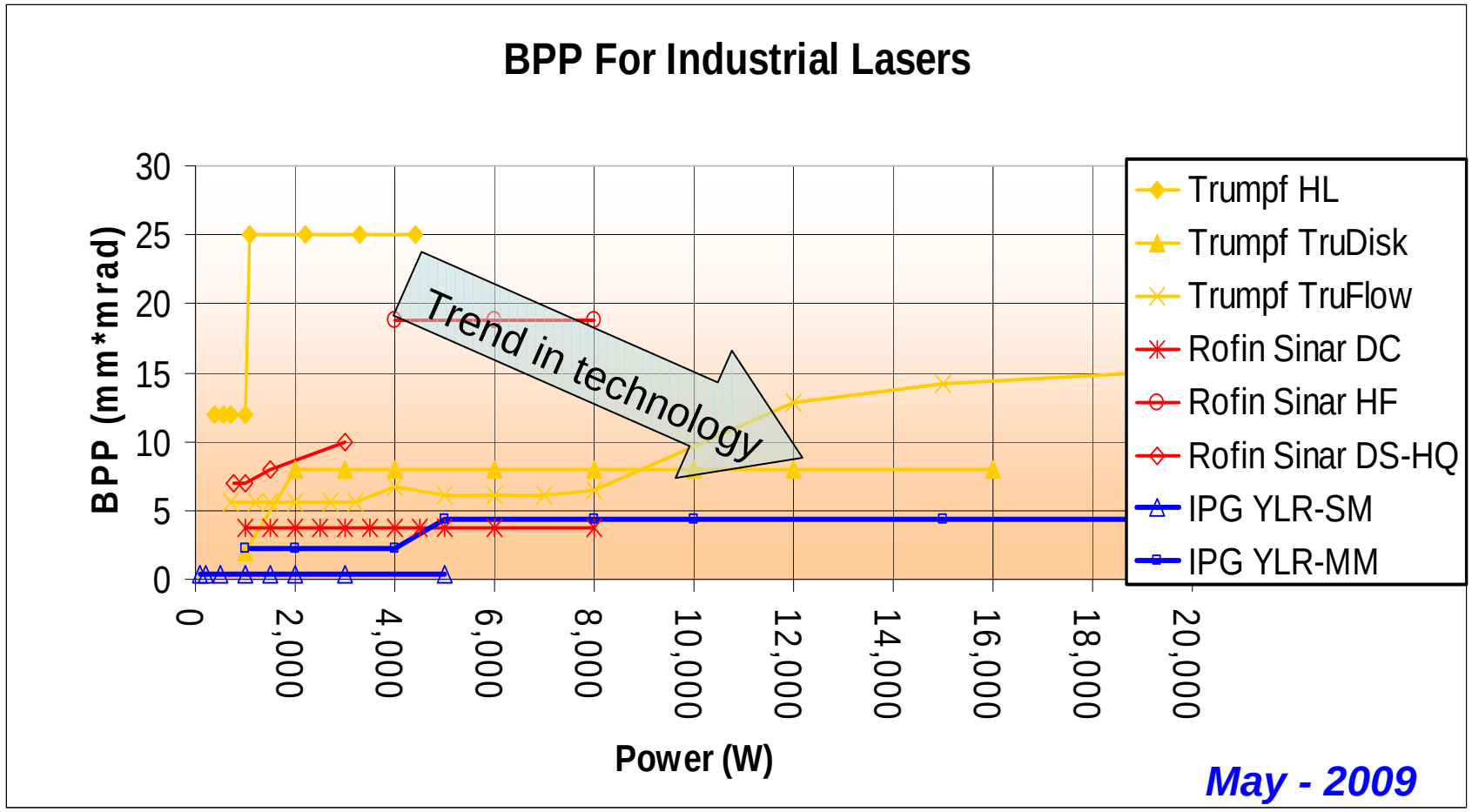
HPFL Layout



Power 1 – 50 kW

IPG Fiber Lasers

IPG Fiber Lasers: The technology



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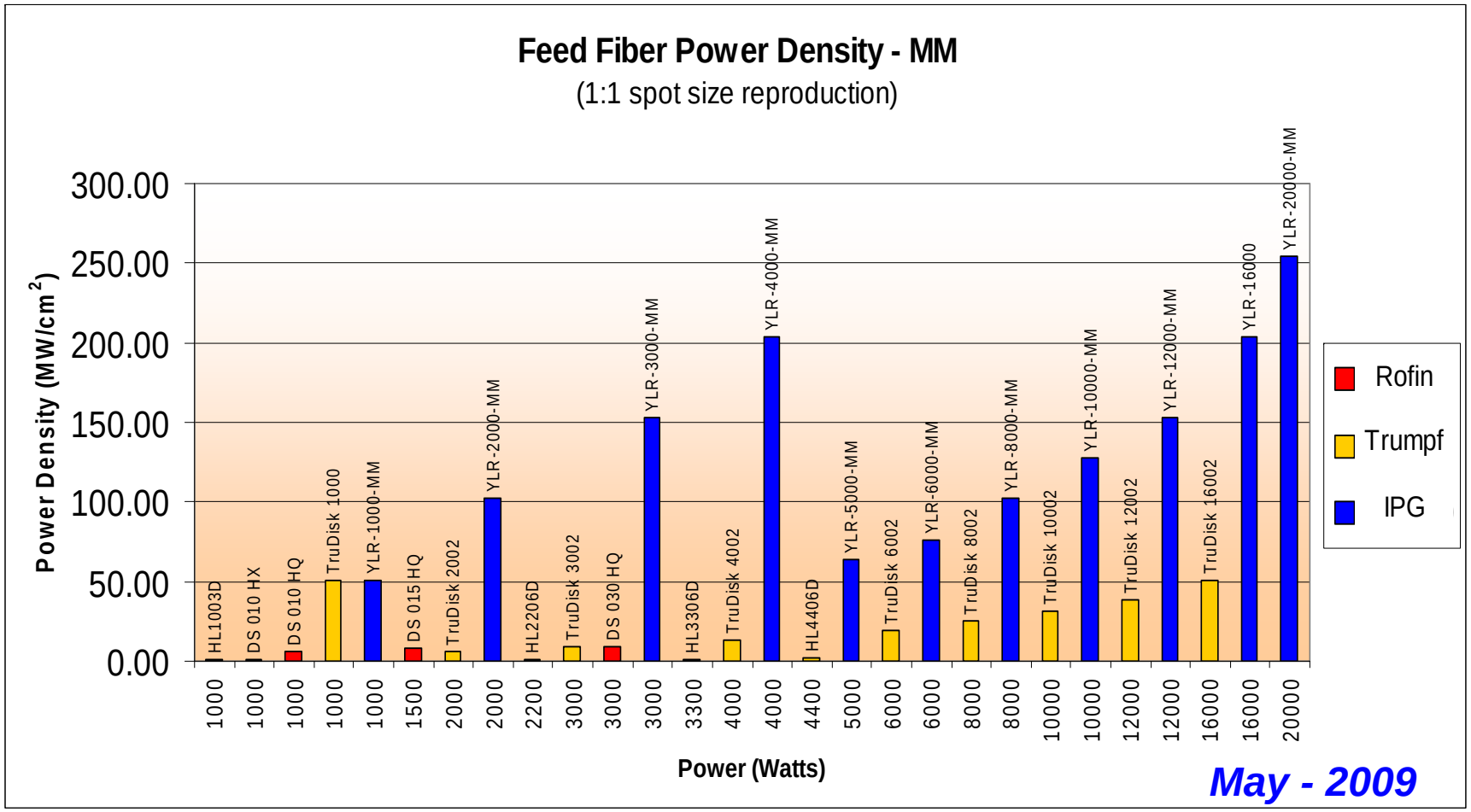
Ref. published information: www.trumpf-laser.com; www.rofin-sinar.com; www.ipgphotonics.com

IPG Fiber Lasers

IPG Fiber Lasers: The technology



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Ref. published information: www.trumpf-laser.com; www.rofin-sinar.com; www.ipgphotonics.com

IPG Fiber Lasers

IPG Product Line:

- CW Single Mode fiber lasers from 5 – 5000 watts (10,000 watts under final development)
- Low order mode CW fiber Lasers available from 100 watts to above 50kW
- Pulsed (Q-switched) over 20 models with peak powers to 50 kilowatts and pulse energies to 10-milli-joules

IPG Fiber Lasers

New products for materials processing (2009):

- 15 Watt CW Single Mode green operating at 535nanometers, narrow line width
- Pulsed Green at 535nm 10 watts 1 ns pulse duration 50-300 kilohertz (scalable to 100 watts, conversion from 1070 to 535 nm @ greater than 84%)
- 2 new pulsed MOPA models operating at 1070nm , peak power >50kW variable pulse duration 1ns-100ns frequency to 500kHz
- 3 & 4 kW fiber laser designed exclusively for cladding, annealing and brazing applications

Fiber Laser Adoption and Growth

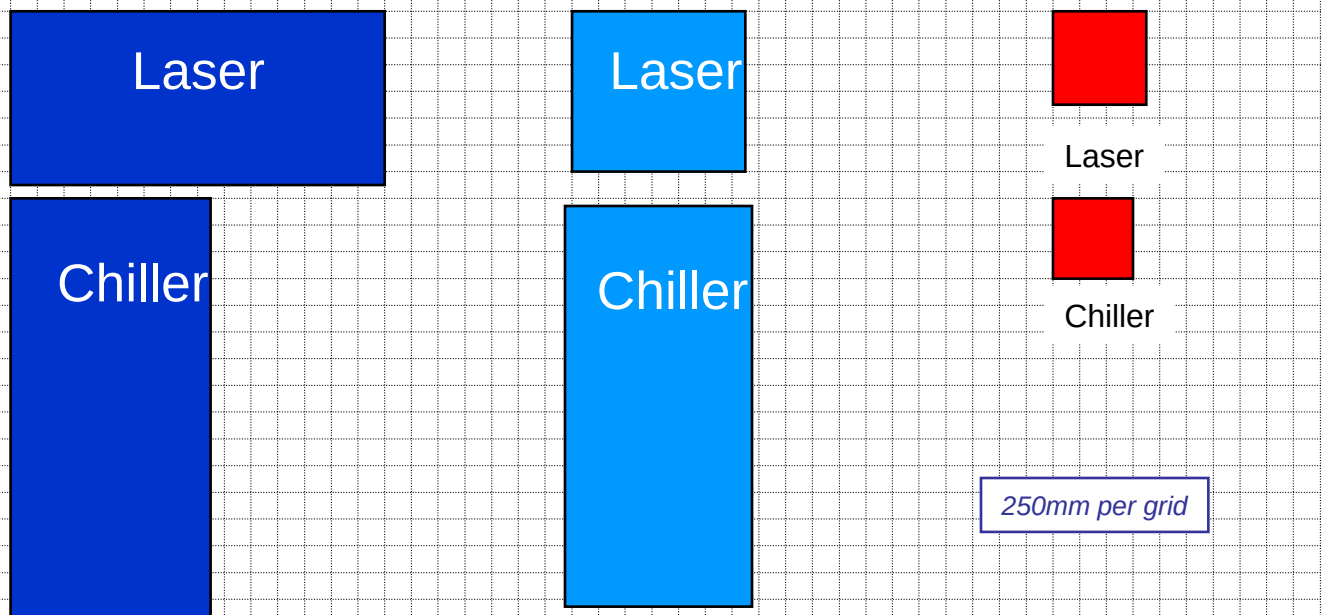
Advantages over previous technologies:

- Long diode life > 100,000 hrs
- High electrical efficiency 30%
- Compact size
- Mobile
- Highest beam quality at all power levels
- Large dynamic power range
- Rapid installation (hours not days)
- No resonator alignment
- Maintenance free
- Single mode - pure Gaussian
- Multi-mode - near top hat
- Consistent spot size over complete dynamic range
- Air cooled to 300 watts
- No warm up, on demand power
- Modules can be added for future power upgrades

Fiber Laser Adoption and Growth

IPG Fiber Lasers: Adoption, progress & growth

Plant floor space is manufacturing real estate: Fiber lasers free up manufacturing capacity. (Ref. 2007)



4kW Nd:YAG	8kW CO2	4kW Fiber Laser
<4% efficient	<12% efficient	~25% efficient
<2000 hrs lamp life	Uses laser & process gas	100,000 hrs diode life
92KW consumption	84KW consumption	16KW consumption
3200 x 1700 x 1250	1665 x 1524 x 1100	860 x 810 x 1500
3000 lbs	3241 lbs	500 lbs
$600-700K USD	$450-500K USD	$350-$450K USD

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Market Driver for FL Utilization

Key market drivers for fiber laser utilization:

- Utilization of high strength steels in automotive production (hot stamped steels requiring laser trimming)
- Increased utilization of remote welding applications
- Electron beam quality welds possible with fiber Lasers
- Energy related automotive applications- fuel cells, batteries
- Extensive use of pulsed lasers in the manufacture of silicon based and photo-voltaic solar cells
- Enabling of new manufacturing processes that improve quality and reduce the total cost of manufacturing
- *Reduced cost to manufacture is always the driver*

Additional Driver for Development

Military applications & objectives:

- Efficiency, effectiveness and mobility of defense services rendered
- Tactical High Energy Laser (THEL) program
- Advanced Tactical Laser (ATL) program
- Airborne Laser (ABL) program
- Joint High Power Solid State Laser (JHPSSL) program
- Seeking 10kW SM laser as a module for 100kW + units
- "*Lasers will challenge the primacy of projectile weapons*" Lasers for Security, Northrop Grumman, Case #07-0573 http://www.osa.org/News/policyprograms/specialevents/Northrop%20OSA%20RD%20Caucus%20Lasers%20for%20Security%20090607rev.pdf

Additional Driver for Development

Military applications & objectives:

- **Feb 25, 2009**
- **IPG Photonics wields high-power laser weapon**

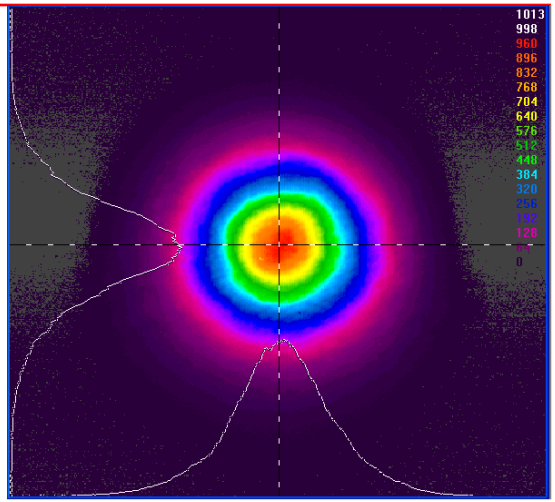
• The fiber-laser maker's diodes are shooting down both the competition and, thanks to a Boeing demonstration, unmanned aircraft.

- Laser Avenger

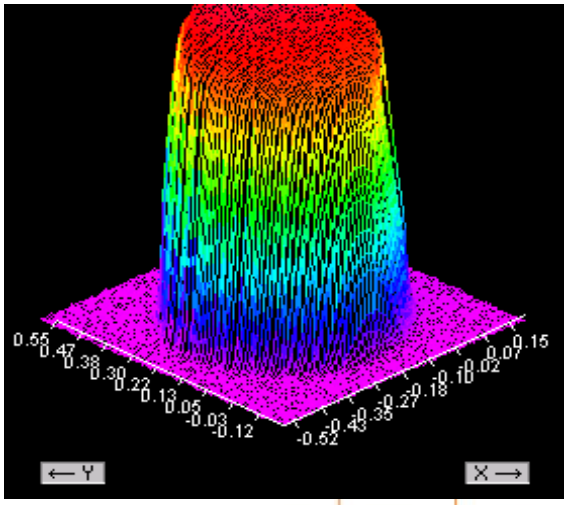
Fiber Laser Power Sources

Single Mode versus Multi-Mode

- Single Mode
  - Near “Gaussian” Power Density Profile
  - ~7 - 20 um feed fiber optic cable dia.
  - mW to 5 kW



- Multi-Mode
  - Lower mode order (quasi-Gaussian)
  - 50 – 100 um feed fiber optic cable dia.
  - 100 W to +20 kW (and greater)



Cutting with Fiber Lasers

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005

YLR1000

DC025
Quelle:Rofin

Process parameters for comparative tests of fiber- and CO_2 - laser cutting

Laser:	YLR1000	DC025
handling system	KuKa	Arnold
focal length	120 mm	127 mm
collimation	120 mm	-
focus diameter	15 µm	140 µm
focus position	0 - -1 mm	0 - -1 mm
distance nozzle-workpiece surface	1 mm	1 mm
cutting gas	N_2	N_2
gas pressure	10 bar	10 bar
nozzle diameter	1,5 mm	1,5 mm

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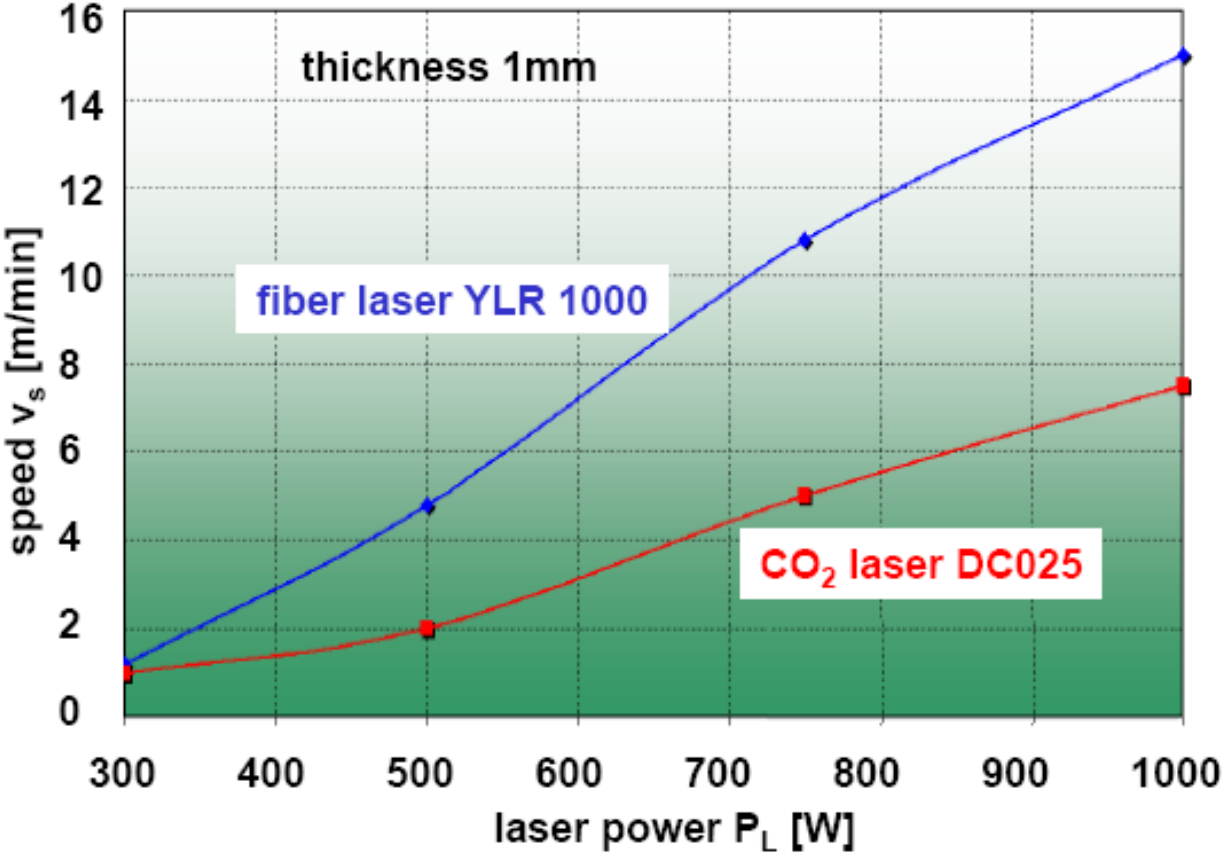
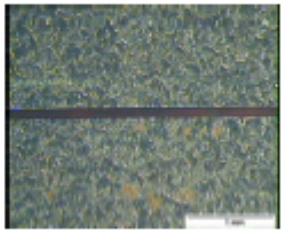
Cutting with Fiber Lasers

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005

Cutting results St1203 (AISI CRS 1005, 1008, 1010)

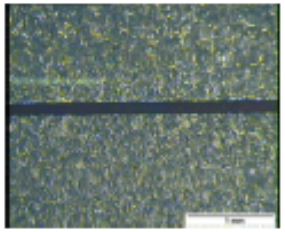


cutting gap:



YLR1000:

100 µm



DC025:

120 µm

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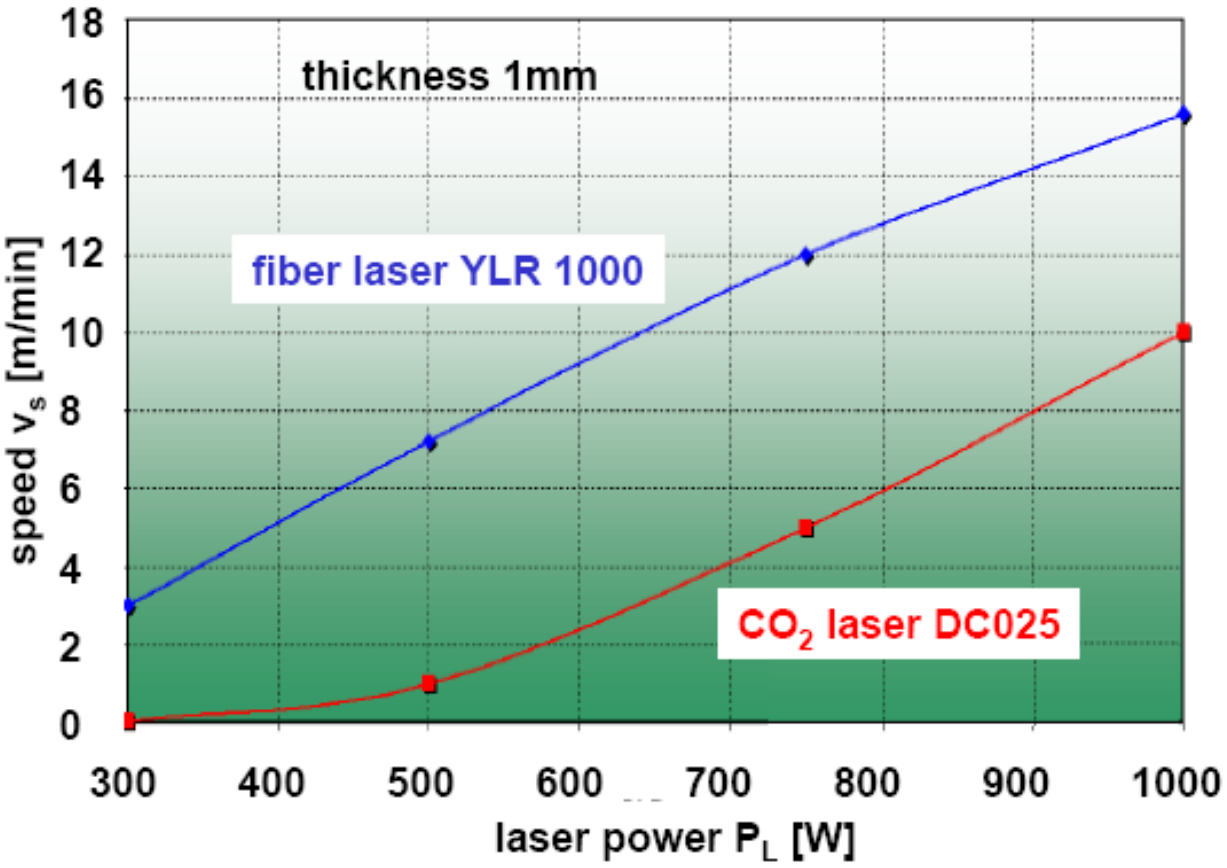
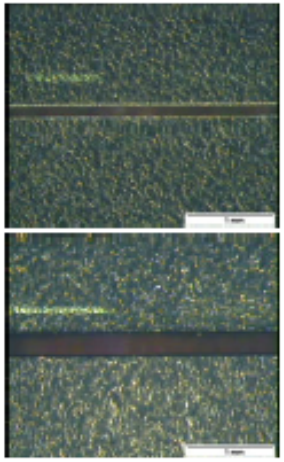
Cutting with Fiber Lasers

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005

Cutting results an AlMg3 (AISI 5XXX, Aluminum)



cutting gap:



YLR1000:
125 µm

DC025:
200 µm

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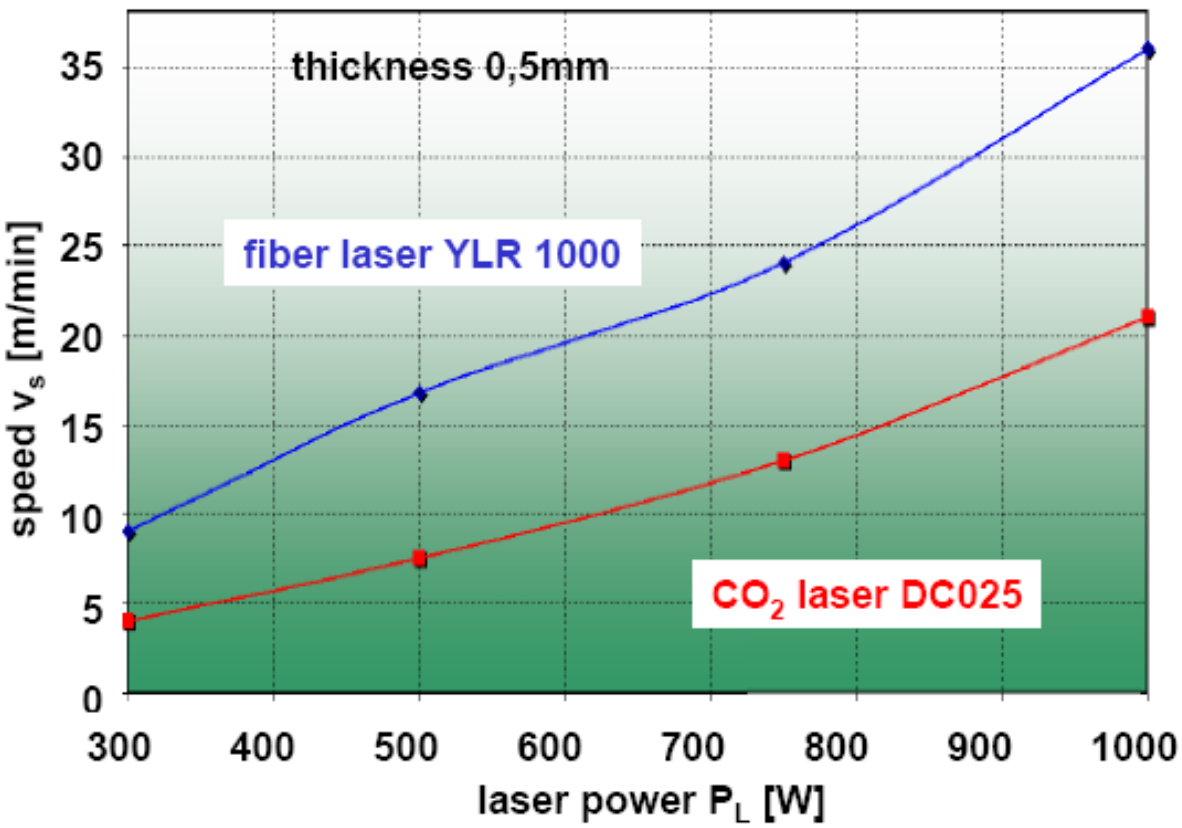
Cutting with Fiber Lasers

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005

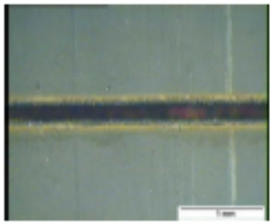
Cutting results an V330-50A (AISI M22, Electrical Steel)



cutting gap:

YLR1000:

124 µm



DC025:

128 µm

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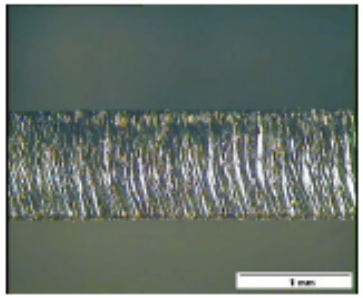
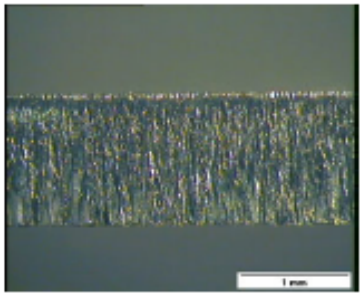
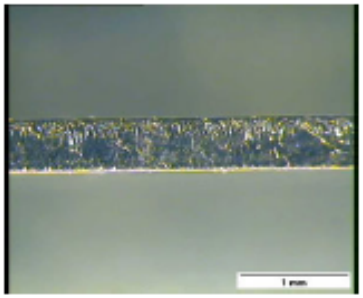
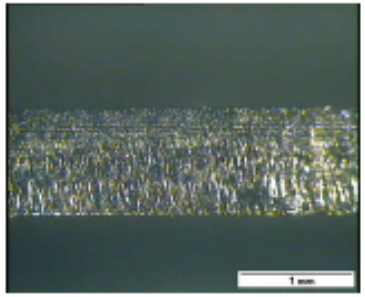
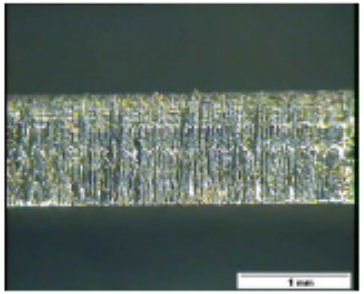
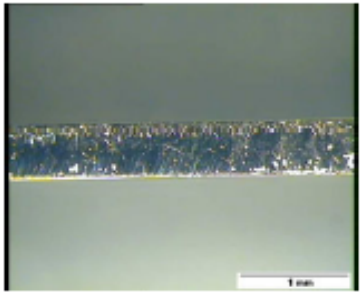
Cutting with Fiber Lasers

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005

Comparison of the cutting edges

	(AISI CRS) St1203	(AISI 5XXX) AlMg3	(AISI M22) V330-50A
YLR 1000 SM			
DC025			

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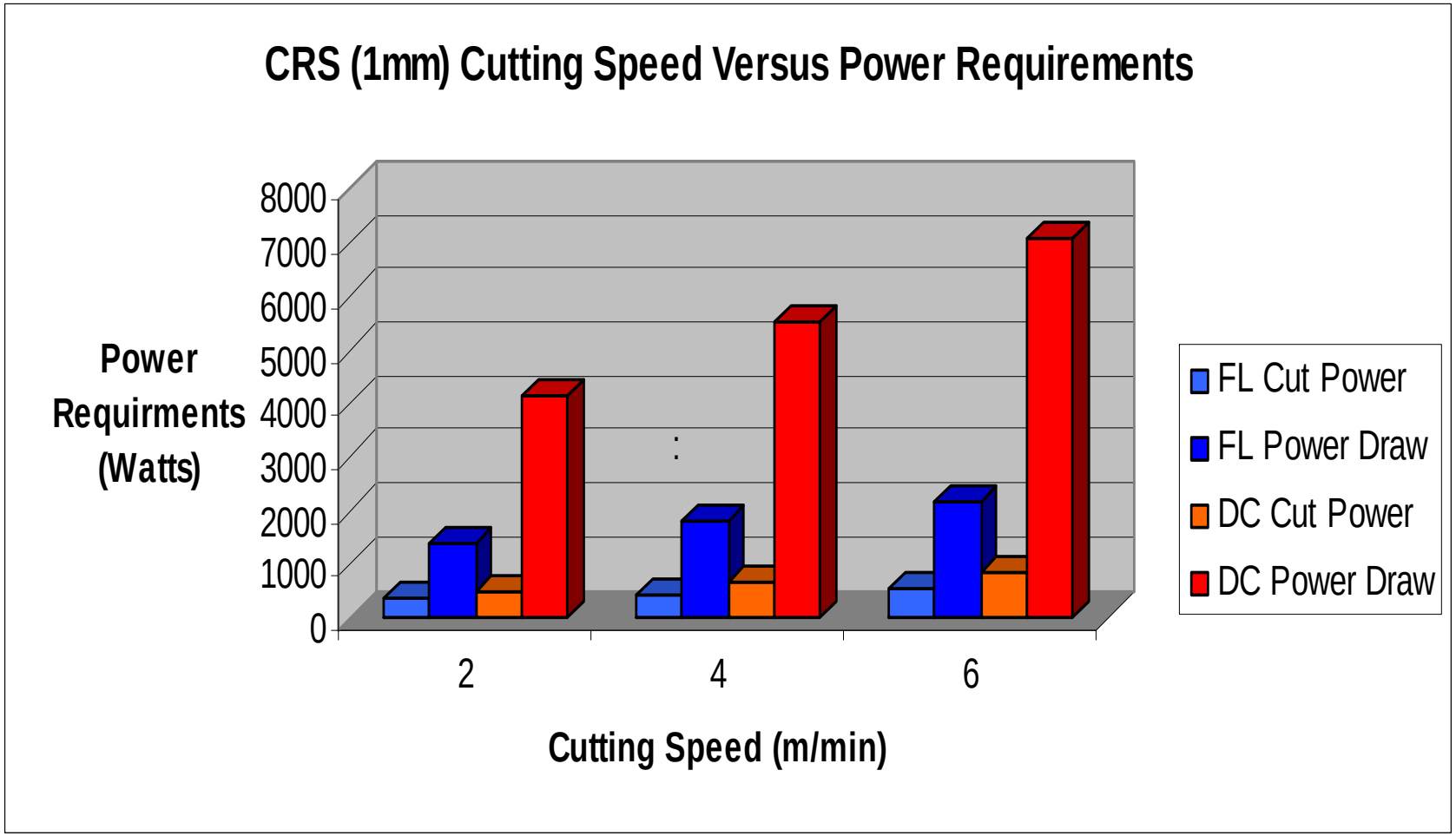
Cutting with Fiber Lasers

Ref: SM FL Conversion Efficiency 25%, DC Conversion Efficiency 12%



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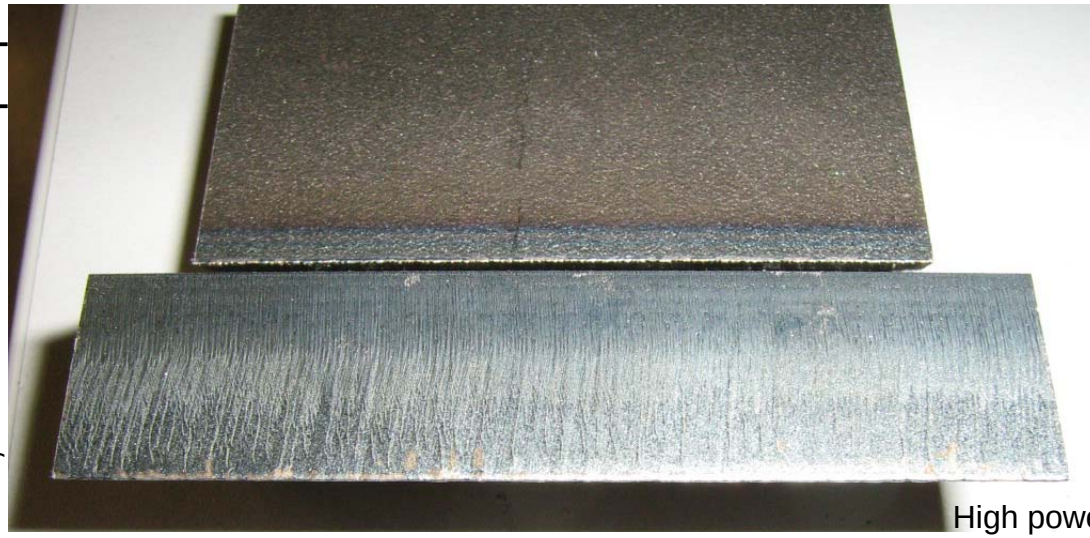
Cutting with Fiber Lasers

Ref: Thick Section Cutting
(these are not optimized, but for reference purposes)



New process regime…

Thick section cutting with NIR lasers

High power and beam quality are making this possible

Material	Thickness	Power (Watts)	Speed (m/min)	Gas (type) & pressure	Focal Position	Tip Dia. & Offset	Angle
Mild Steel	16mm	4000	0.5	O^2 (2.5bar)	+3.0	Ø1.0 @ 0.5mm	30º
Stainless Steel	16mm	5800	0.5	N^2 (20bar)	-12.5	Ø1.8 @ 0.4mm	30º
Stainless Steel	16mm	5800	0.5	N^2 (20bar)	-12.5	Ø1.8 @ 0.4mm	30º

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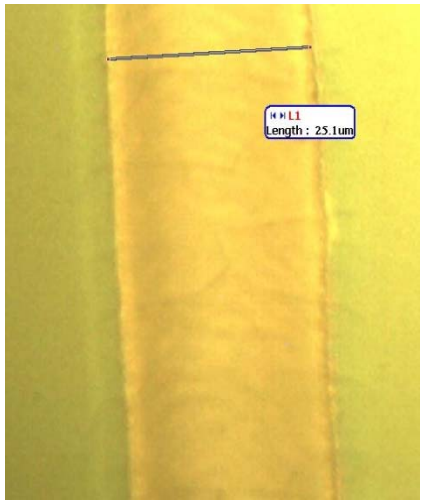
Fiber Laser Applications - SM

Single Mode (SM) fiber laser applications:

- Stent cutting
- Cutting surgical blades
- Cutting solder-masks
- Welding of razor blades
- Silicon cutting (solar panels)
- Adjustment of disc drive flexures (bending)
- Laser engraving (rolls and flat plate)
- Welding of medical devices
- Laser sintering
- Soldering
- Laser marking
- Remote cutting



CdTe Isolation
YLP-RA-1/50/30/30

Fiber Laser Applications - SM

Scanner welding of copper contacts

YLR-200-SM
f= 100 mm (~25 µm spot size)

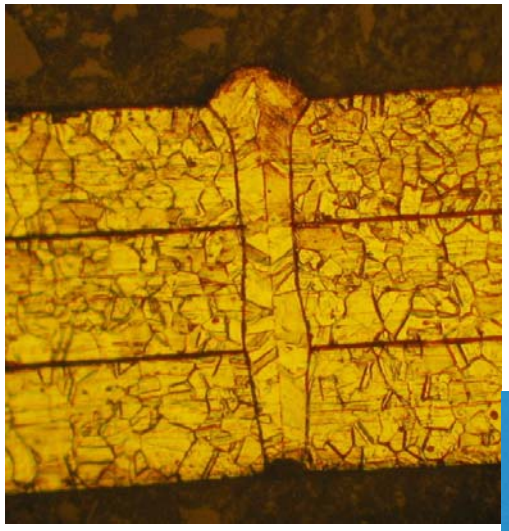
Overlap welding E-Cu58
0.3 + 0.3 mm

top view

bottom view

Fiber Laser Applications - SM

Micro welding of fuel cell components



v= 80 m/min

Laser: YLR-500-SM

v= 40 m/min

Fiber Laser Applications - SM

There is now the power and beam quality to achieve "excessively" high power density and/or a wide spectrum of caustic beam profiles to examine the boundaries of existing processes and explore new process regimes.

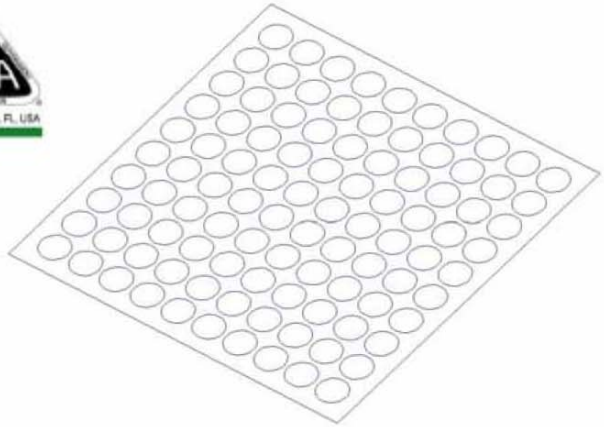
Consider the advent of remote cutting…

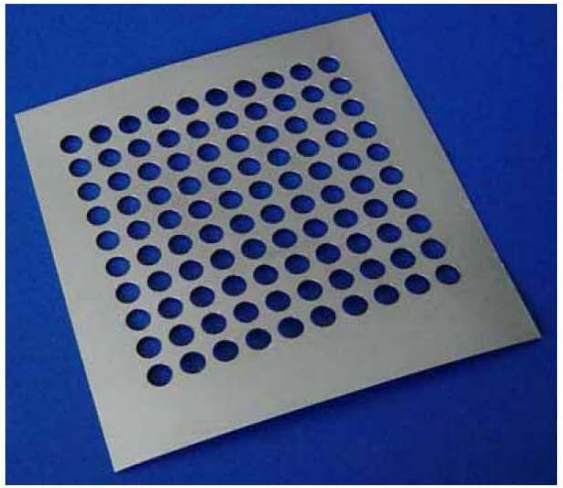
Fraunhofer

Task: 100 Holes in stainless steel
Thickness to cut: 50, 100 and 200 µm

ICALEO 2007

Thickness [µm]	Time [s]
50	1,17
100	1,92
200	2,55





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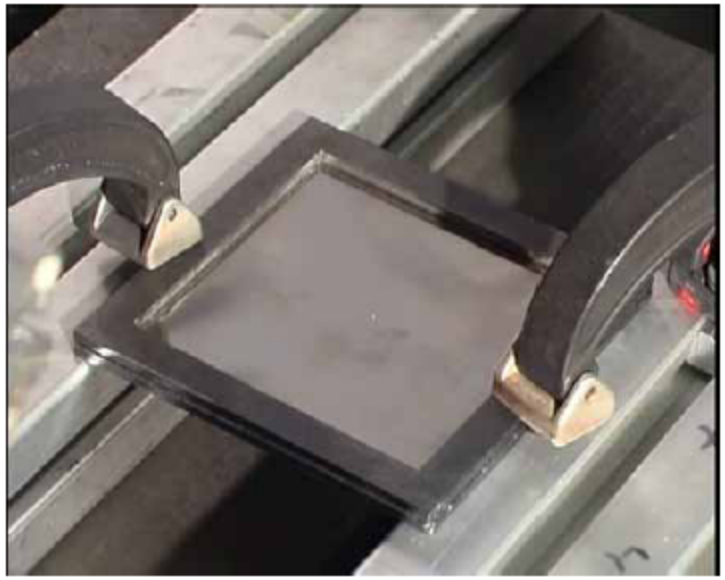
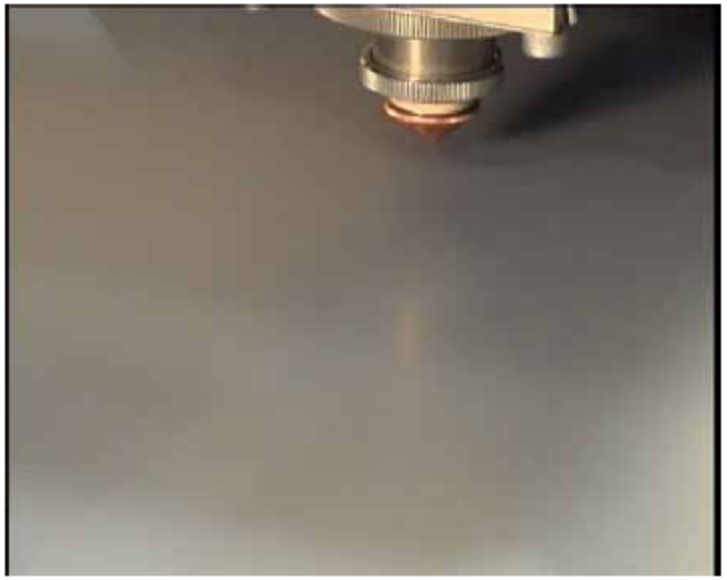
Fiber Laser Applications - SM

Comparison: Remote Cutting - Linear Drive Machine

Cutting time: **1,17 s** **19 s**





24.10.2007 slide: 20

Fraunhofer Institut Werkstoff- und Strahltechnik

2007 ICALEO

Fiber Laser Applications - MM

High power, low-mode order fiber laser applications:

- Cutting of hydro-formed automotive frames
- Blank welding for automotive industry
- Titanium welding of aircraft skins and structures
- Laser cladding for Aerospace and Oil industries
- Battery welding for automotive and medical device industry
- Pacemaker welding for medical device industry
- Transmission welding for Automotive Industry
- Sheet metal cutting and welding

Fiber Laser Applications - LAM

Laser Additive Manufacturing:

- Low volume manufacturing
  - Medical devices
  - Defense components
  - Space components
  - Functional prototypes
- Surface modification and repair
  - Gas turbine engines
  - Tools and dies
  - Heavy equipment
    - Shafts
    - Bearings
    - Other wear surfaces

LAM
LASER ADDITIVE MANUFACTURING
WORKSHOP

RPM

IPG PHOTONICS

Fiber Laser Applications - LAM

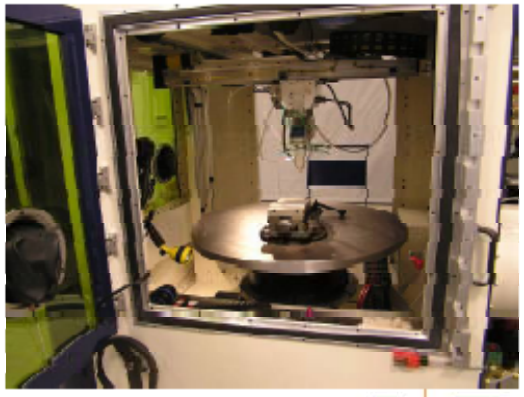
Laser Additive Manufacturing:

- Advantages over existing technologies
  - Metallurgical bond versus mechanical bond
  - Very low and controllable heat input with minimum dilution and heat affected zones
  - Minimal stress and distortion created by deposits
  - Rapid cooling rates
  - Cost effective for repairs and manufacturing
  - Ability to add a high abrasion resistant wear surface(s)
- Ref. LAM Workshop March 3-4, 2009, San Antonio, Texas
  - RPM & Associates Inc., Rapid City, SD
  - Optomec, Albuquerque, NM

Fiber Laser Applications - LAM

850-R Utilizing 3 KW IPG Fiber Laser

RPM



- Controlled chamber – less than 10ppm O2
- Motion controlled to +/- 0.001"
- Travel: "X"–3', "Y"–5', "Z"-3',with tilt and rotate table
- Large Front Door: 73.5" Tall x 45" Wide
- Small Rear Door/Window: 42" Tall x 42" Wide
- Approximate Glove Box: 94" Length x 75" Wide x 89" Tall

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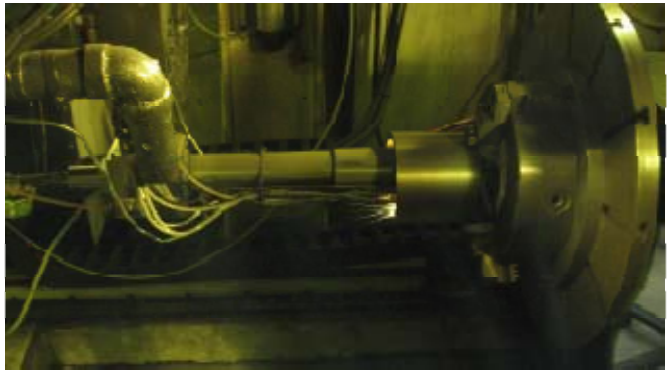
Fiber Laser Applications - LAM

Laser Clad Male and Female Bearing Adapters



Female Bearing Adapter ID cladding

-Developed WC overlay process for Male and Female Bearing Adapters.

-Laser Clad proprietary WC on 4340 bearing adapters, which increases wear area.

RPM

Final Grinding – Female Bearing Adapter

Laser Deposit – Male Bearing Adapter

Final Grinding – Male Bearing Adapter

IPG PHOTONICS

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Fiber Laser Applications - LAM

IPG Fiber Lasers: Adoption, progress & growth

Laser Repair of 4340 Atomizer Shaft Used In Electric Power Generation

RPM

-This atomizer shaft is a high speed (8800rpm) precision shaft used to drive a rotary spray head typically used in "Flue Gas Desulfurization" (FGD) scrubber systems in Coal Fired Power Plants and Incinerators.

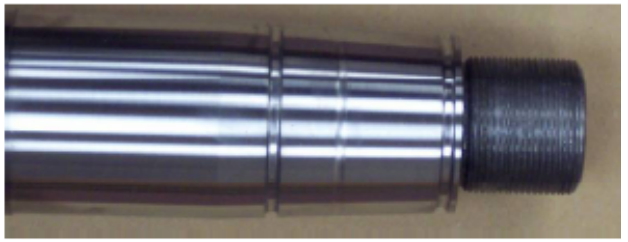
-Developed Repair Process for tapered fit section and seal surface of 4340 Atomizer Shaft utilizing 420 SS.

-Shafts were previously repaired by a Spray Process featuring a "Mechanical Bond." The LCT Process utilizes a "Metallurgical Bond" that generates a high quality permanent repair, which saves over $14,000.00 over purchase of a new shaft.

-Repeat customer, several parts have been repaired.

Atomizer Shaft as Received

Atomizer Shaft with Laser Deposit



Atomizer Shaft Final Machining

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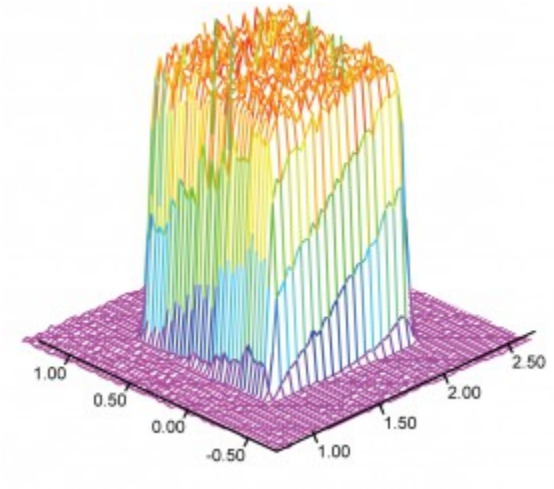
IPG PHOTONICS

Fiber Laser Applications - LAM

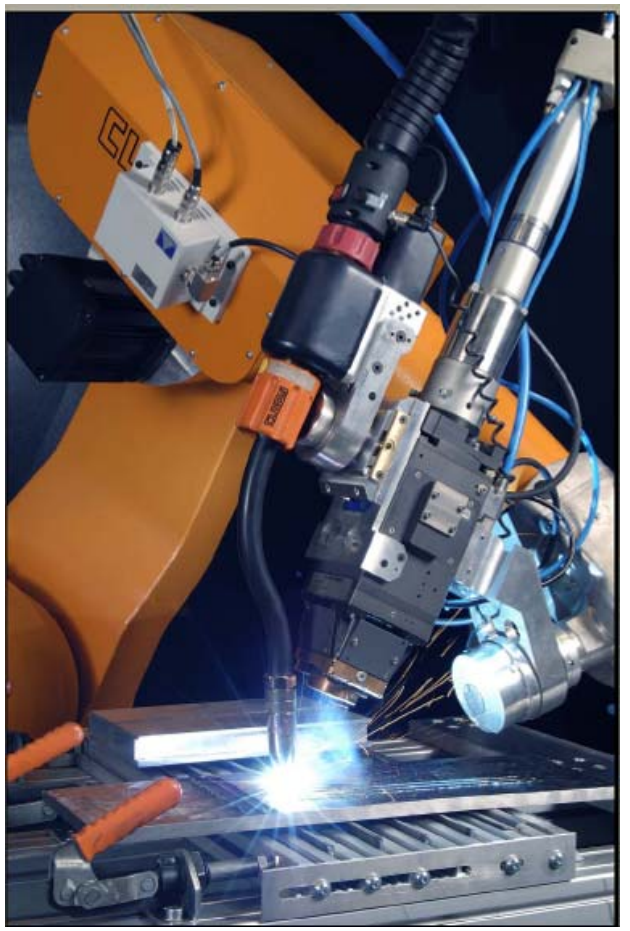
3 & 4 kW Power Supplies
(Others available upon request)

- Beam switchable for multi-cell production.
- Plug and play fiber sizes and geometries



Fiber Laser Applications – Welding

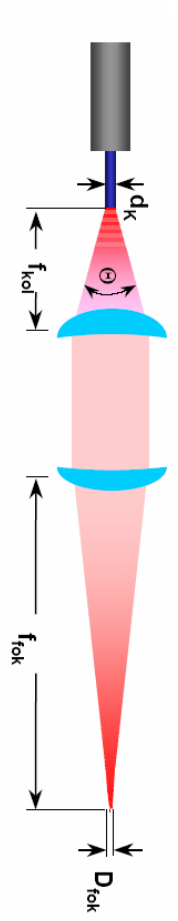
- Autogenous laser welding
  - Remote (thin sheet)
  - Close coupled (thin & thick)
- Cold wire (filler wire)
- Hybrid (Laser +MIG)
- Hybrid (Laser +TIG)
- Hybrid (Laser + TIG + Wire)
- Hybrid (Laser + Plasma)
- Hybrid (Laser + Plasma + Wire)



Fiber Laser Applications – Remote Welding

IPG Fiber Lasers: Adoption, progress & growth

***Scannerfree* Remote Processing**

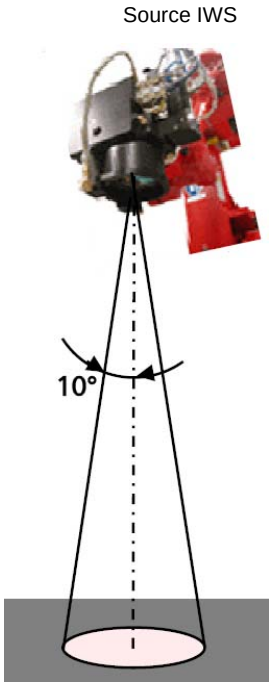


Source Kuka

Working Distances
1000-1500 mm

***Scanner* Remote Processing**

Source Highyag



Source IWS

Working Distances
~ 500 mm

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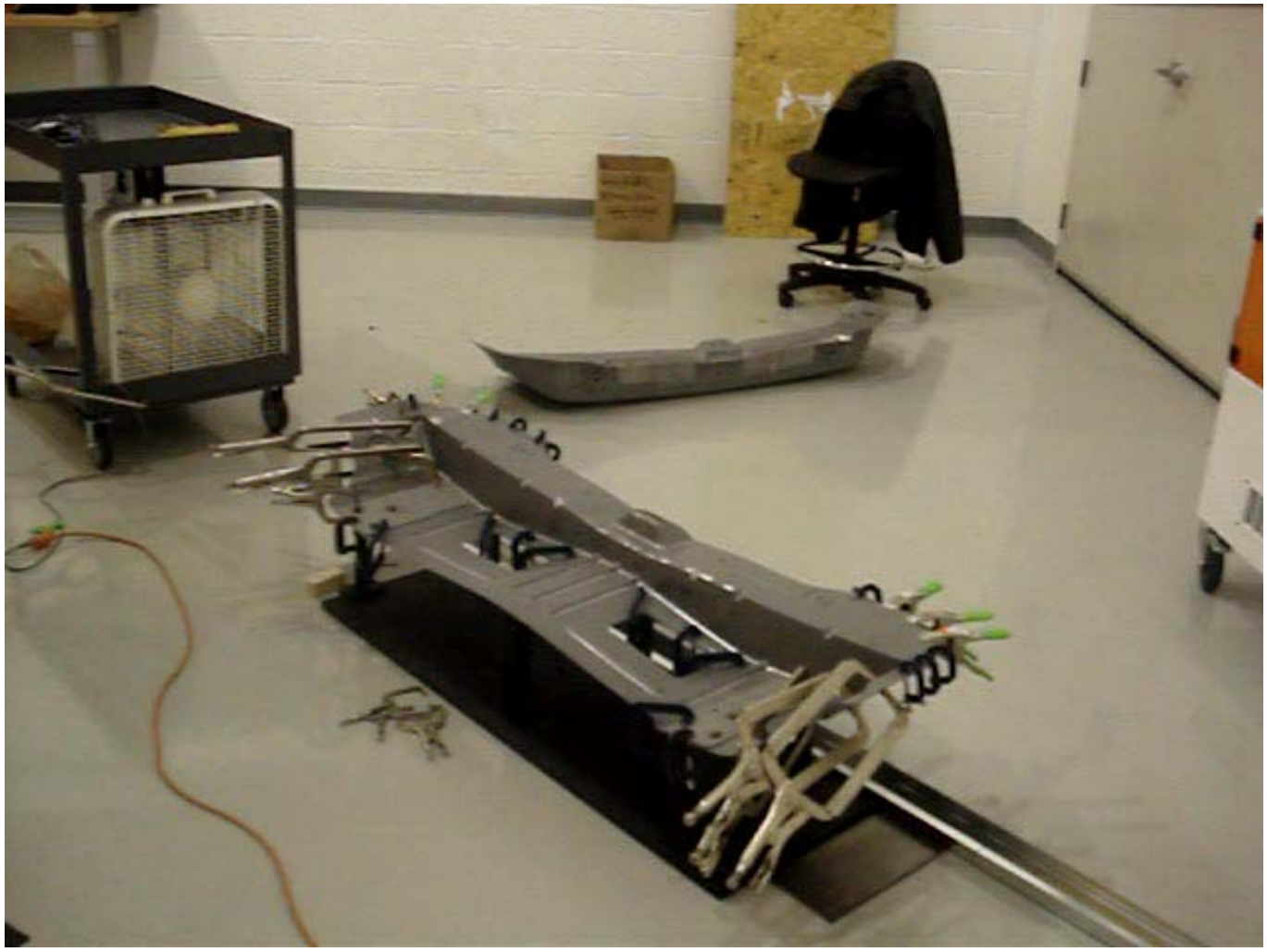
Fiber Laser Applications – Remote Welding

IPG Fiber Lasers: Adoption, progress & growth



Ref.: HighYAG, FANUC, NuTech

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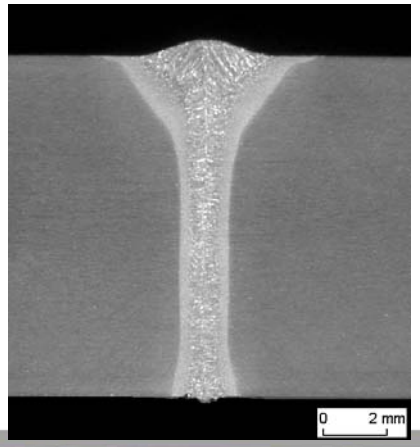
Fiber Laser Applications - Welding

Hybrid Laser Welding – Examples & Candidates

- *Ship building*
- *Pipeline welding*
- *Tube welding*
- *Off-Shore-Industry*
- *Railcars*



Quelle: BIAS

Laser-Hybrid
X70
t = 12 mm
P_L = 10.5 kW
v_S = 2.2 m/min

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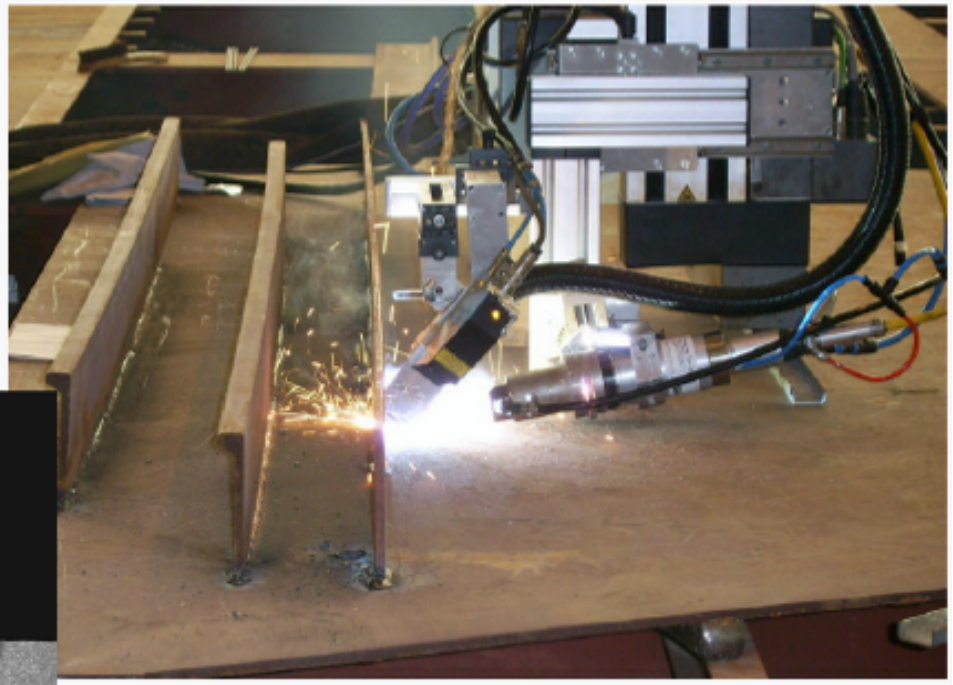
Fiber Laser Applications - Welding

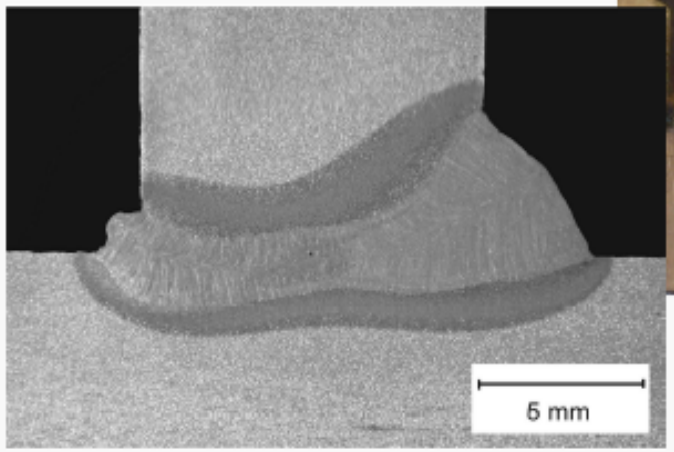
Hybrid Laser Welding – Examples & Candidates

- Laser GMA hybrid welding tractor (fibre laser version)

DOCK LASER

- T-joint welding at Navantia, Spain
- 10 mm stiffener thickness
- 1.5 m/min welding speed





IPG PHOTONICS

Fiber Laser Applications Welding

Monfalcone, Italy

The first outfitting of a welding gantry with a 10 kW fibre laser source for hybrid welding in production at Fincantieri Shipyard in Monfalcone in 2007

Fiber Laser Applications

New Process Regimes for Fiber Lasers

The limitation is no longer the power source, but how it is applied and the physics of the process application itself:

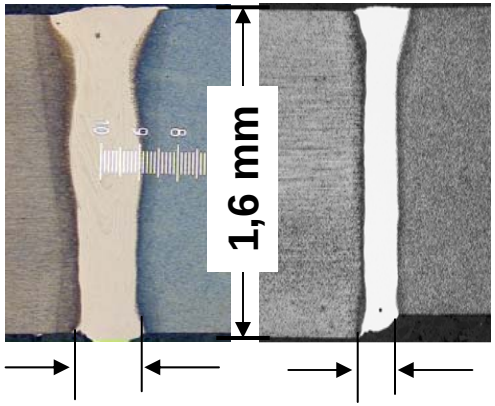
- Extreme narrow gap welding
- Hybrid thick section welding
- Remote welding
  - Fixed optic
  - Scanner optic
  - Flying scanner optic
- Remote cutting
- Thick section cutting
- Fixed cutting head (no capacitive height sensing)

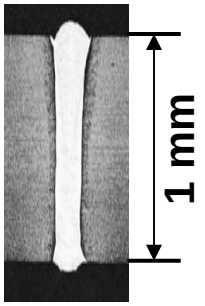
New Process Regimes for Fiber Lasers

Saw Blade Welding

laser power 1.0 kW

electron beam | *fiber laser* | *fiber laser*

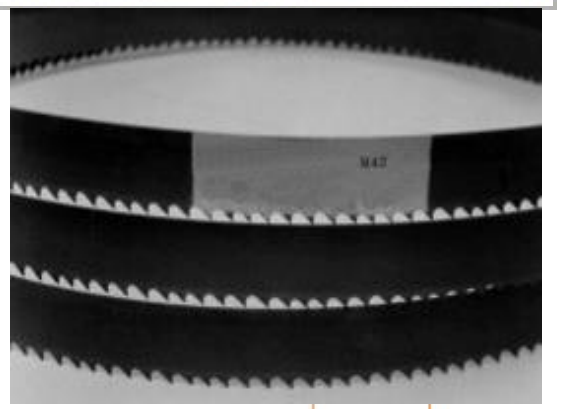




0,37 mm **0,18 mm**

v_s = 8 m/min **v_s = 10 m/min**

v_s = 30 m/min



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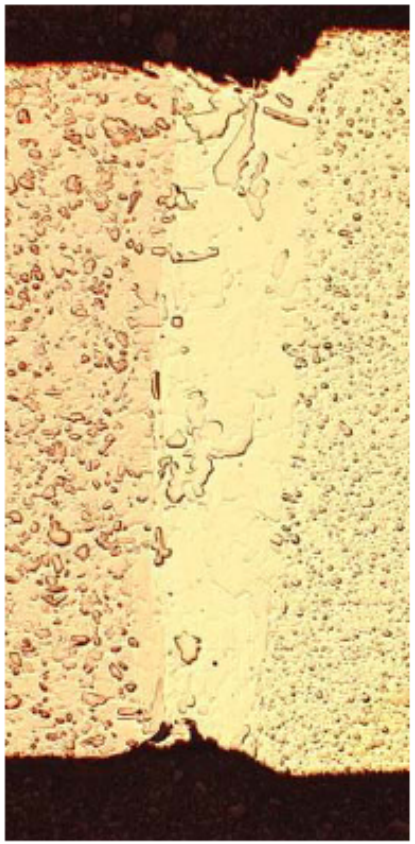
New Process Regimes for Fiber Lasers

Welding copper



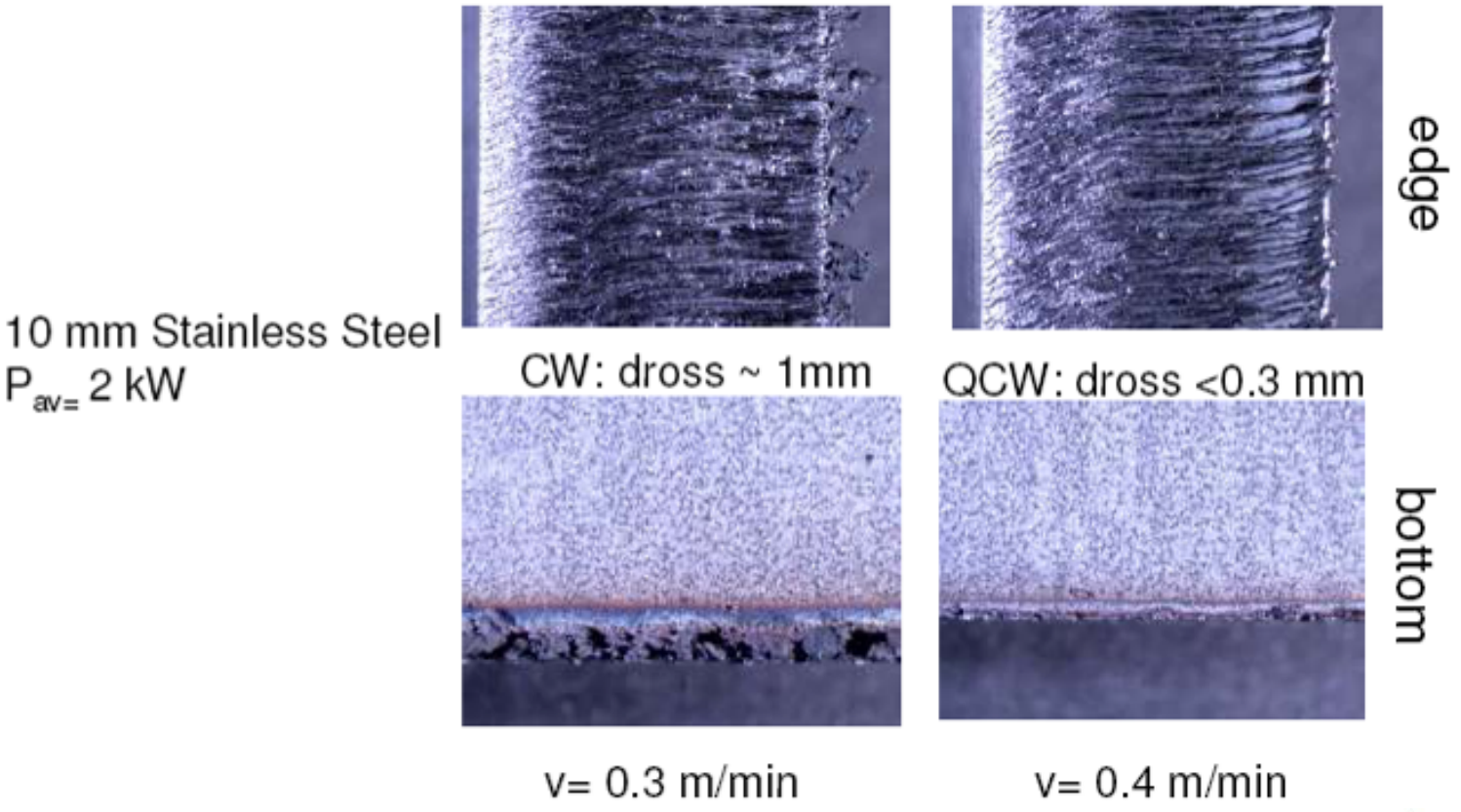
Conclusions

- fiber lasers are definitely able to weld copper under certain precautions
  (angle of incidence, fiber diameter, focal position)
- wide range of parameters to meet the requirement of different applications
- with 4 kW laser power, penetration depth of 4 mm possible
- use of shielding gas and cross jets increases welding depth
- mixed alloy joints (copper/ brass/Manganin) possible
- the excellent beam quality of fiber laser opens new application areas in copper welding

Fraunhofer IWS Institut Werkstoff- und Strahltechnik

New Process Regimes for Fiber Lasers

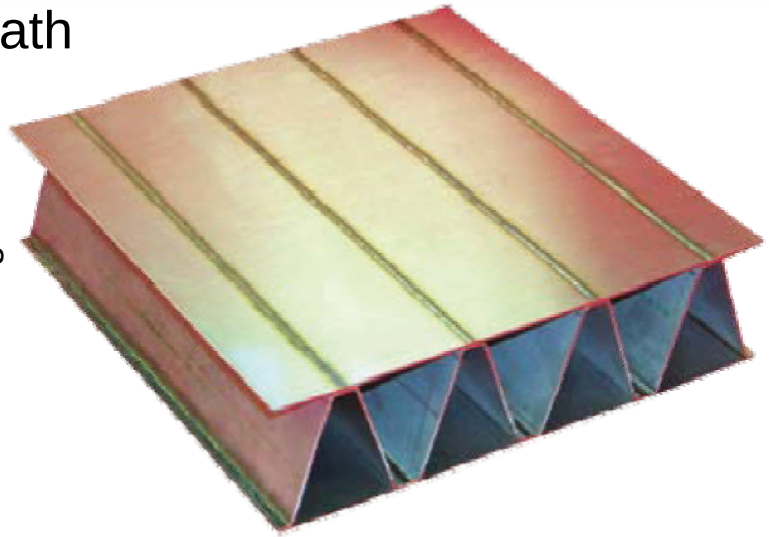
Cutting with QCW Lasers



New Process Regimes for Fiber Lasers

Orthotropic bridge construction:

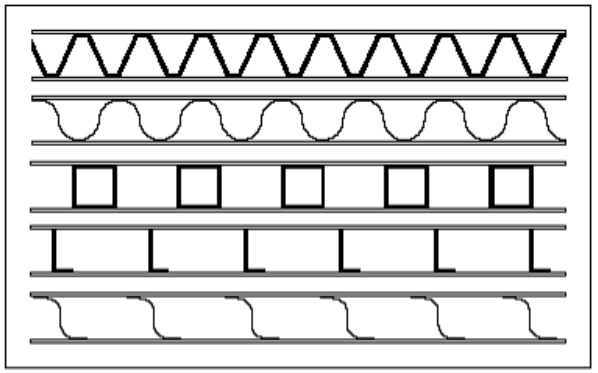
New core and sandwich solutions for structural panels enabled by laser welding, thick section blind welds of 3/8” – 1” thick deck plate to ribs and webs beneath

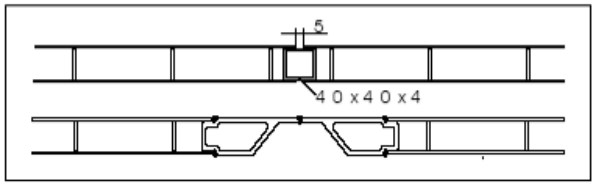


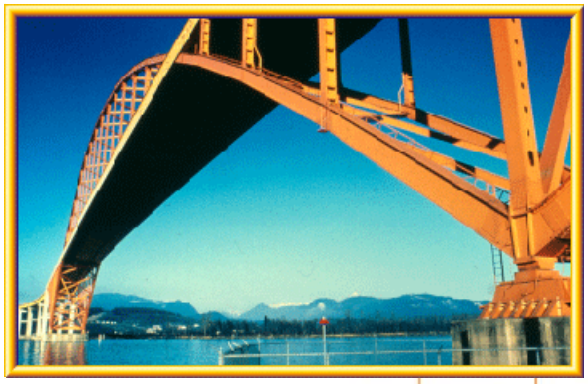
Stiff, lightweight metallic sandwich panels offer the potential for significant weight and cost reductions.

Image courtesy of:
Applied Thermal Sciences Inc.,
and Naval Metalworking Center

Ref. http://sandwich.balport.com/public_downloads/public-project-summary.pdf

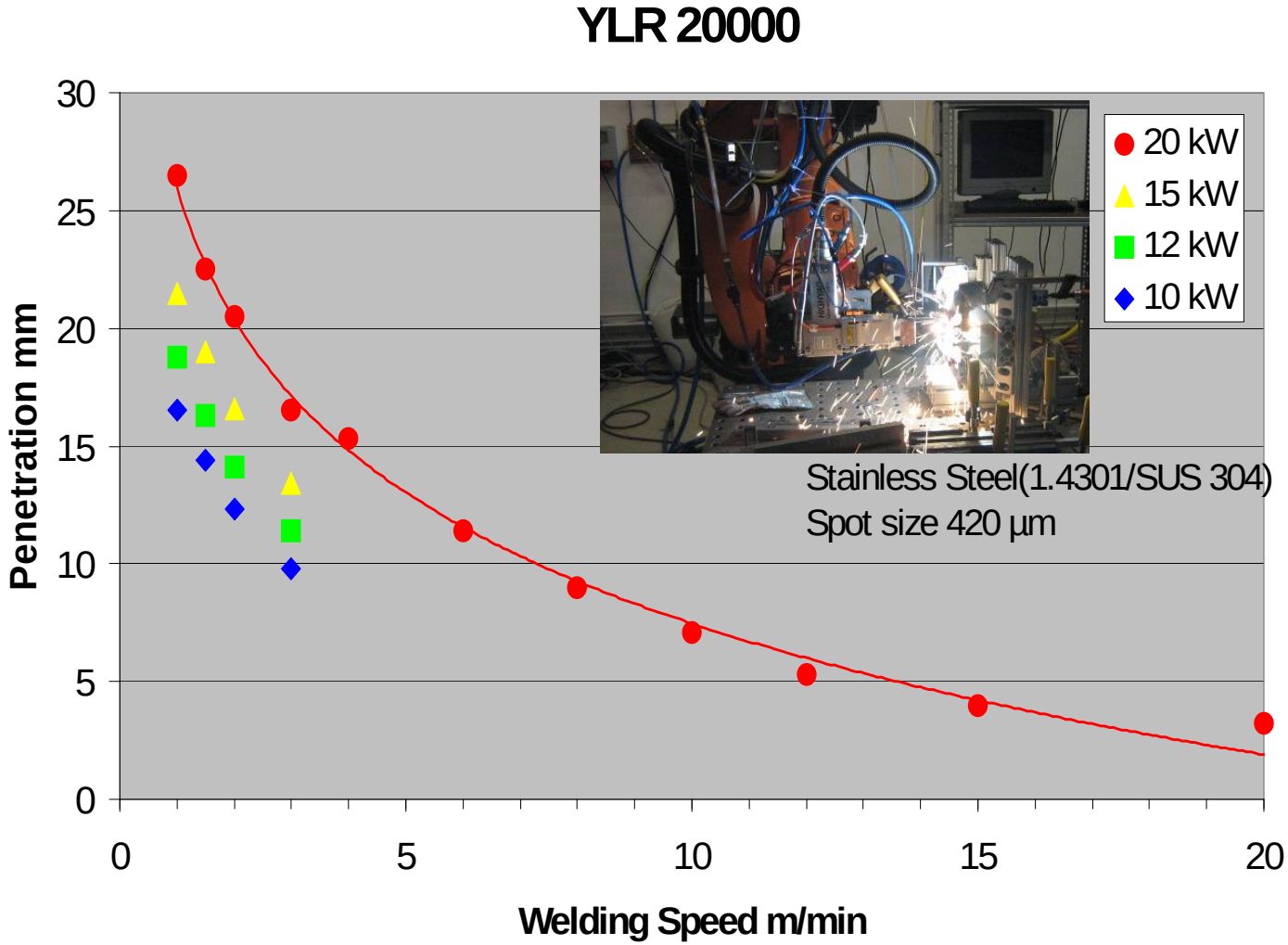


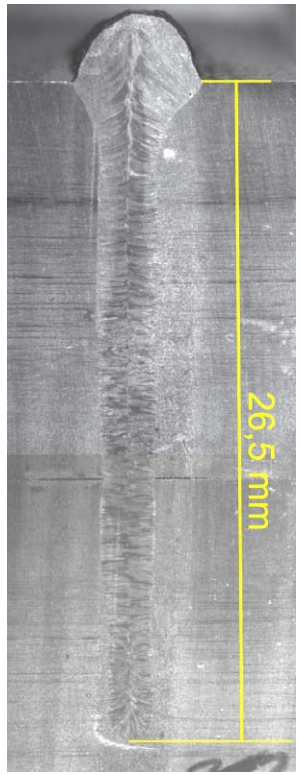




New Process Regimes for Fiber Lasers

IPG Fiber Lasers: New process regimes for fabricators





Overlap joint 2x 15 mm
Stainless steel 1.4301,
1 m/min.

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Future

Outgrowth of continuous improvements at IPG:

- Increase in SM power (near future target of 10kW)
- Diode coupled fiber delivery (e.g. for brazing applications)
- Increased beam quality and power from single element diodes
- QCW fiber lasers
- Increased modulation capability of pulsed fiber lasers

Fiber Laser Summary

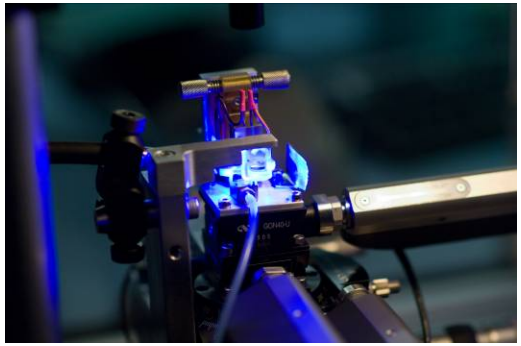
Conclusions:

- Fiber lasers have made a major Impact in the world wide material processing market
- Fiber lasers have expanded the material processing market
- Reliability has been proven on multiple material processing applications at all power levels in production environments
- The performance of fiber lasers exceeds previous laser technologies while offering substantial cost benefit to users
- Fiber lasers can compete, on a cost basis, with other technologies such as Plasma, EDM and Electron Beam

Fiber Laser Summary

IPG is committed to:

- Continuing improvement and expansion of product offerings
- Continuing reduction in the cost of ownership
- Expansion of the market through application development
- Our mission is to make Fiber Lasers the preferred choice for manufacturing technology
- Commitment to support of our customers



THANK YOU FOR YOUR ATTENTION

rpaura@ipgphotonics.com

Please consider joining the LIA & FMA

- Great networks of knowledge
- Training seminars, webinars…
- Conferences (ALAW, ICALEO, ILSC, etc.)