SPI® Lasers

Fiber lasers
Made for

Micro Marking
Macro Medical

nqa. ISO 9001 Registered

UKAS QUALITY MANAGEMENT

Applications of high-performance OEM CW and pulsed fiber lasers in precision manufacturing processes

Paul Harrison

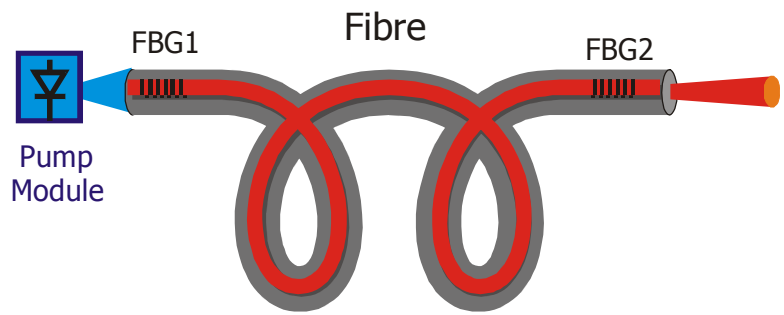
26th June 2012

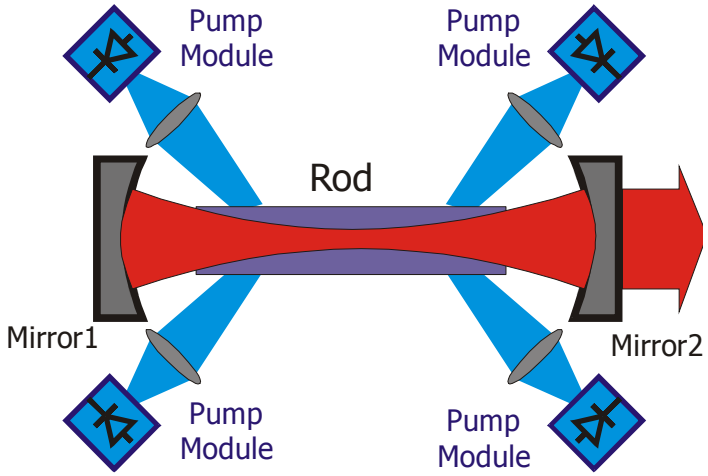
Contents

- Introduction to fiber lasers
- CW-M laser applications
  - Cutting
  - Welding
- Pulsed laser applications
  - Marking/engraving

Cladding-Pumped Fiber Lasers

Fiber Laser





Solid-State Laser

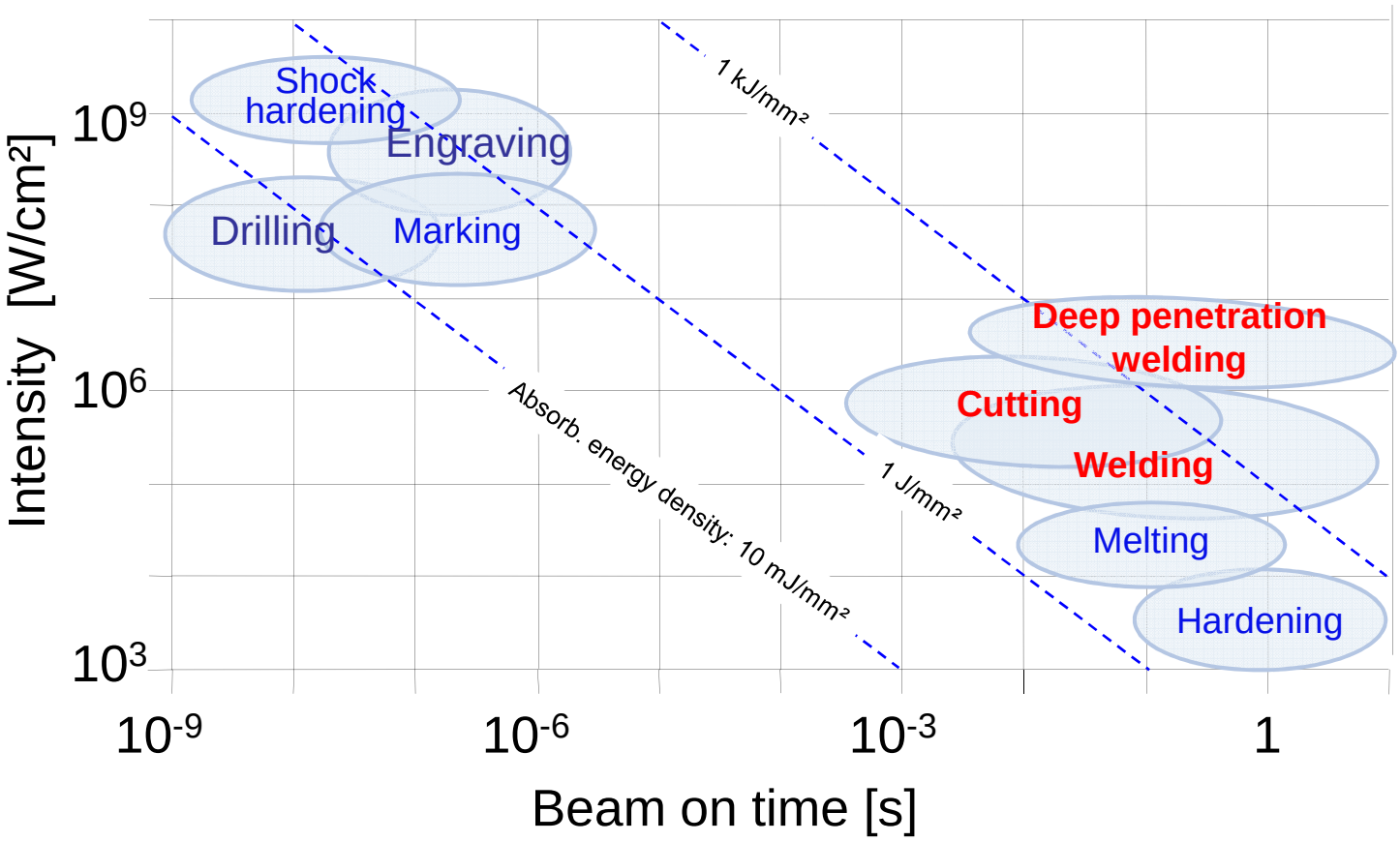
- in-fiber FBGs form robust cavity – no optical alignment
- large inner-cladding guides commercially available MM pumps
- RE-doped core converts low-brightness pump to high-brightness signal beam
- core design defines the output beam quality
- long & slim –vs- short & fat
- no thermal effects - tremendous potential for power scalability

Benefits of Fiber Lasers

- **Parametric Performance**
  - High stability and linearity
  - High beam quality
  - Modulation range CW to 100kHz
- **Ease of integration and operation**
  - Robust monolithic fiber architecture
  - No user alignment or adjustments
- **No preventive maintenance requirements**
  - High reliability single emitter pump diodes
- **High energy efficiency**
  - up to 10x equivalent Nd YAG lasers/CO_2 lasers
  - Single phase mains operation

Material processing parameters

- Intensity vs Interaction time – Thermal regimes



(Courtesy Fraunhofer CLT)

SPI CW-M laser range

25-200W
Aircooled R4

100-500W
Watercooled R4

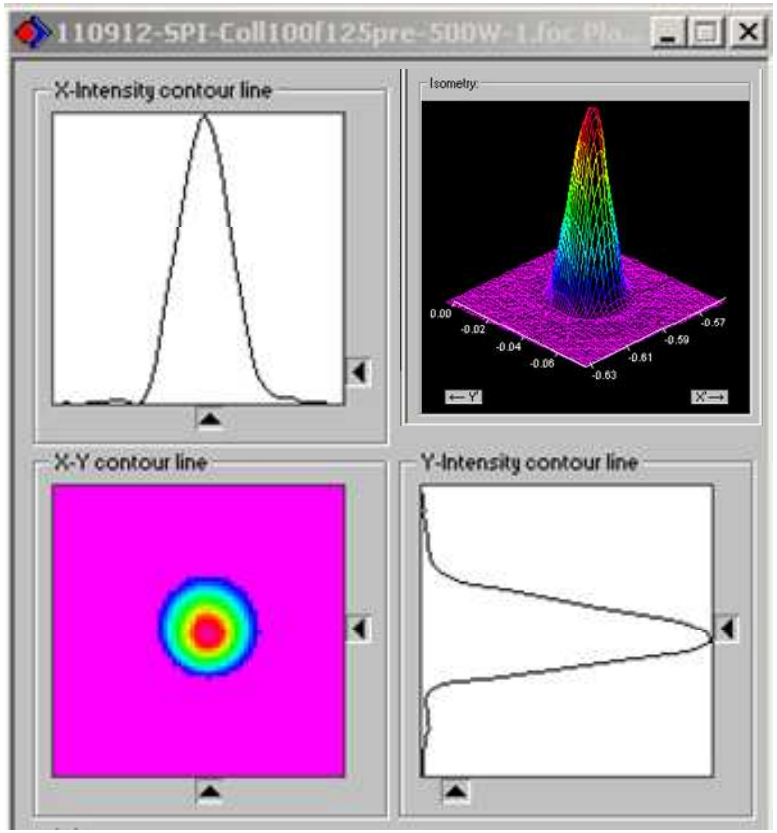
500-1000W
Watercooled

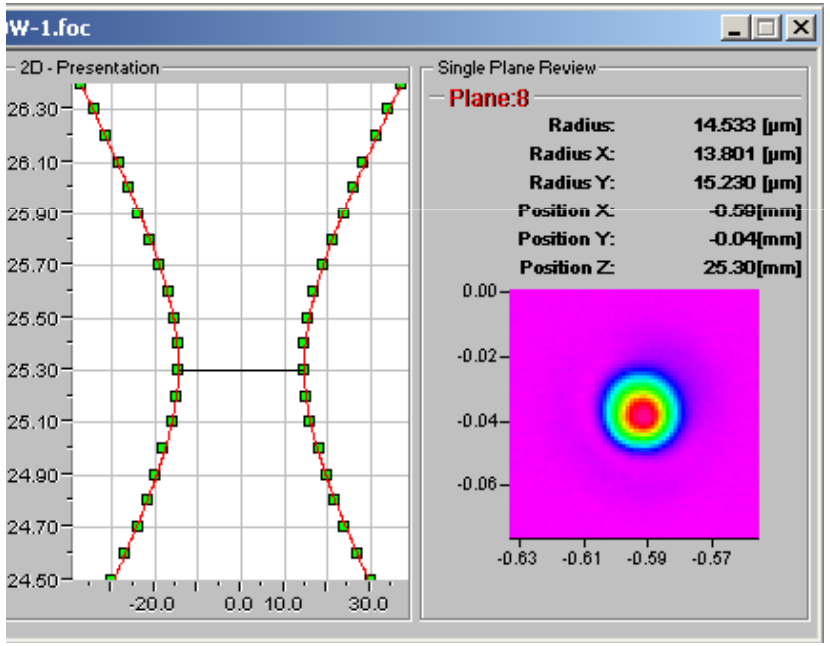
2 main application areas:

Cutting **Welding**

500W CW laser – beam quality

- 500W M^2 ~ 1.1 CW-M Laser
- 20µm core diameter, 100mm FL collimator, 125mm FL focusing lens



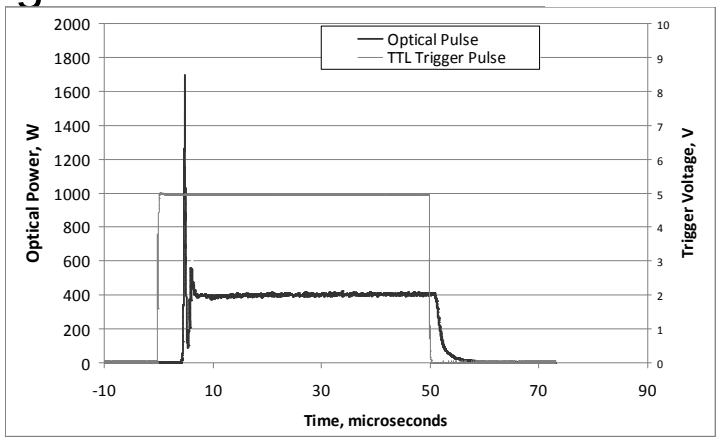


Beam caustic through focus @ 500W, spot size ~30µm dia

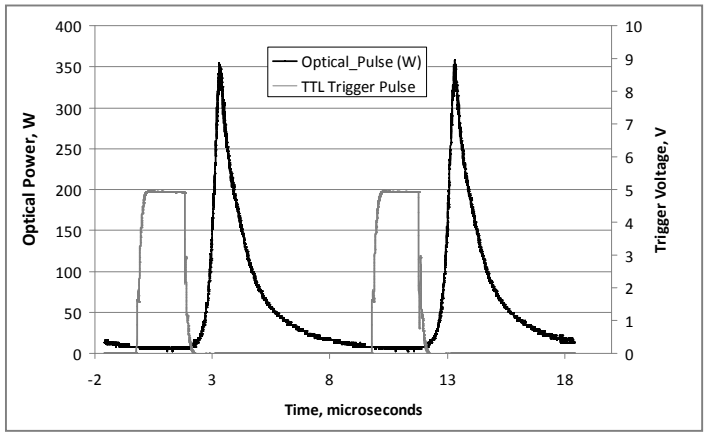
Parametric performance

- Digital modulation

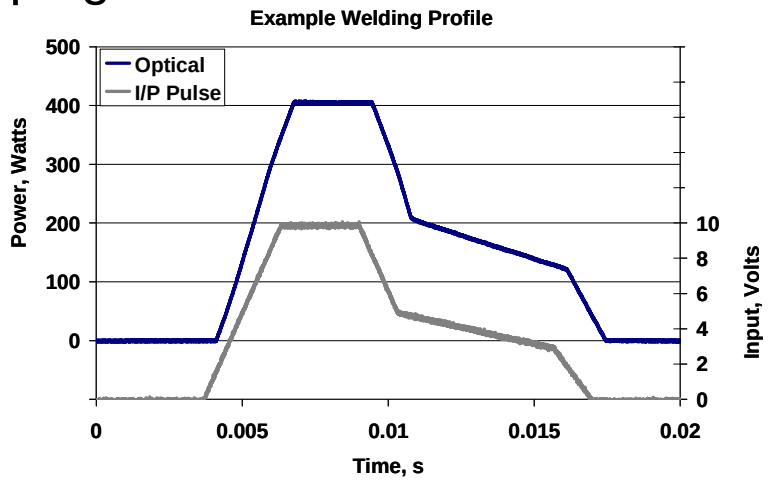
10 kHz



100 kHz

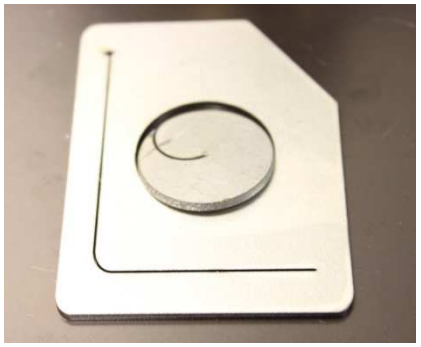


- Analog pulse shaping



500W – Cutting Performance

Mild Steel

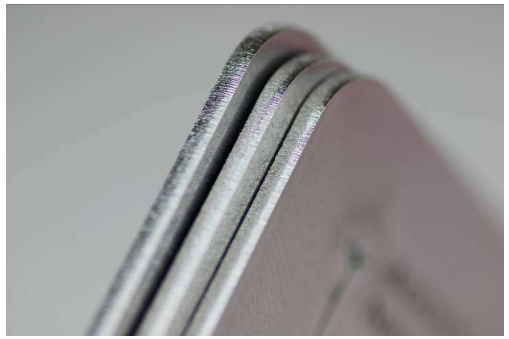


2mm thick @ 2.6 m/min

5.3mm thick @ 0.9 m/min

Stainless Steel

0.5mm thick @ 20 m/min



1.5mm thick @ 1.25 m/min

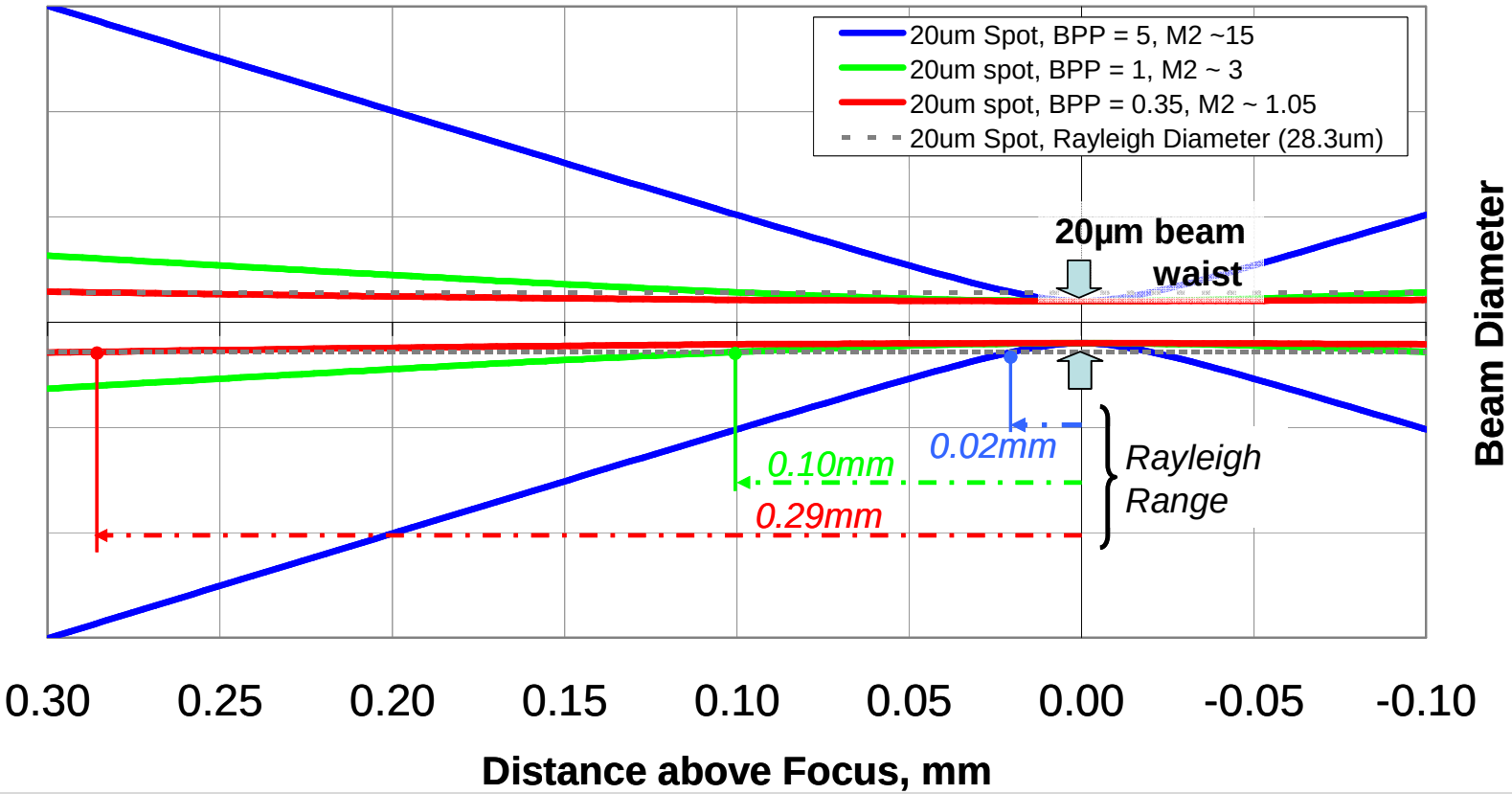
Aluminium

1mm thick @ 2 m/min

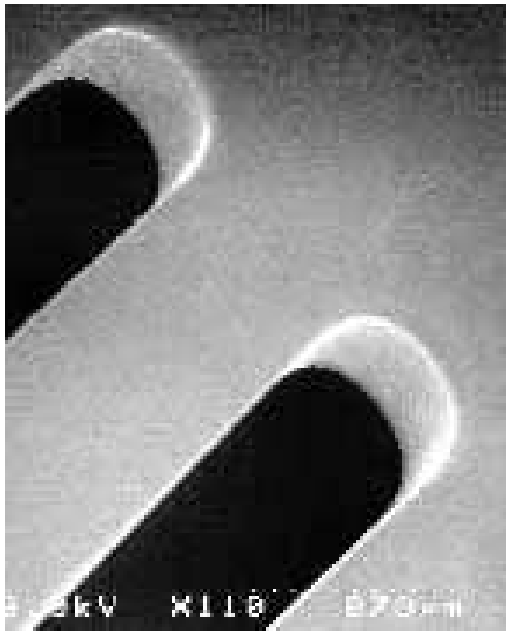
Fine Kerf Precision Cutting

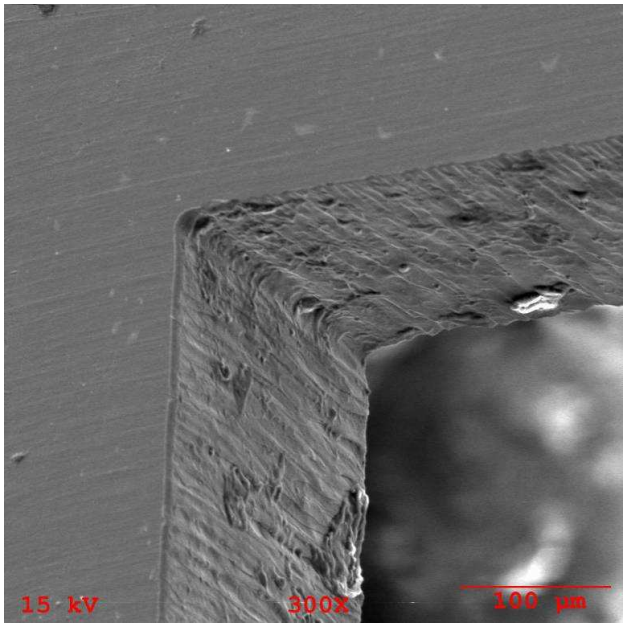
- High speed thin section cutting
- Bright metals, ceramics cutting

Beam Quality Advantage of Singlemode for Fine Kerf Cutting



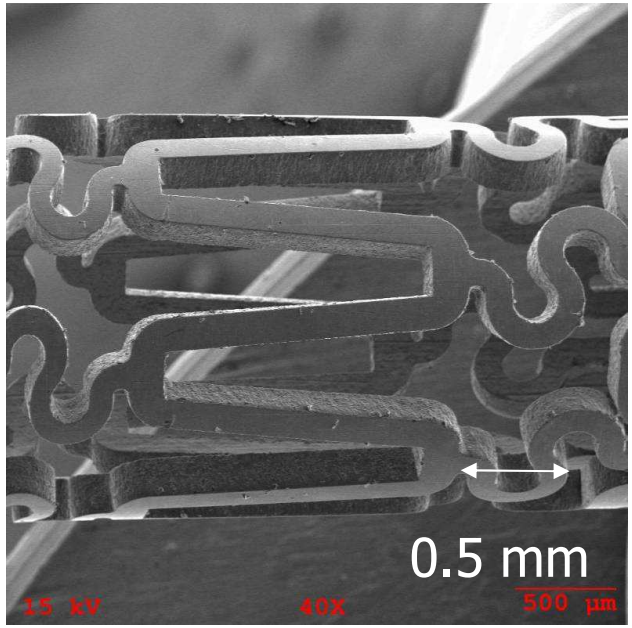
Fine Cutting – Foil

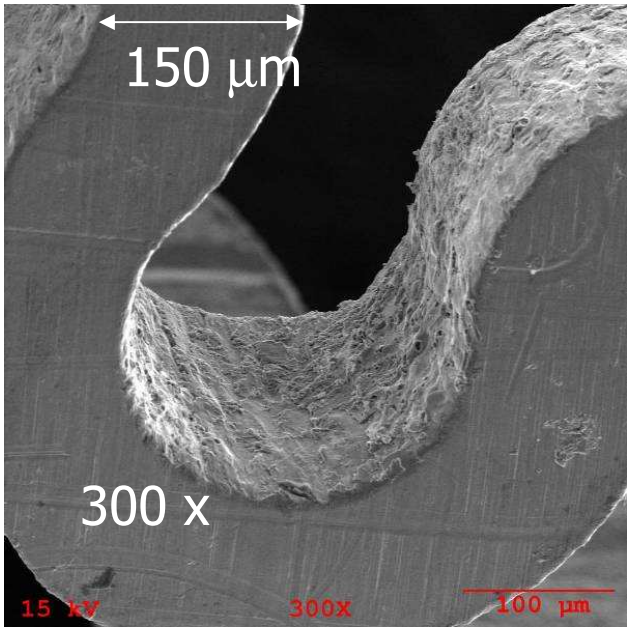




- High speed, high quality cutting of thin SS sheet
- Mainly electronics sector – stencils, etc.
- High beam quality and pulse modulation enable increased productivity and finer detail
- Process parts have smooth, burr-free walls

Medical - Nitinol Stent Cutting





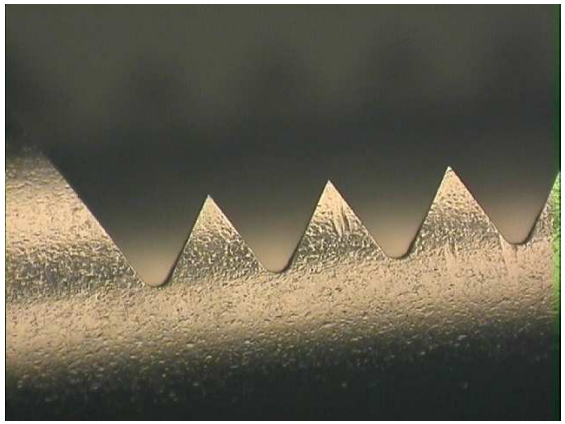
0.2 mm wall thickness cut at 10 W, 1.2 m/min

Courtesy LPL Systems

Precision micro cutting - Medical

- Medical devices - metal tube cutting
- “Repeatable quality is everything”
- Use PWM of laser beam to maintain constant power per mm of cut

Courtesy of Reliance Laser

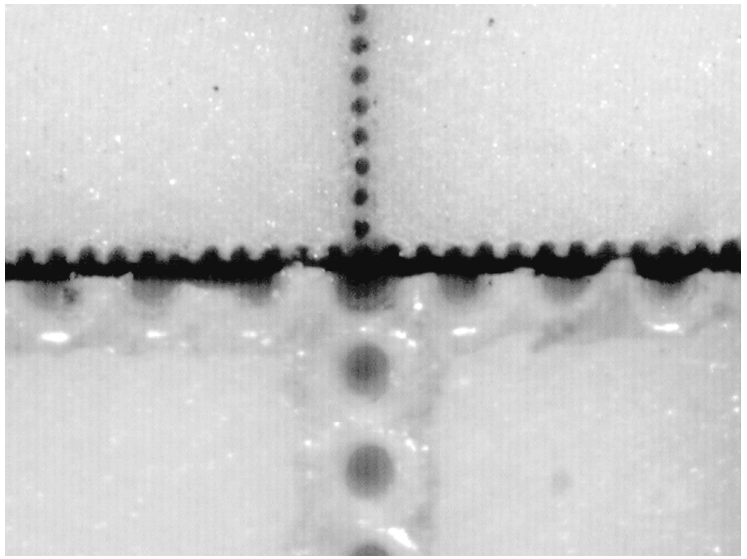


Courtesy of Miyachi Unitek Corporation

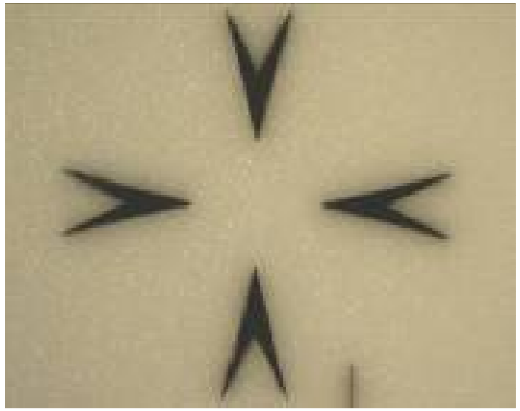
Ceramic fine processing

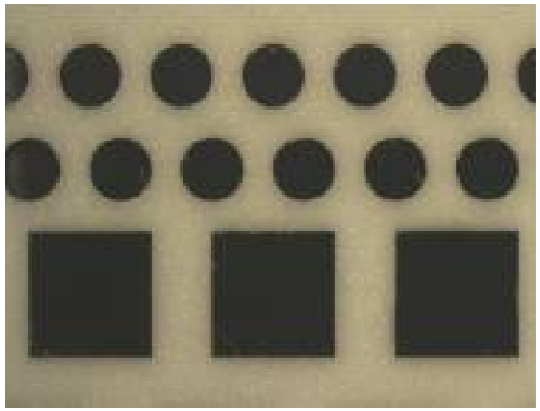
200W Fibre Laser
λ=1.07um, M^2<1.1

500W CO_2 Laser
λ=10.6um, M^2~1.3



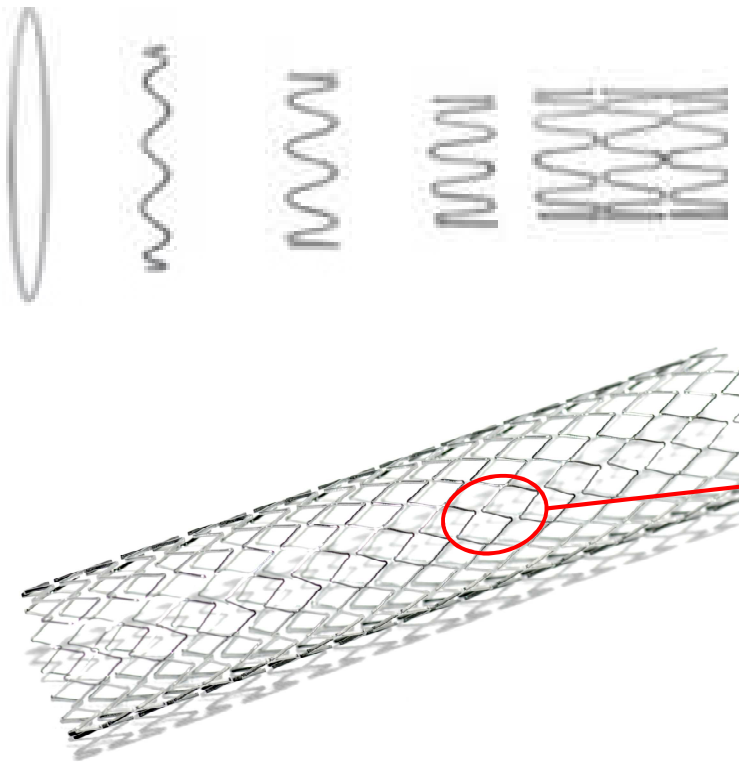
High precision alumina substrates cut with 200W laser

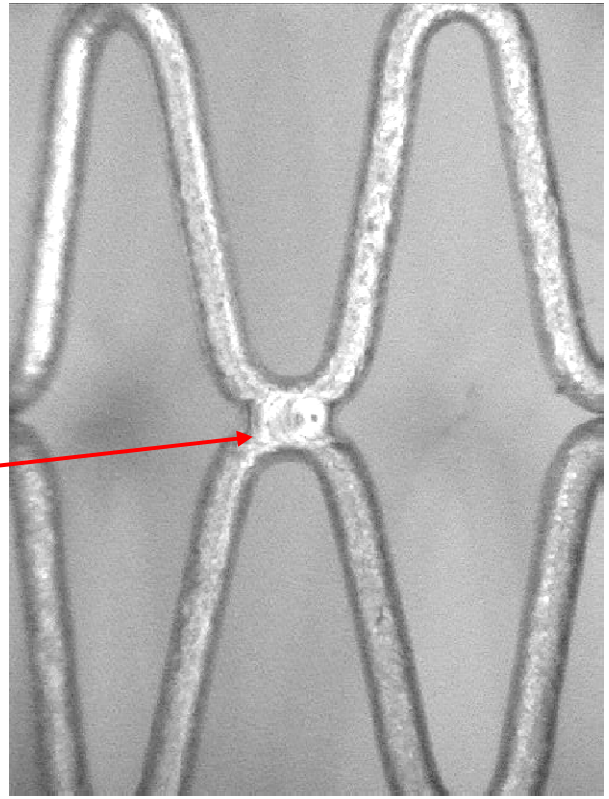




Precision micro welding - Medical

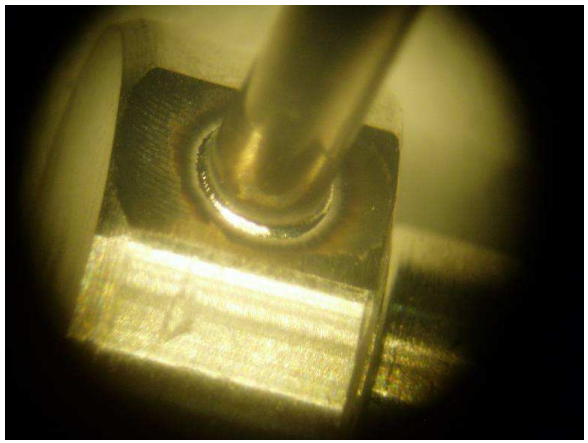
- Welded-Wire “Crown” Stent
- Must be spatter-free





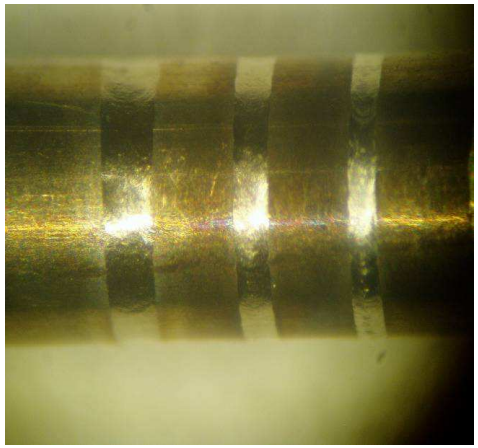
Precision micro welding - Medical

- Replacing high pulse energy welds with lower energy, better controlled CW-M pulses



2 mm OD tube 0.2 mm wall

1.8 mm diameter



1. 5 mm diam, 0.4 mm wall

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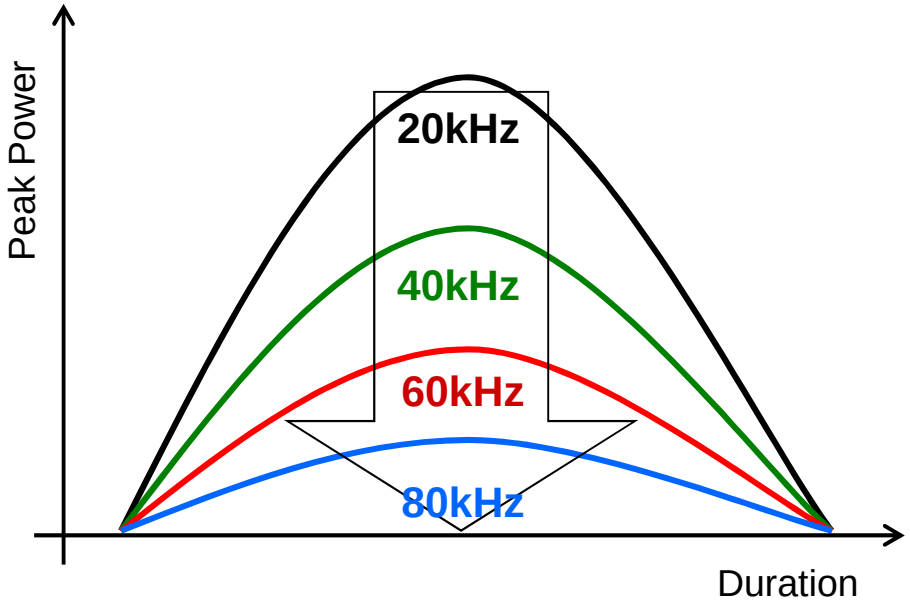
HS – Series Pulsed Fiber Lasers

- SPI's HS lasers offers true laser flexibility
  - Beam quality S,L & H types – **M^2**
    - Tailored spot size, depth of field & energy distribution
  - PulseTune pulse width control - **WF**
    - 10-200ns pulse widths with 25 Waveforms
  - High frequency range 1-1,000kHz - **kHz**
    - HS lasers can operate from 1kHz – 1MHz and also in CW mode
- No maintenance, air-cooled, no alignment, compact
- Standard 3 year warranty

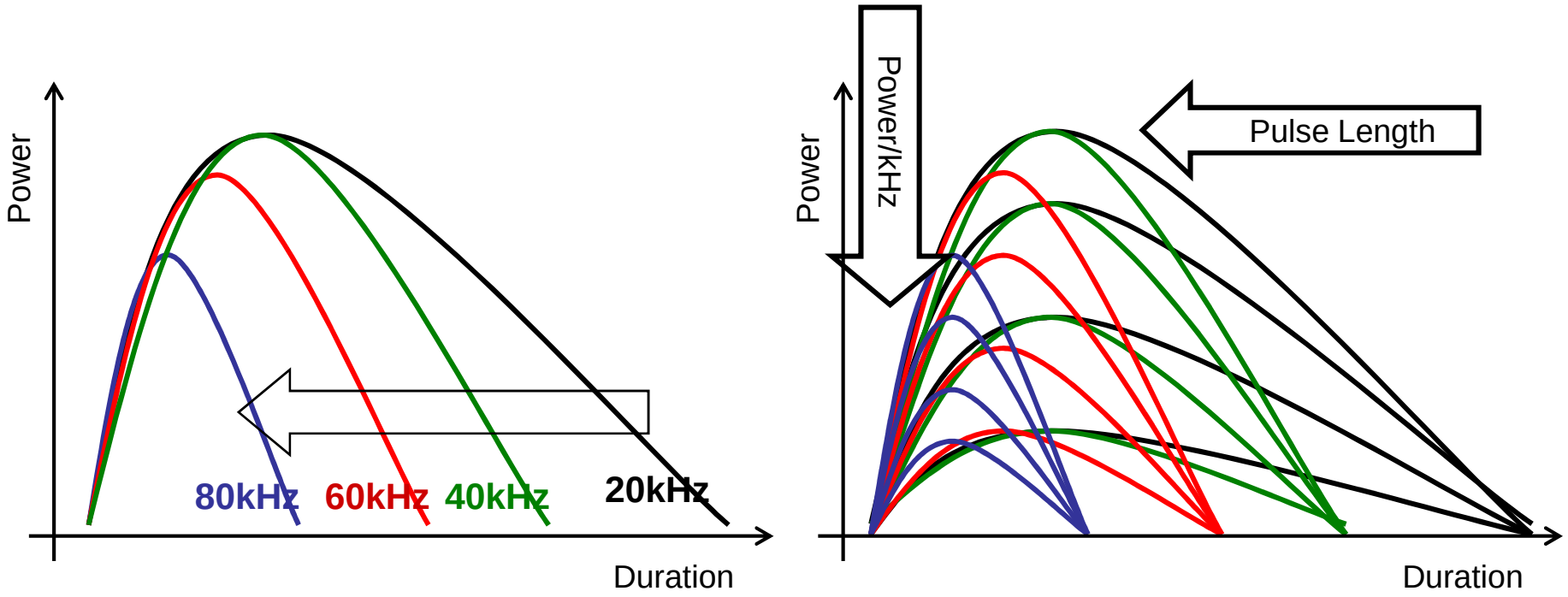
Typical Pulsed Output – Q switch

- For a typical q-switched fiber laser, increasing pulse frequency results in decreased peak power
  - …..but constant Average Power
- Full pulse length constant



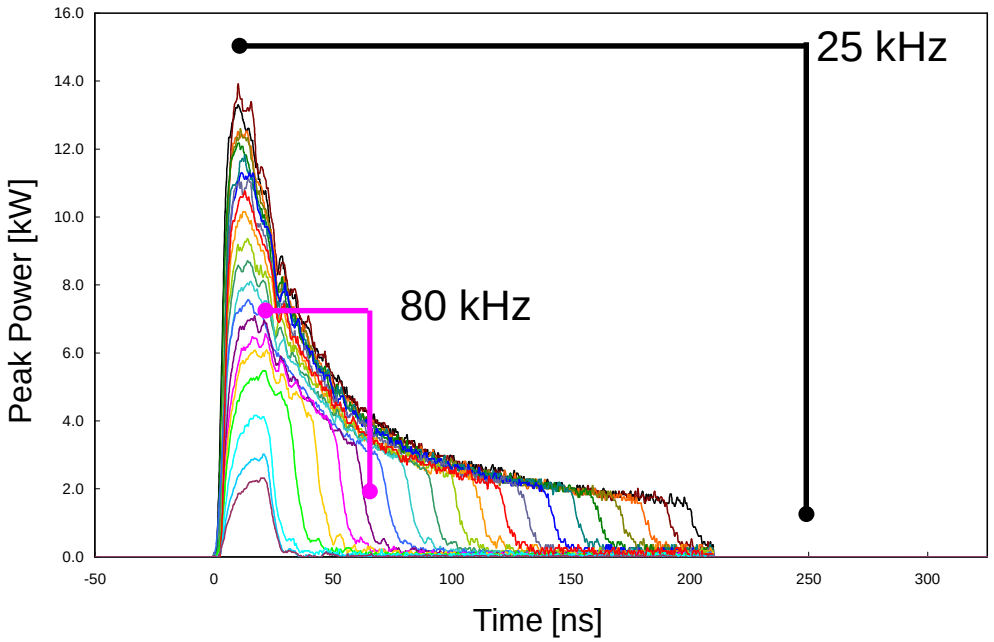
SPI Pulsed Laser Pulse Characteristics

- Can optimise peak power at higher rep rates by decreasing pulse length
- Each pulse length can operate at any frequency
- Provides an additional dimension of process control



Optical Pulse Characteristics

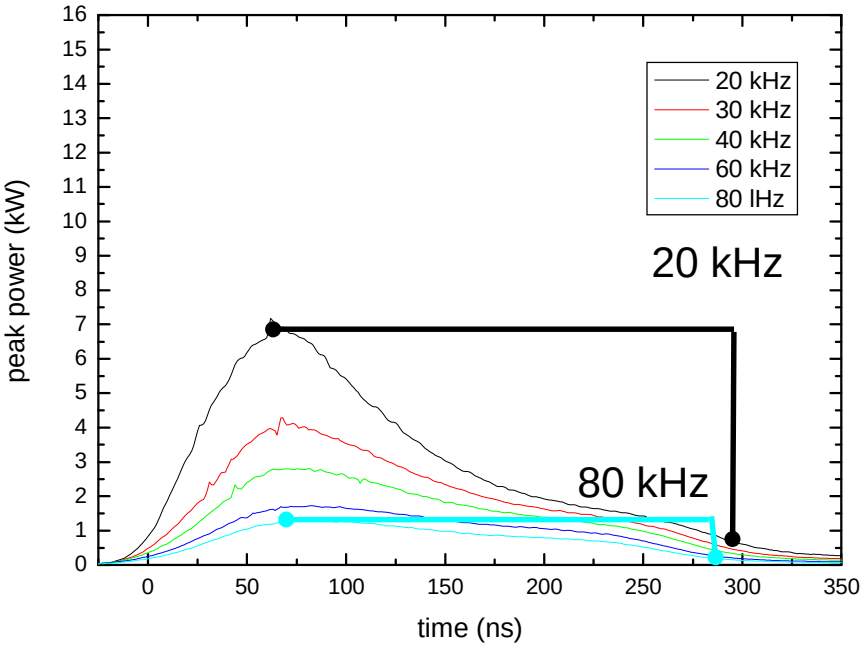
Directly Modulated @ 20W



Increasing rep rate by using different Wave Forms

- limits peak power reduction by using shorter pulse length

Q-Switched Fiber laser @ 20W

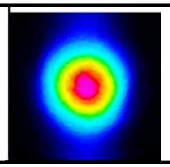
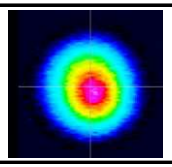
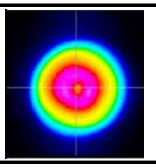
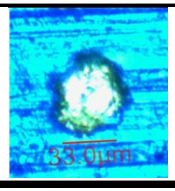
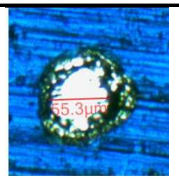
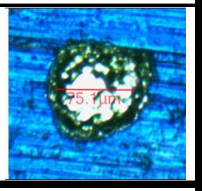
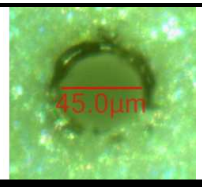
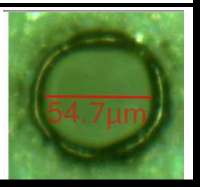


Increased rep rate significantly affects peak power

Mode Quality

- SPI has a range of beam qualities tailored for key applications
- The beam quality effects the focused spot size but note that this does not always reflect actual materials processing result.

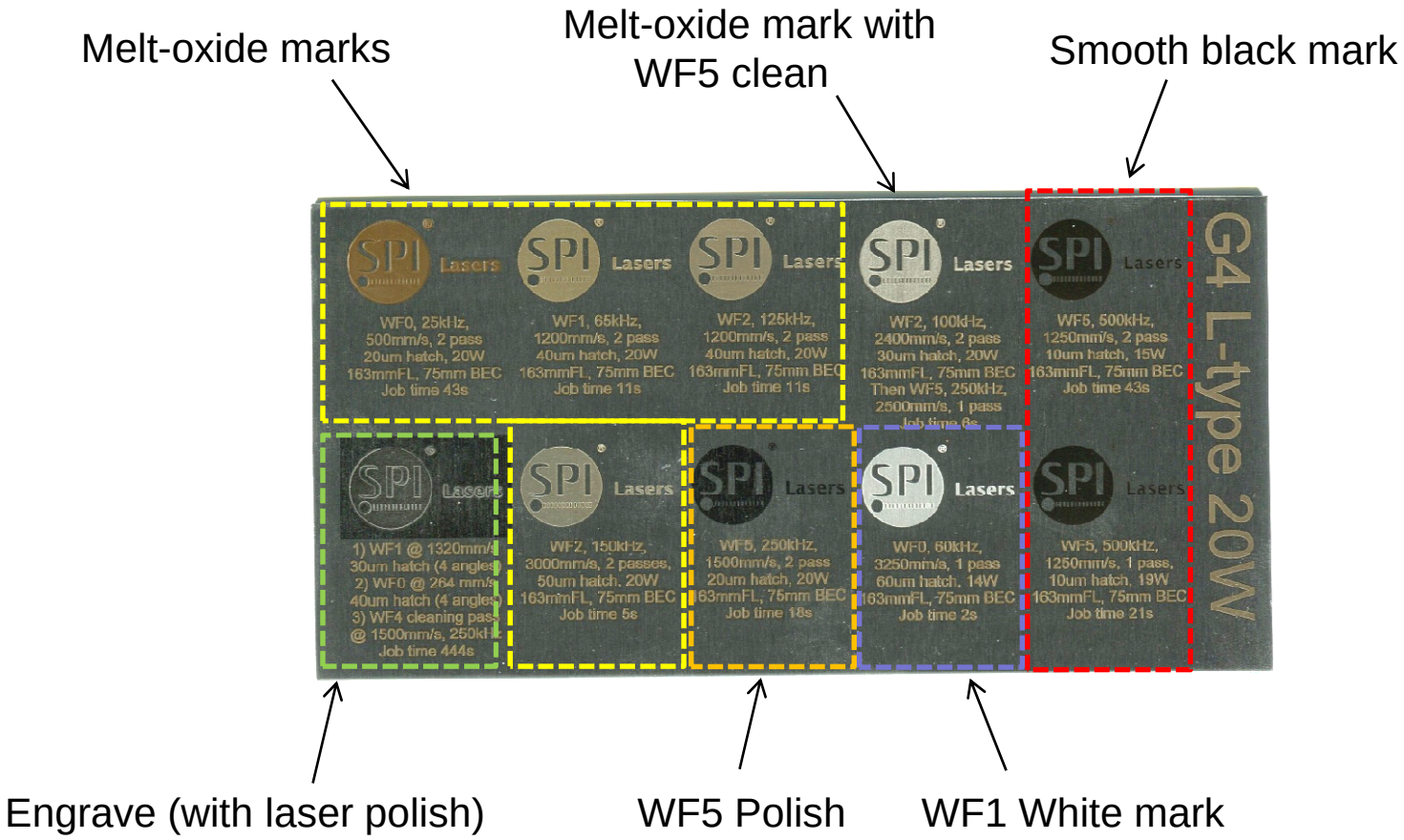


Laser model	S-type	H-type	H-type
Beam Quality	1.2	1.9	3.2
Mode			
Spot Size $1/e^2$ (calculated)	30 µm	45 µm	75 µm
Mark Diameter (measured)	33 µm	55 µm	75 µm
Image of single spot mark			
Hole Diameter (measured)	38 µm	45 µm	55 µm
Ceramic drilling surface hole size			

G4 20W L-type

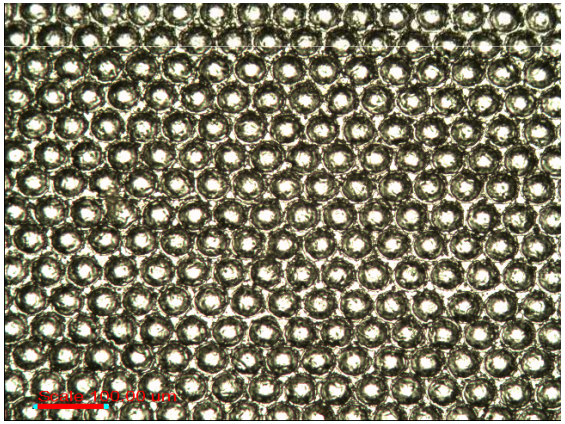
- Sample plate made using G4 20W L type laser
  - Standard setup163mm FL scan lens, 75mm collimator, focal spot Ø56µm ($1/e^2$)
- All marks made at focus
- No mechanical changes between marks
  - Only changes are laser output parameters and scan speed

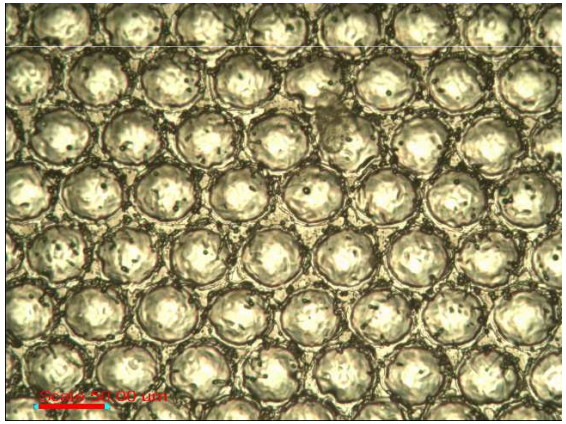
G4 20W L-type – 10 mark plate

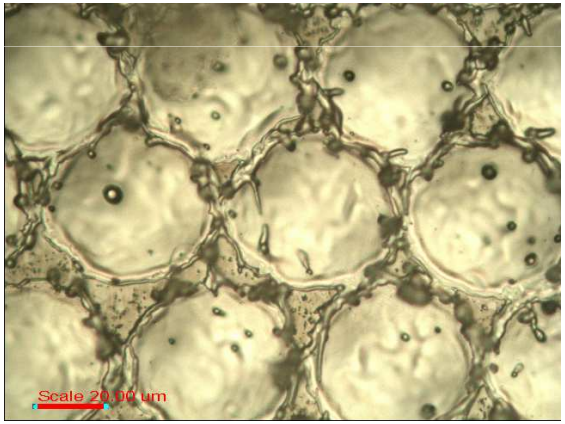


G4 20W L-type – White marking

- *High speed process*
- *Single pass, single pulse*
- *WF0, PRF0*

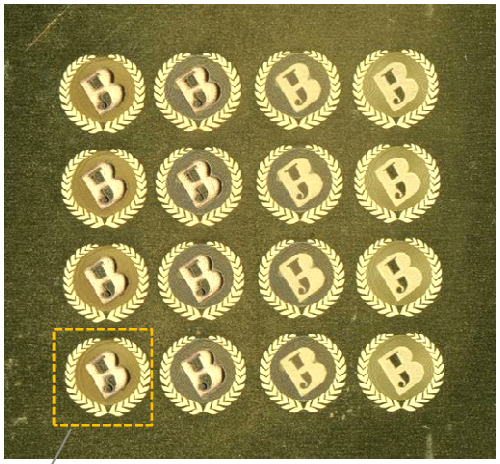


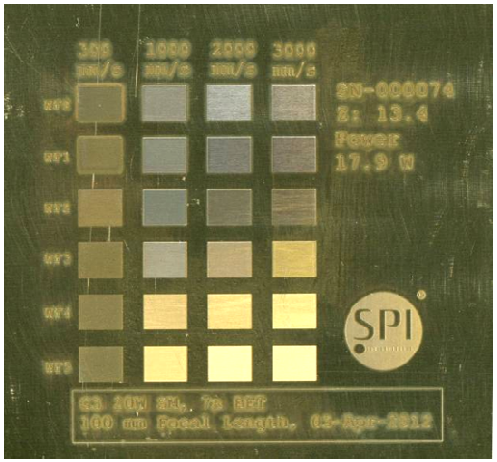




- Better stability of laser is demonstrated by good white marking
  - Homogenous areas without banding

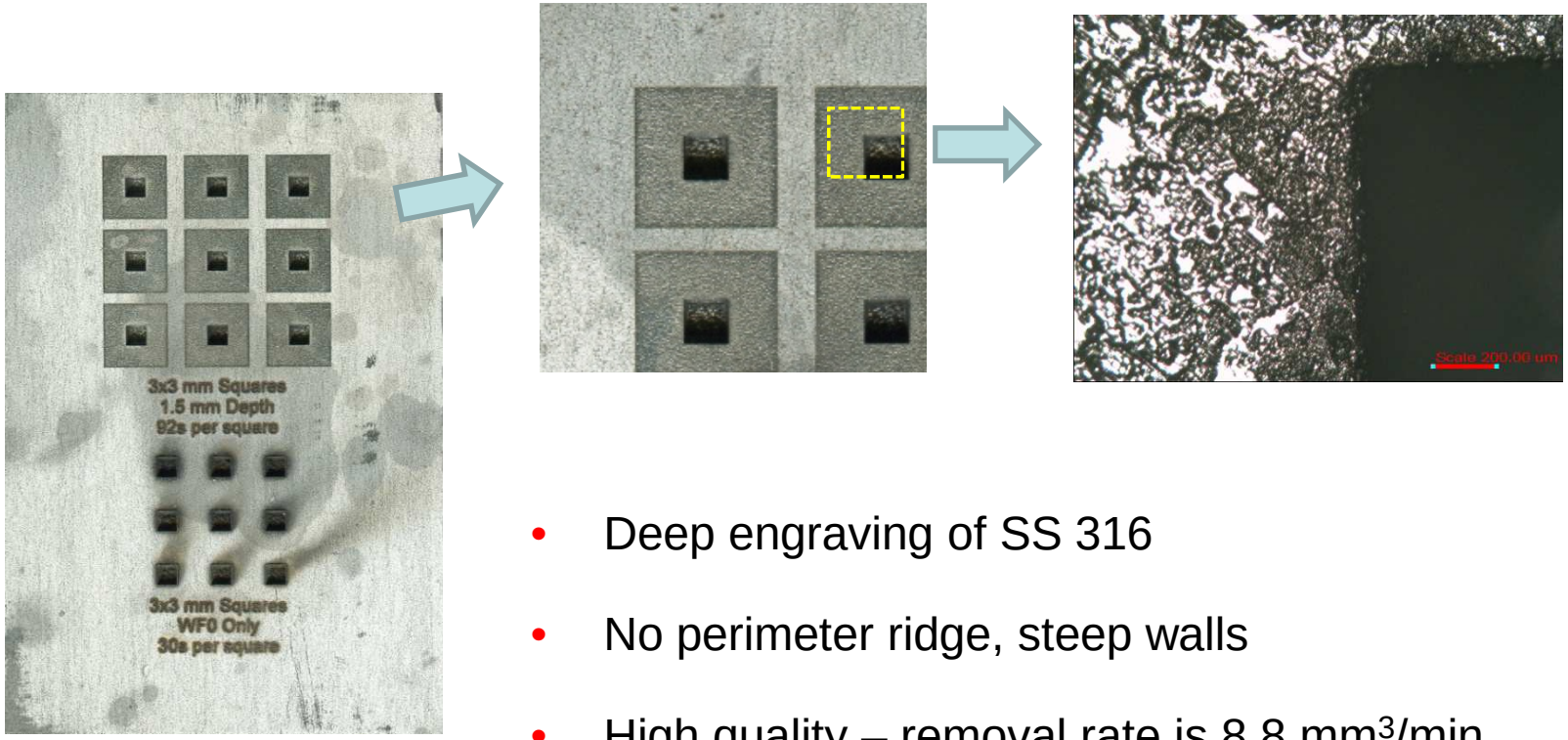
G4 20W S-type – Brass Processing





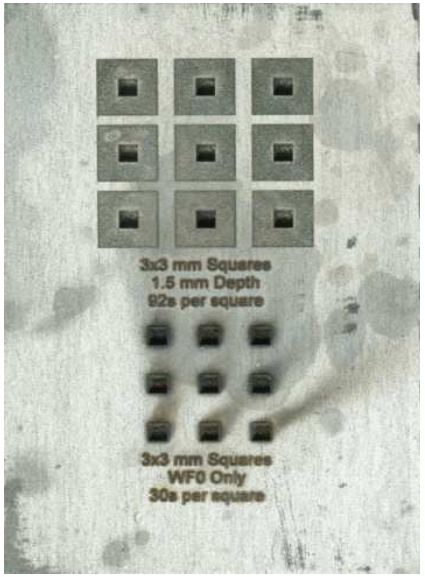
- Range of colours can be produced, including:
- White / yellow (WF4)
- Brown (WF1)
- Grey (WF2)
- Dark grey (WF3)
- Pink
- Plus Engraving (WF1, WF5)

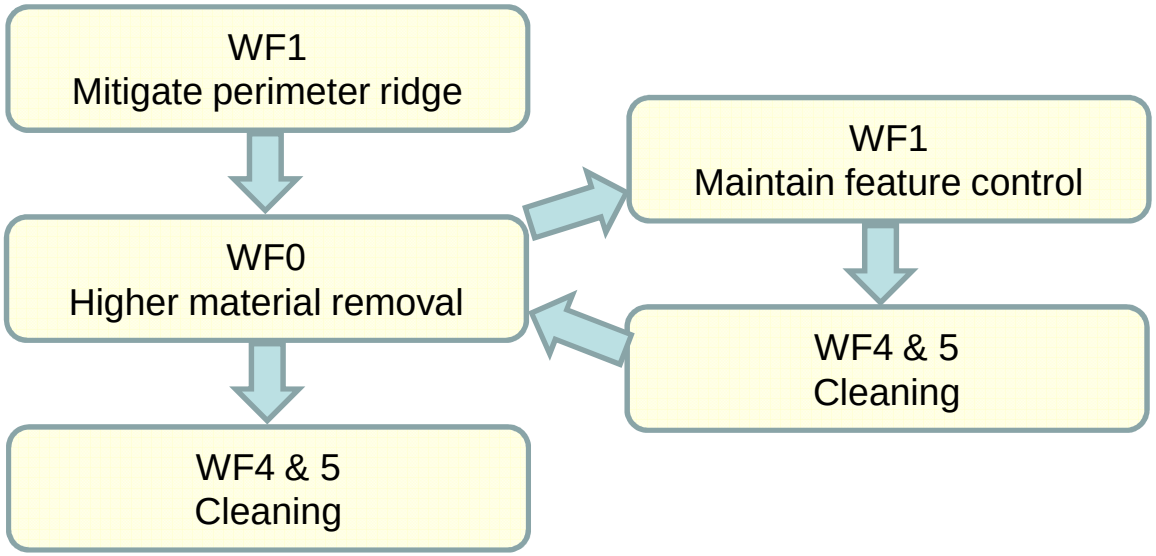
G4 50W S-type – Deep Engraving



- Deep engraving of SS 316
- No perimeter ridge, steep walls
- High quality – removal rate is 8.8 mm^3/min
- High speed – removal rate is 14.4 mm^3/min

G4 50W S-type – Deep Engraving





Colour Marking – DIME project

VTT TECHNICAL RESEARCH CENTRE OF FINLAND

10 mm x 10 mm squares: parameters

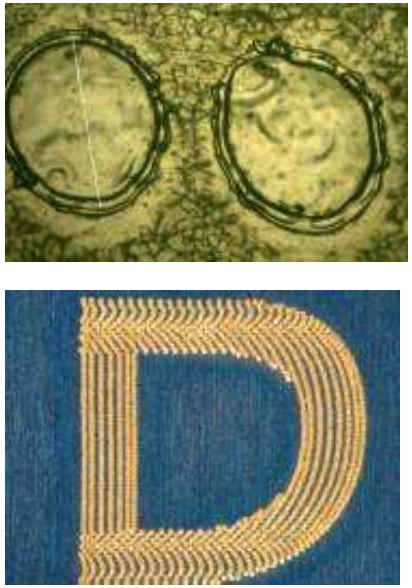
104 mm/s 5 W 75 kHz 120 ns f160, Ø 38 µm 30 µm 32 s	84 mm/s 5 W 75 kHz 120 ns f160, Ø 38 µm 30 µm 40 s	1200 mm/s 15 W 200 kHz 30 ns f160, Ø 64 µm 5 µm 17 s	900 mm/s 15 W 200 kHz 30 ns f160, Ø 64 µm 10 µm 11 s
1600 mm/s 20 W 125 kHz 65 ns f254 Ø 104 µm 30 µm 2 s	200 mm/s 11 W x2 100 kHz 65 ns f254 Ø 104 µm 30 µm 33 s	150 mm/s 12 W 100 kHz 65 ns f254 Ø 104 µm 30 µm 22 s	1000 mm/s 20 W 150 kHz 65 ns f254 Ø 104 µm 6,5 µm 15 s
100 mm/s 11 W 100 kHz 65 ns f254 Ø 104 µm 30 µm 33 s	1000 mm/s 20 W 150 kHz 65 ns f254 Ø 104 µm 3,4 µm 29 s	510 mm/s 15 W 200 kHz 65 ns f254 Ø 104 µm 5 µm 39 s	1000 mm/s 10 W 150 kHz 65 ns f254 Ø 71 µm 2 µm 50 s
1000 mm/s 20 W 150 kHz 65 ns f254 Ø 104 µm 7 µm 14 s	1000 mm/s 10 W 150 kHz 65 ns f254 Ø 71 µm 1,2 µm 83 s	50 mm/s 8 W 200 kHz 30 ns f254 Ø 104 µm 30 µm 67 s	50 mm/s 8 W x2 200 kHz 30 ns f254 Ø 104 µm 30 µm 133 s
Frame: 1000 mm/s, 20 W, 500 kHz, 200 ns, f160 Ø 38 µm, 30 µm			

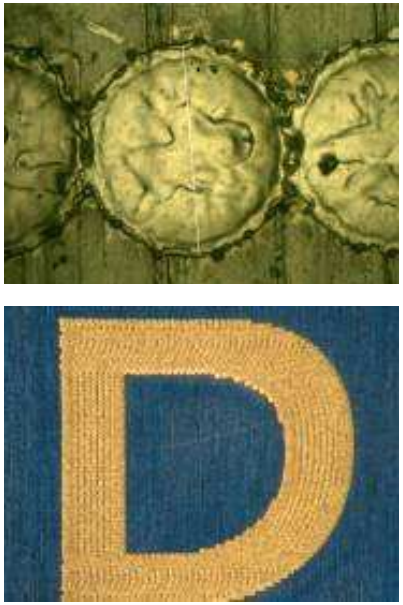
Marking speed
Average power
Repetition rate
Pulse width
Optic, beam diameter
Hatch
Marking time

Conclusion

- Fiber lasers have several distinct features which allow them to be used for many precision applications
  - High beam quality
  - Accurate beam control / modulation
  - Long term stability
  - PulseTune waveforms

Spot Overlap – the key to mark quality





No Spot Overlap
poor resolution dotted-line

<5% Spot Overlap
low resolution "scallop" edge

>60% Spot Overlap
high resolution smooth line edge

Spot overlap is a key visual factor in determining mark quality

How to get greater spot overlap?

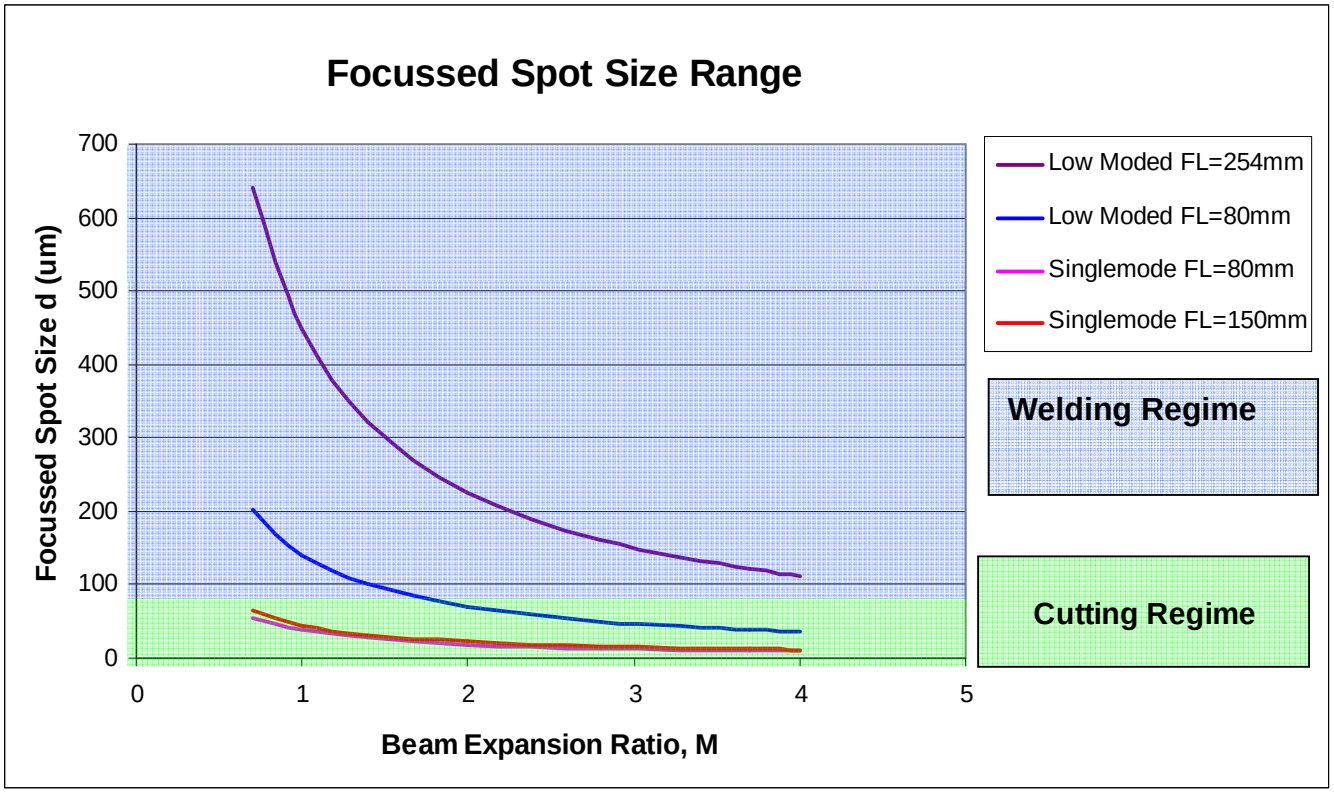
- Slow down the mark until the pulses overlap
- **Increase the pulse repetition rate at your desired marking speed !**

Coloured Anodise Marking

- Growing use of anodised materials
  - Giftware
  - Product ID
- Power = Productivity
  - Higher M^2 allows increased fill
  - Higher kHz allows higher speed
  - Higher WF enables removal at higher speed

Focal Spot vs Application

- Process application determines incident spot size



Pulsed Laser Processing Applications

- Laser materials processing is governed by:
  - **Peak pulse power -** which is typically required to overcome processing thresholds. **(kW)**
  - **Pulse energy -** which governs the amount of thermal energy available to effect any material processing. **(mJ)**
  - **Pulse duration -** which impacts the beam material interaction time. **(ns)**
  - **Power Density** – which reflects the intensity of the laser energy on the substrate. **(J/cm^2)**
  - **Beam Quality** – Energy distribution within the beam **(M^2)**
- It is a combination of all of these parameters that needs to be considered.