Fibre Lasers for Medical Devices and Applications

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Presenter:
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CTO, SPI Lasers

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inspiring your products & manufacturing

Agenda

- **Medium-power ~1µm CWM fiber lasers**
  - Design and benefits overview
  - Application requirements and performance
- **Advanced manufacturing applications in medical devices**
  - Tube cutting: Stents and devices
  - Medical device welding
  - Prosthesis manufacture using metal-powder laser sintering.
- **1.55µm Fibre lasers for direct medical applications**
  - Choice of laser wavelength, e.g. in dermatologicial treatments
  - Laser design / performance overview
  - Example application: medical aesthetics
- **Summary & Conclusions**

R4 CWM Laser Systems

25 – 200W Air Cooled

100 – 400W Water Cooled

Features

- CW or Modulated to 100 kHz (modulated pulses <10µs to CW)

-TEM_{00} (M^2 <1.1), BPP < 0.37 mm.mrad

- Low moded (M2~4) BPP < 1.33 mm.mrad option

- Central Emission Wavelength: 1070 ± 10nm

-High stability laser (typically <±0.5% output power variation)

-Extended Performance Range (XPR) & Pulse Shape Equalisation (PSE)

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R4 Laser System Applications

- *Application Areas*
  - *Micromachining*
  - *Rapid prototyping*
  - *Anilox engraving / Flexo*
  - *Cutting / scribing- Ceramics / silicon*
  - *Plastics cutting / welding*
  - *Precision soldering*
  - *Fine wire balling / welding*
  - *Glass/ceramics marking*
  - *Scientific: Diamond anvil cell / atom trapping*
  - *Thicker section cutting*
  - *Welding (M^2 ~1.1 and M^2 ~ 4 variants)*

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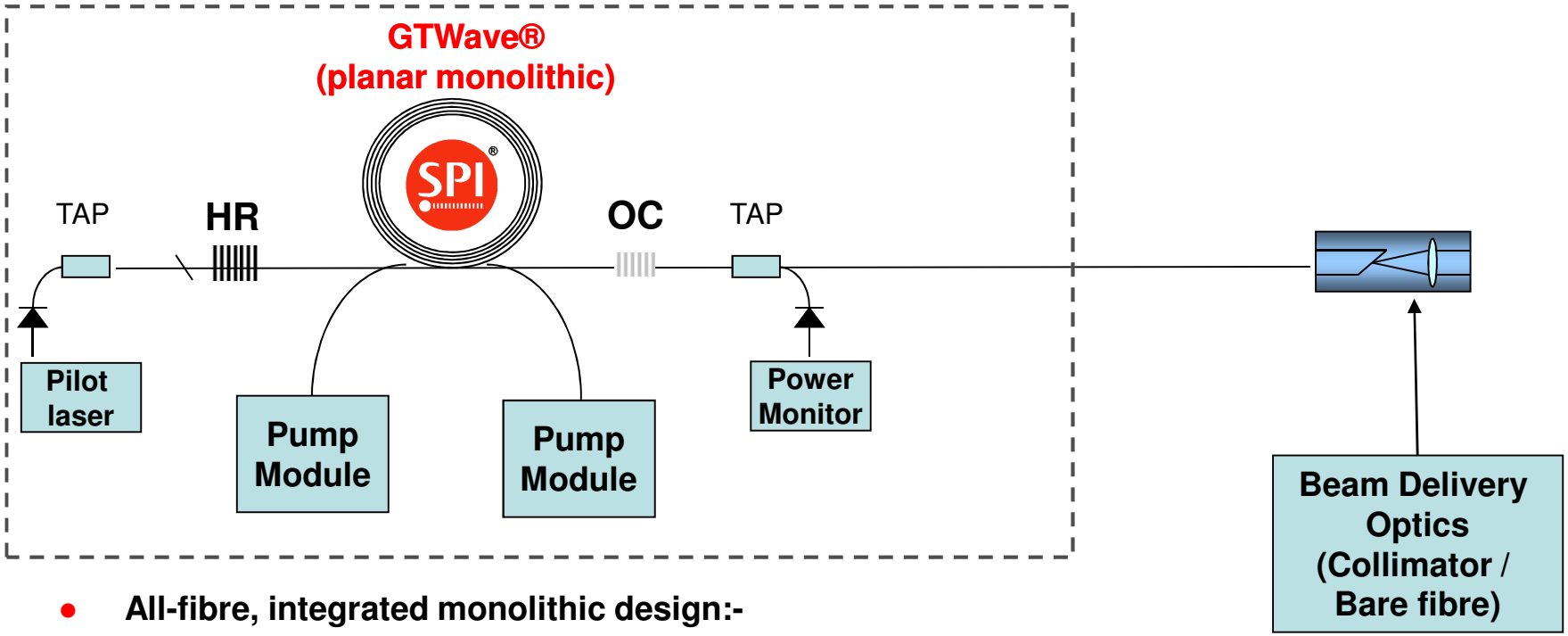
R4 GTWave® Fiber Laser Technology



- **All-fibre, integrated monolithic design:-**
  - Patented GTWave side-pumped technology
  - High-brightness beam-combined pump modules (~200W / module)
  - Beam delivery options for free-space / fused fibre laser combiners
- Power Scalable to 500W+

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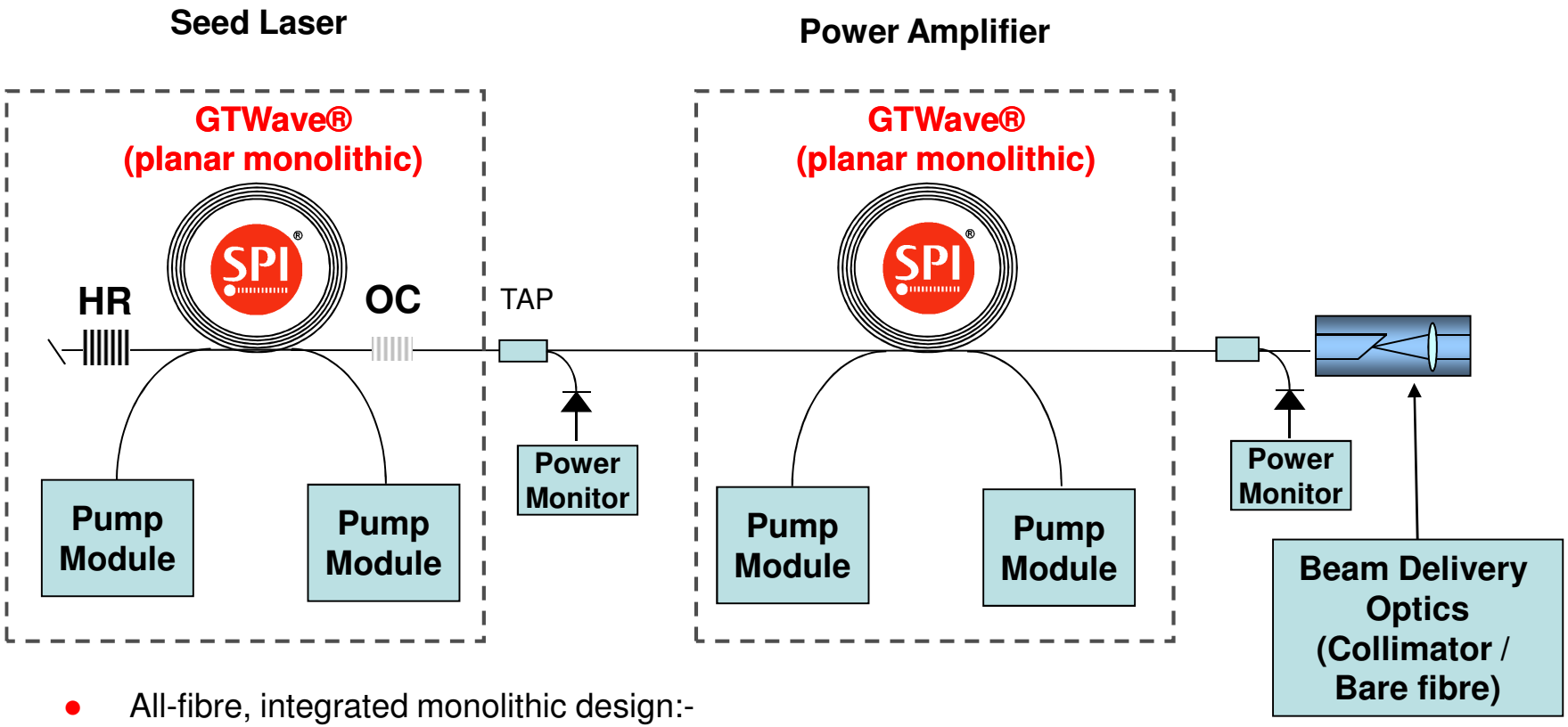
Power scaling: 2-Stage GTWave® Architecture



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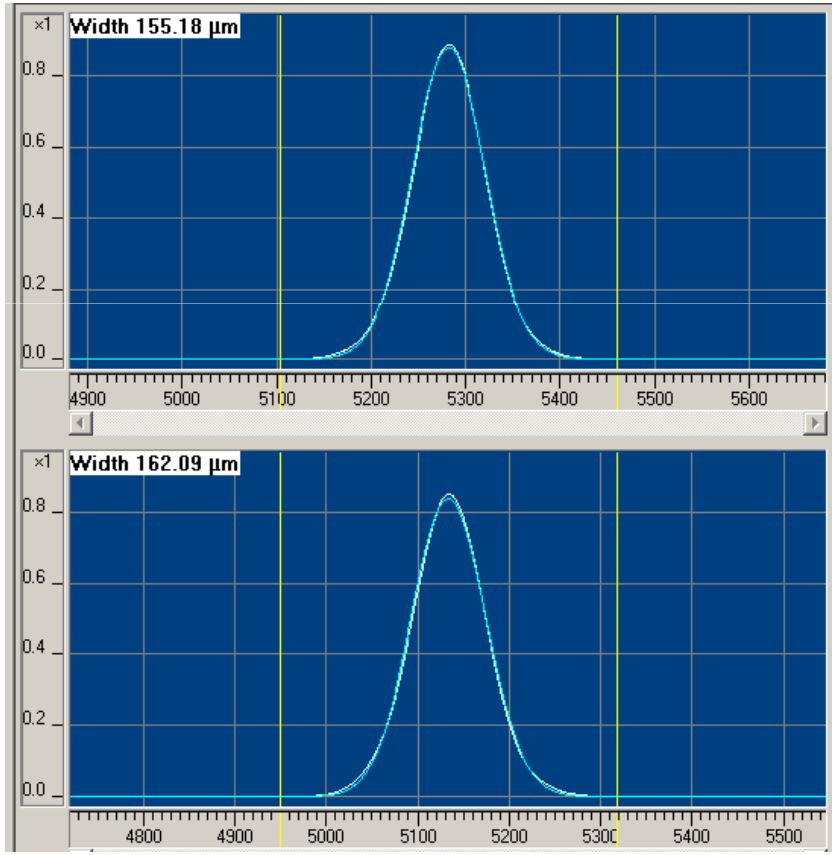
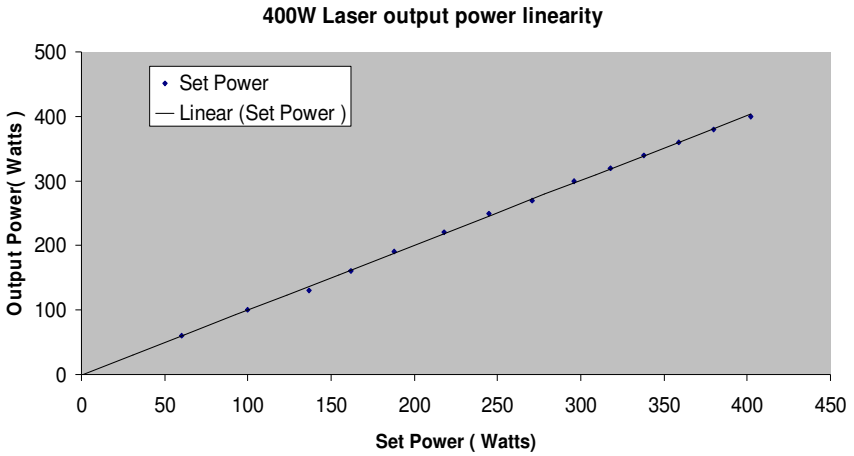
M2<1.1 Lasers Beam Quality

Focused Spot @ 400W
(using 512mm FL reference lens)



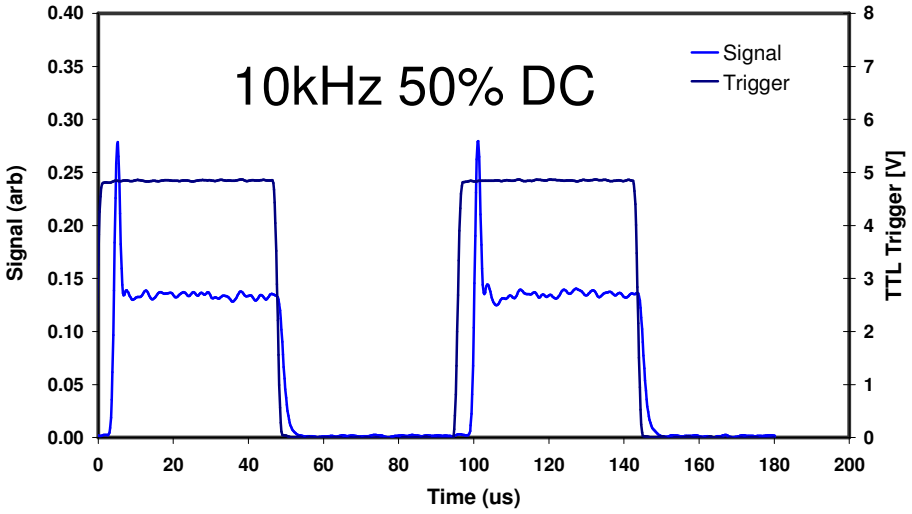
Beam parameters

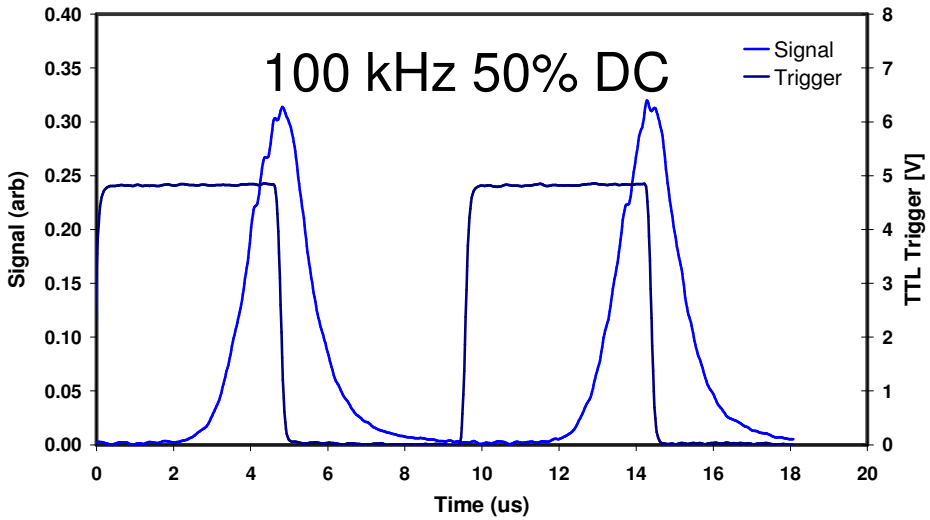
Parameter	Unit	50W	400W
Diameter	**mm**	**5.17**	**5.16**
Circularity	**%**	**99.1**	**98.9**
M2	**-**	**1.01**	**1.02**
Divergence	**mrad**	**.28**	**.31**
Astigmatism	**zR**	**0.08**	**0.1**
Thermal Lens parameter	**zR/kW**	**1.48**	

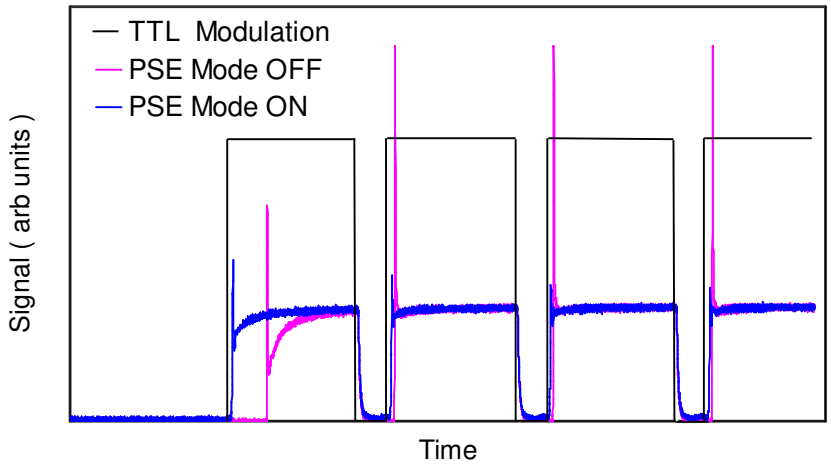


Modulation pulse shape control

- **Precise & stable optical pulse shape control achieved by electronic control of pump diodes**





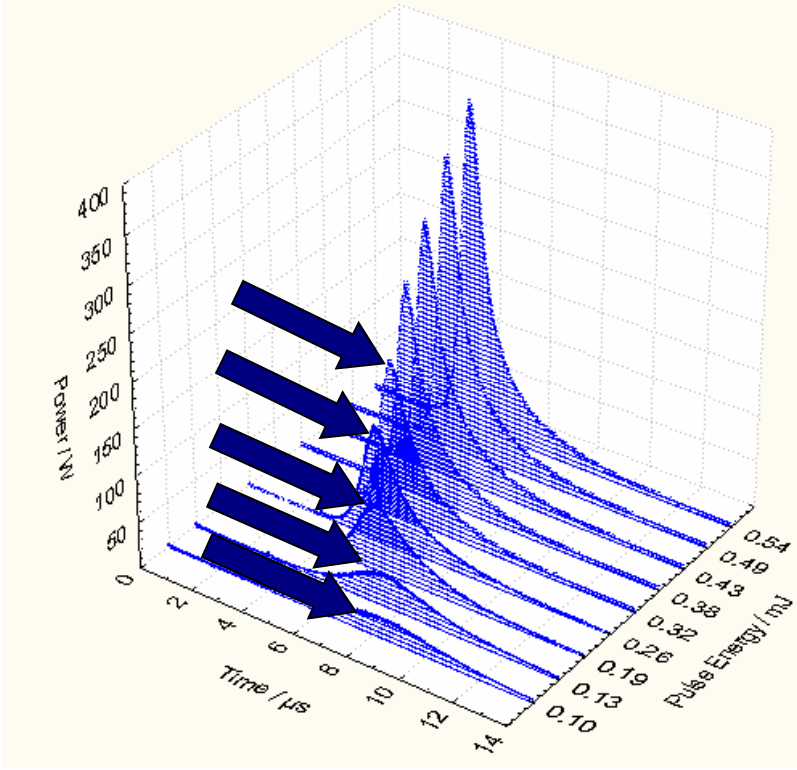


PSE: Pulse Shape Equalisation &
Pulse Turn-On Control

XPR – Extended Performance Range

70kHz Pulse Profiles by Pulse Energy

200W Laser - Standard Configuration

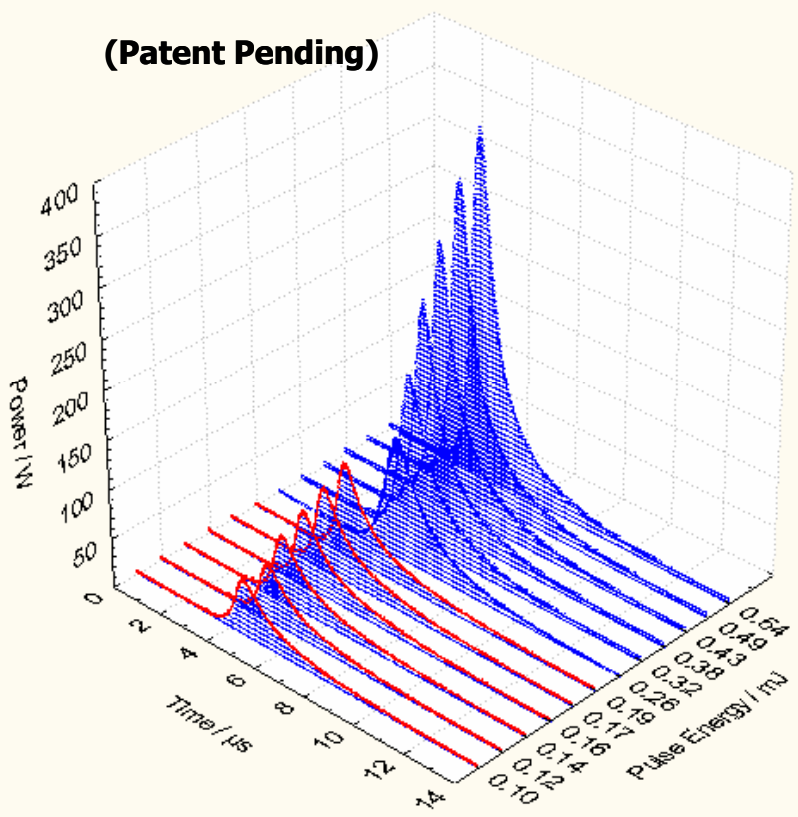


Pulse profile broadens with energies < 0.3 mJ

70kHz Pulse Profiles by Pulse Energy

200W Laser - XPR Configuration

(Patent Pending)



XPR mode maintains pulse profile down to <0.1 mJ

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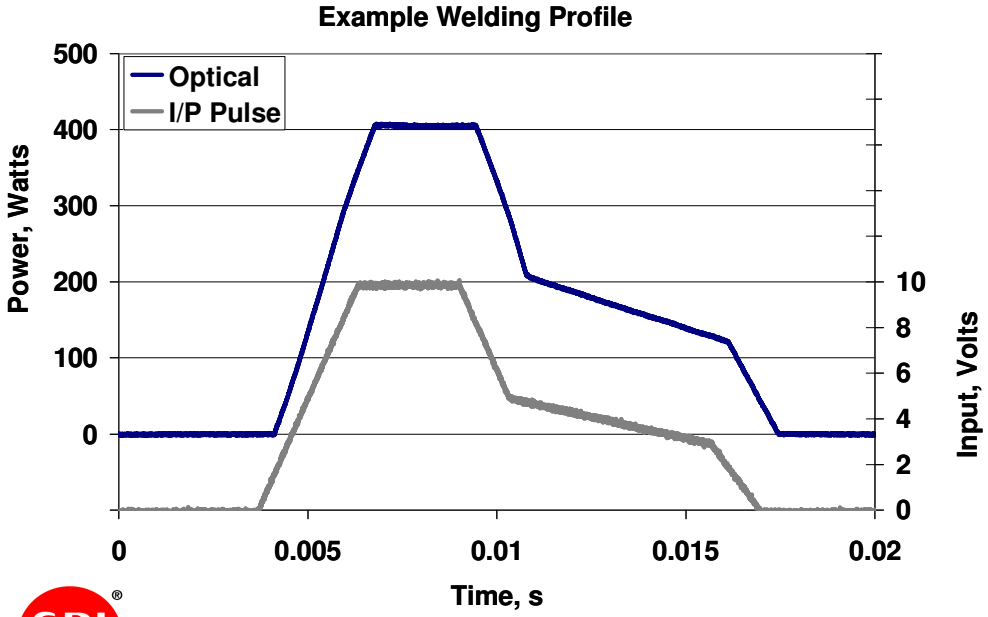
Pulse shape profiling: e.g. welding

- **Using the analog I-O setpoint and trigger inputs**
- **Output waveform can be controlled for process optimization eg:**
  - Welding: Controlled melt pool cooling
  - Cutting: Overshoot/heating



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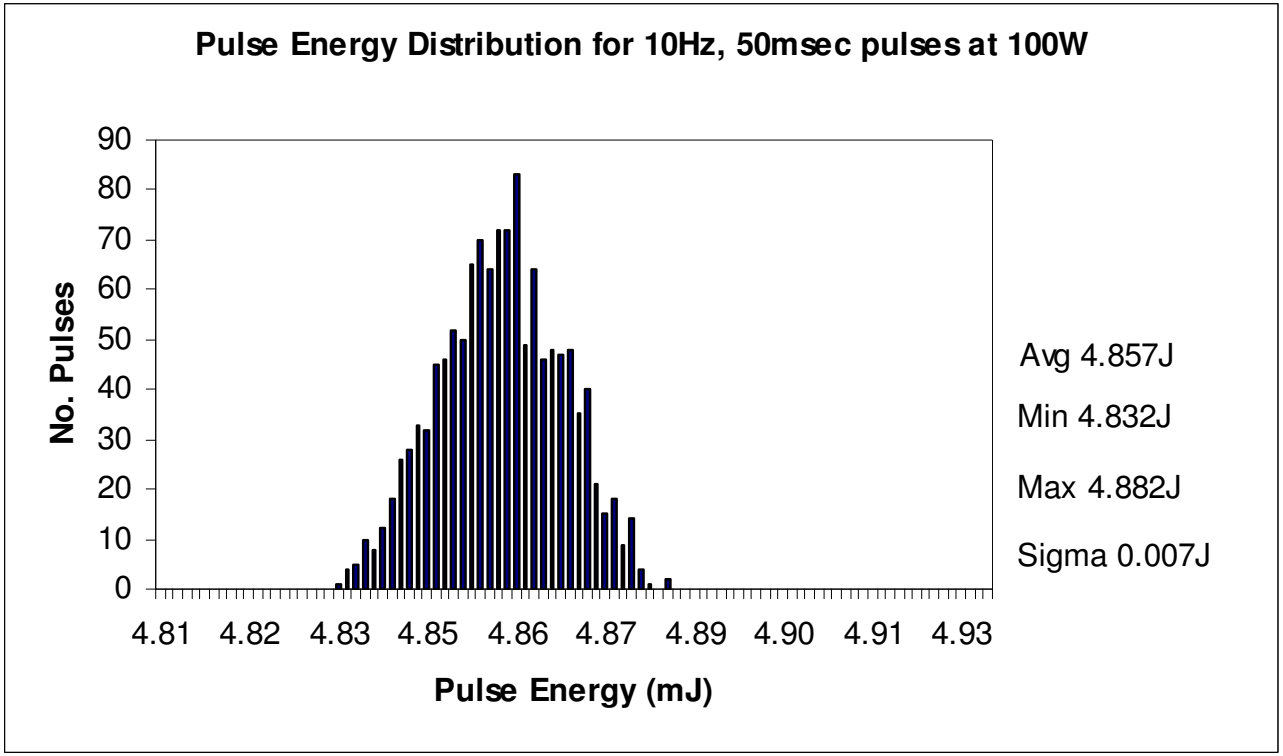
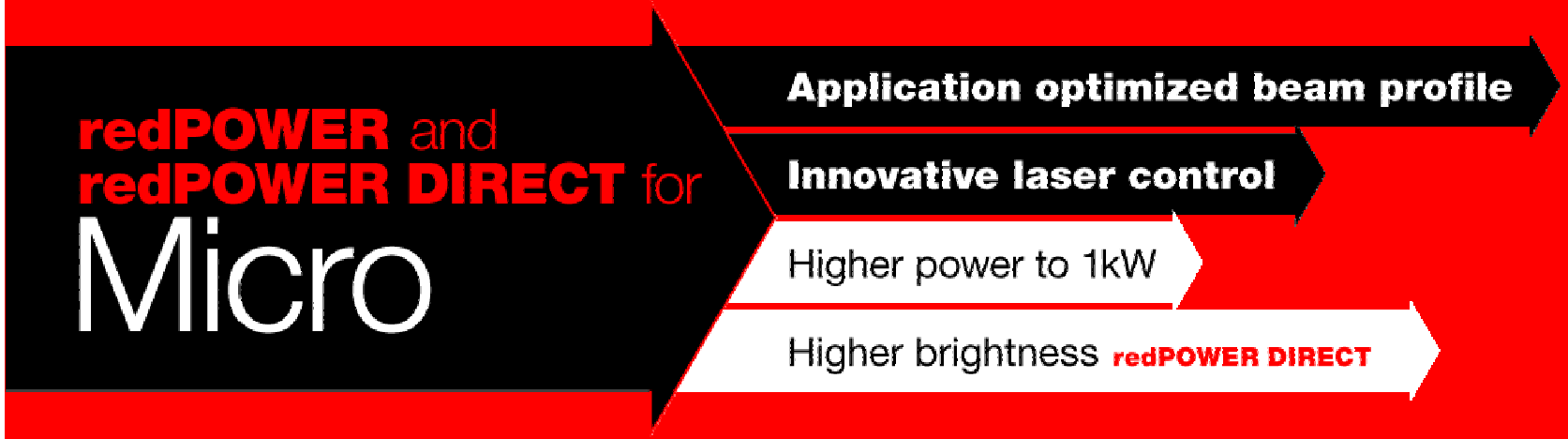
Pulse to pulse stability

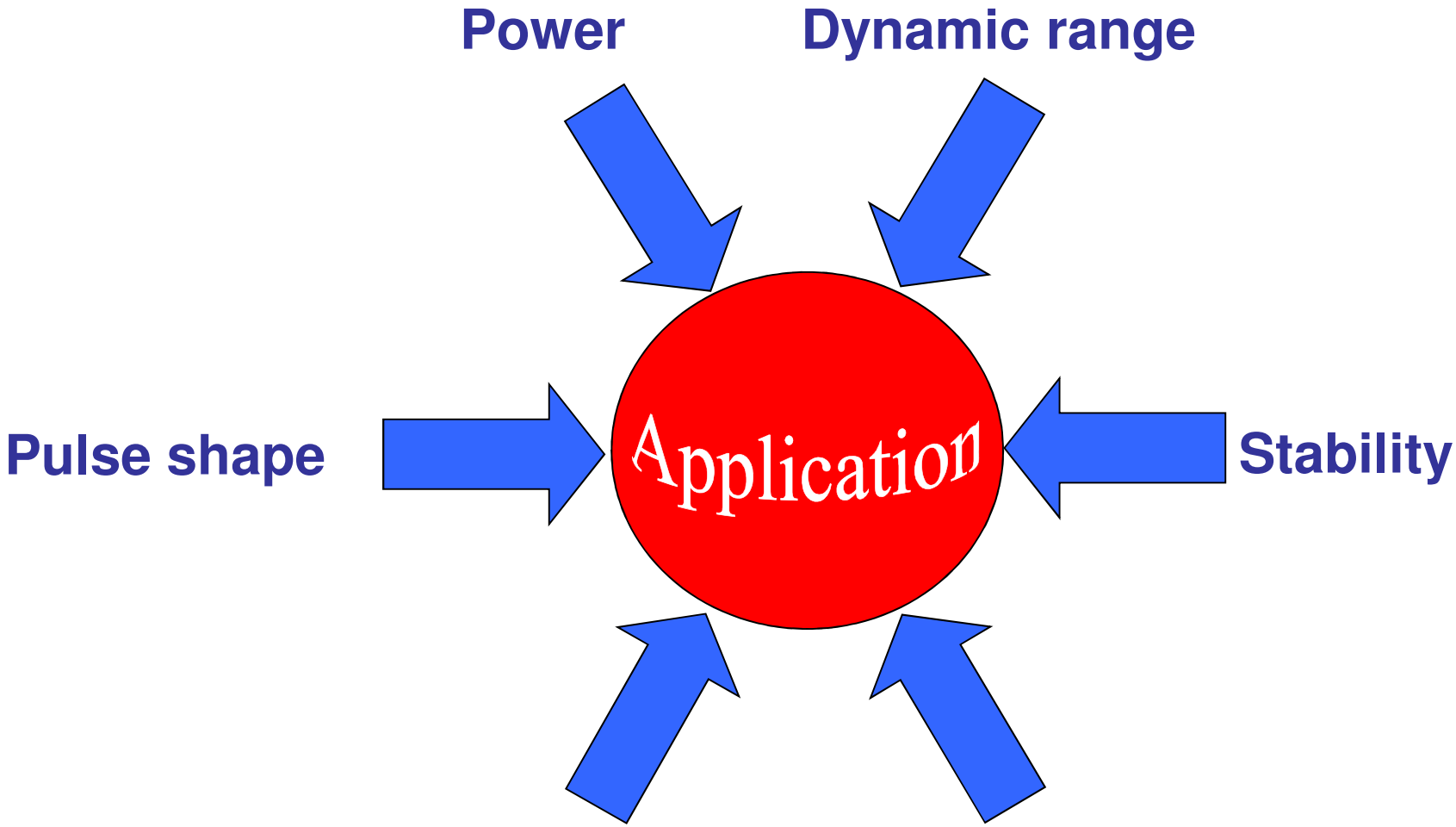


68.26% of all pulses are within ±0.007J of 4.857J (0.15%)
95.46% of all pulses are within ±0.014J of 4.857J (0.31%)
99.73% of all pulses are within ±0.021J of 4.857J (0.46%)



Applications Considerations & Examples

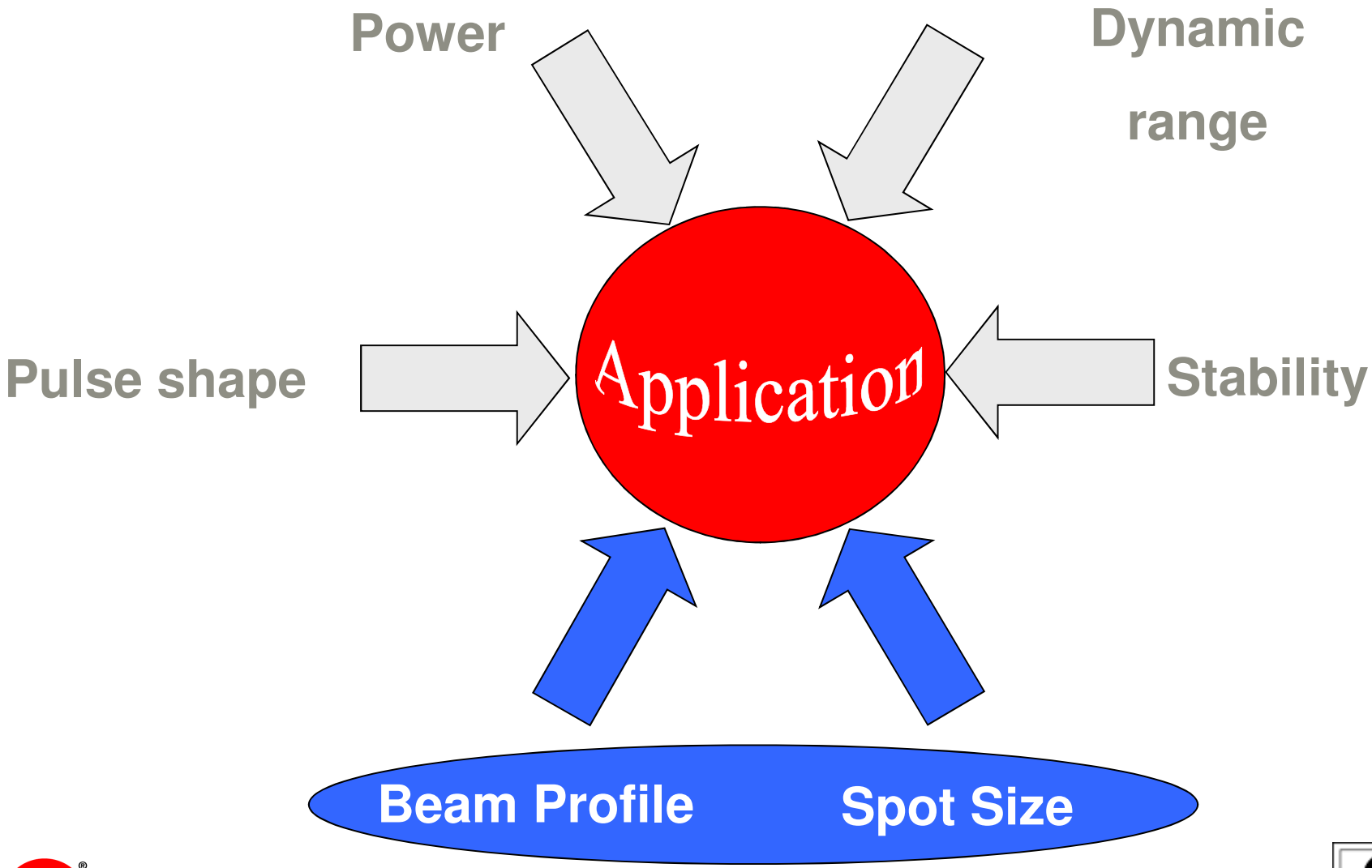
Process Dependencies



Processing Considerations

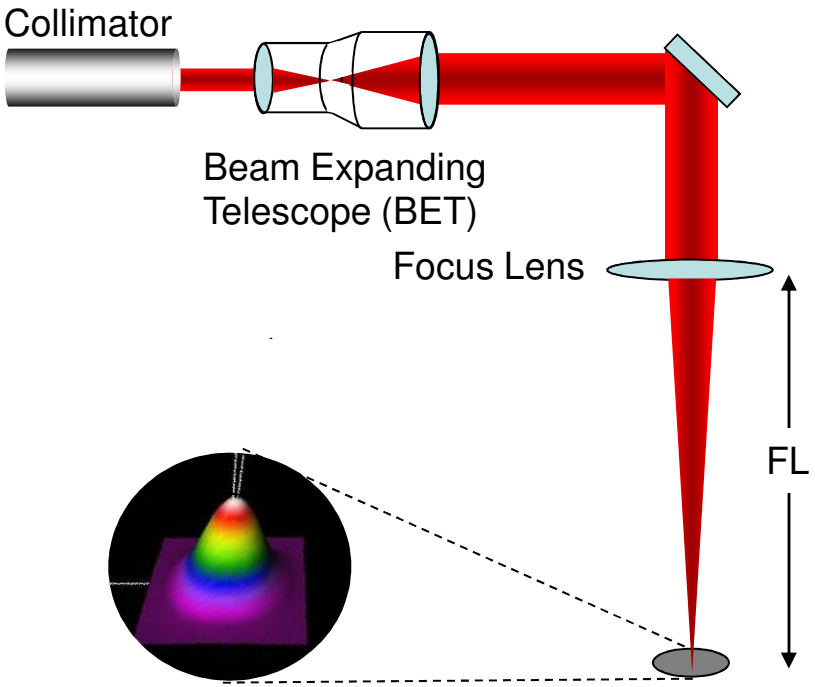
- **The majority of materials processing applications are governed by:-**
  - **Average Power** – Determines the amount of thermal energy available to effect any materials processing application
  - **Pulse Peak Power**: Which is typically required to initiate coupling and to overcome processing thresholds.
  - **Pulse energy & Duration:** Which impacts the material interaction
  - **Power Density & Beam Profile** – which reflects the intensity of the laser energy on the substrate.
- **It is a combination of all four of these parameters that needs to be considered in laser materials processing applications.**

Process Dependencies



Spot size control and optimization

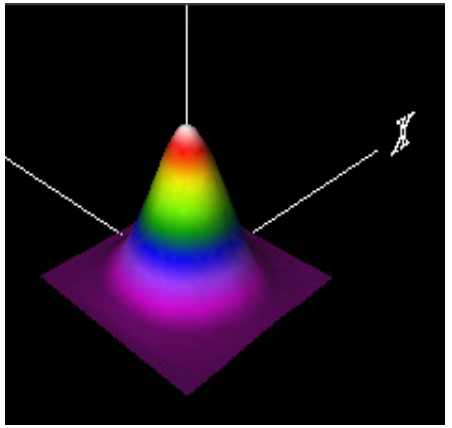
- **Spot size on the workpiece can be controlled by changing the process head lens focus length and/or the input laser beam diameter**



Spot size (um) vs Focus Lens FL and beam expansion				
	Focus Lens Focal Length (mm)			
BET x	80	125	150	200
0.7	34	54	65	86
1	24	37	45	60
1.4	17	27	32	43
2	12	19	23	30
2.8	9	13	16	12

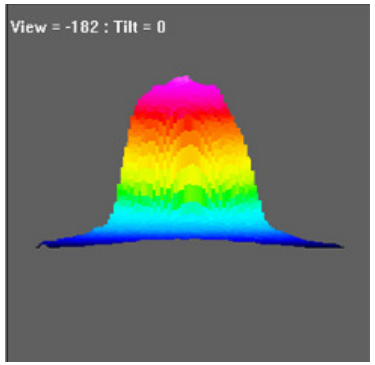
Gaussian or Flattened Beam Profile: M^2=1 or M^2~4?

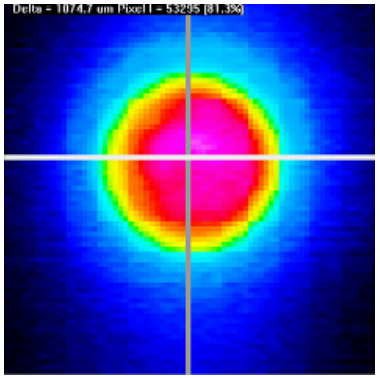
- **Application optimized beam profile**
  - Cutting
    - Precision thin section cutting, fine kerfs in sub 1mm materials
    - General thicker section (1 - 4mm) cutting
  - Welding: M^2 ~ 4
    - Narrow or wider profile – Application Dependent
    - Uniform energy distribution ═► Improved process control
    - Larger spot size ═►Relaxed piece part tolerances



M^2 ~ 1.1

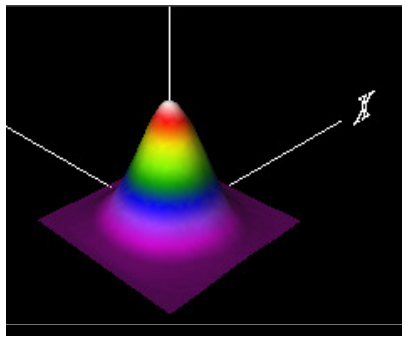
M^2 ~ 4





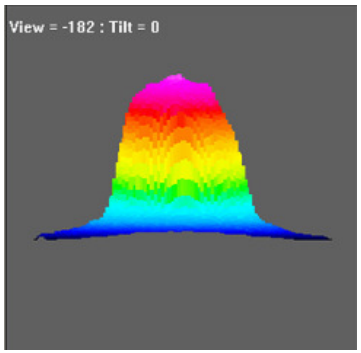
Typical Fibre Laser Applications & Ideal Beam Shapes

Single-mode
M^2<1.1



Low Moded
M^2~4

- *Fine kerf cutting / Micromachining*
- *Rapid prototyping*
- *Printing: Anilox engraving / Flexo*
- *Cutting / scribing- Ceramics*
- *Fine wire balling / micro welding*
- *Thicker section cutting*
- *Welding*
- *Plastics cutting / welding*



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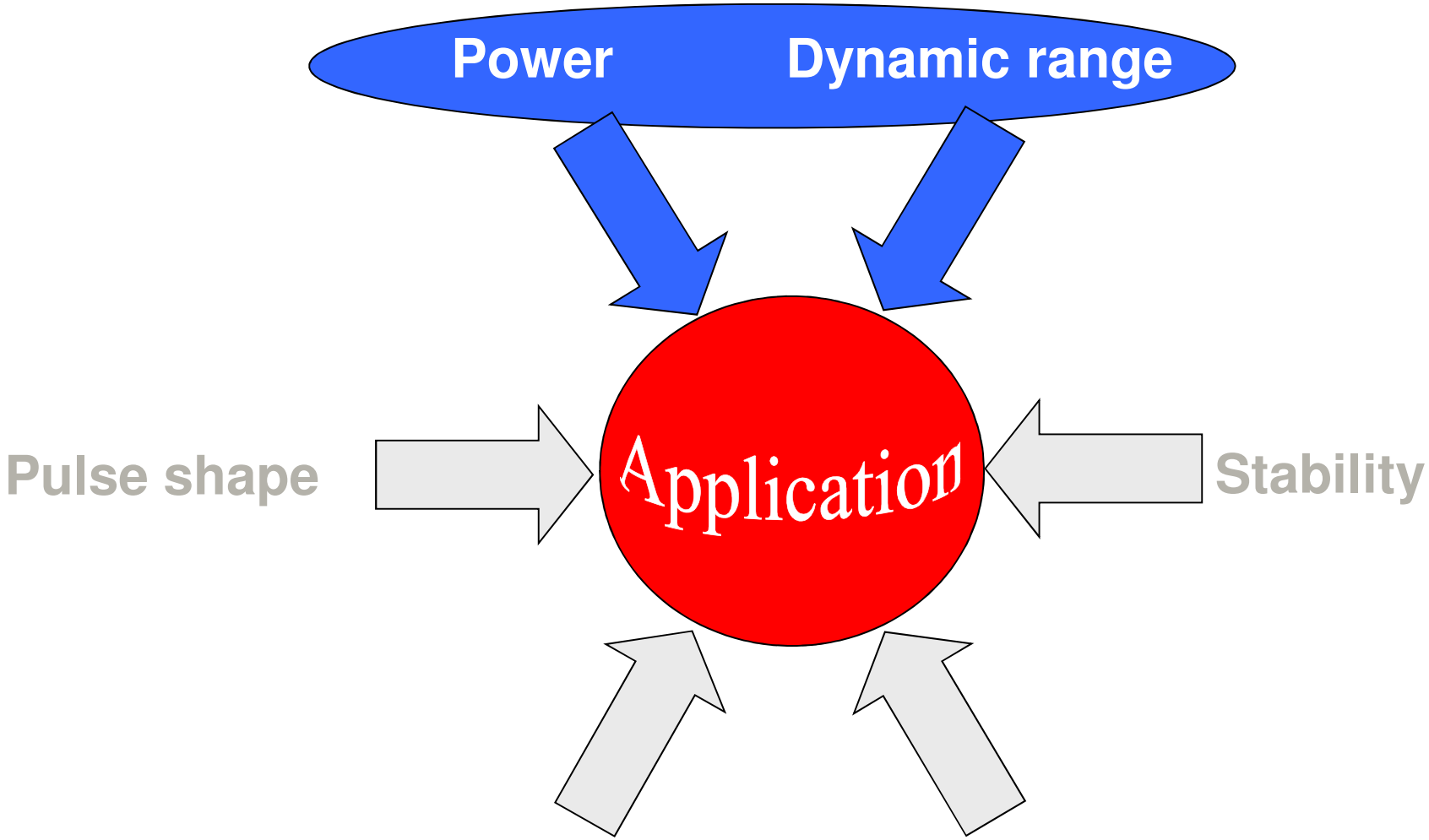
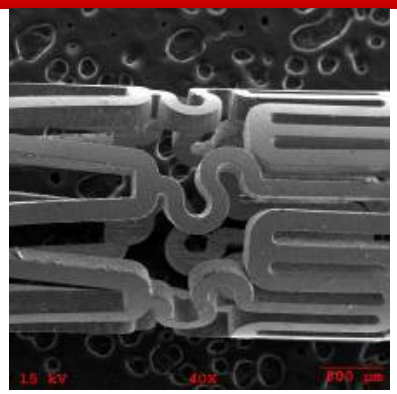
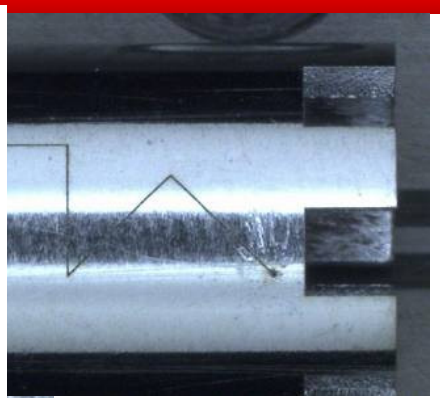
Process Dependencies



M^2<1.1 Micromachining / Fine tube cutting



Cutting Nitinol Coronary Stents - 100W



1.8mm Titanium 0.5mm Nitinol - 400W

- **High beam quality allows very fine kerf as low as 15um width**
- **Cutting speeds with conventional solid state lasers are limited by repetition rates of a few kHz**
- **Modulation capability up to 100kHz**
  - Higher speed cutting process achieved, lower thermal effects
  - Productivity improvements >5x in cutting speeds achieved
- **400W, M^2<1.1 laser enables thicker-wall medical devices**

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Medical Device Manufacturing: Case Studies

- **Problem:**
  - Shrinking device size
  - Expensive components, i.e. pacemaker can welding
  - Manufacturing in high cost areas requires high throughput, small footprint, 24/7 operation, reduced maintenance

- **Fiber lasers offer solutions:**
  - Excellent beam quality allows smaller feature size, higher throughput
  - Excellent stability enables higher reproducibility, increased yields
  - No maintenance, high reliability

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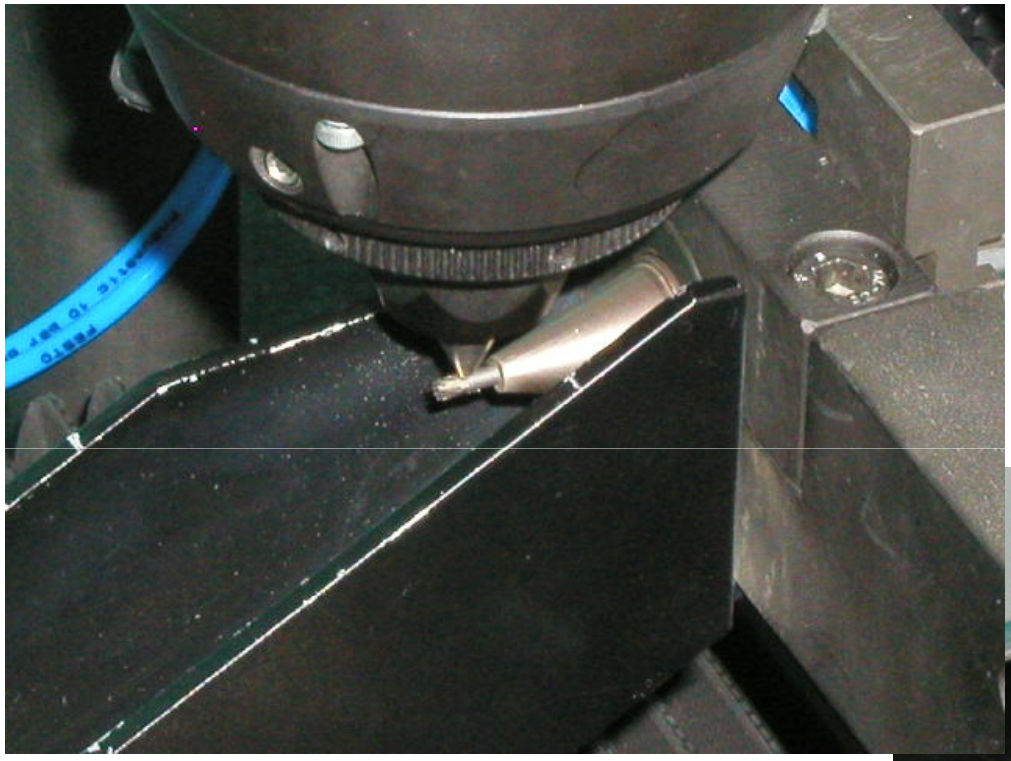
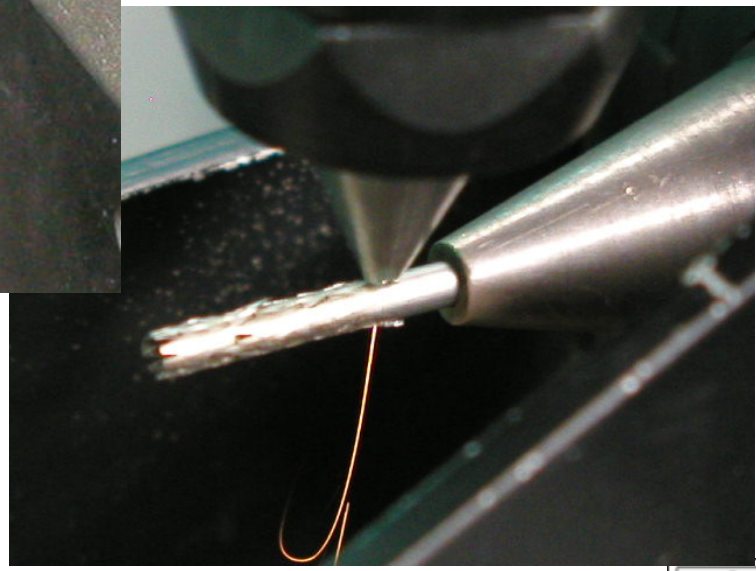
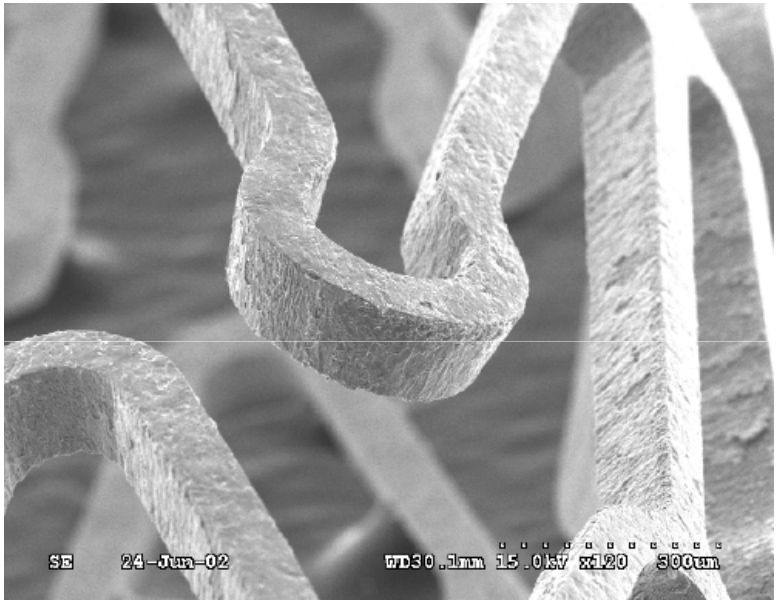
Stent Manufacturing: Fine-Tube Cutting Process





Stent Manufacturing: *Case study*

- **Requirements:**
  - Iincrease in manufacturing capacity
  - Improvement of quality & yield
  - Reduced operational / maintenance costs
- **Fiber laser benefits:**
  - Higher cut speed due to direct laser modulation
    - Up to 30% increase in throughput
  - Better cut quality
    - Higher yield, shorter post processing
  - Smaller size
    - Double throughput per square metre of laser facility
  - No maintenance
    - No laser downtime, no maintenance cost



>100 lasers in use 24x7 since 2006 with outstanding reliability

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Stent Manufacturing: *Cost Benefits of Fiber Laser*

Conventional Nd:YAG laser

- **<3% efficiency**
- **1 billion shots / flashlamps requires weekly – biweekly flashlamp replacement**
- **>1m^2 clean-room floor space**

Fiber Laser

- **25% efficiency**
  - $7.5k pa electricity savings (12c/kWh)
- **No flashlamps**
  - $10-15k pa savings for replacement parts
  - No laser technician required
- **<1m^2 space**
  - VERY significant capital cost saving in cleanroom space

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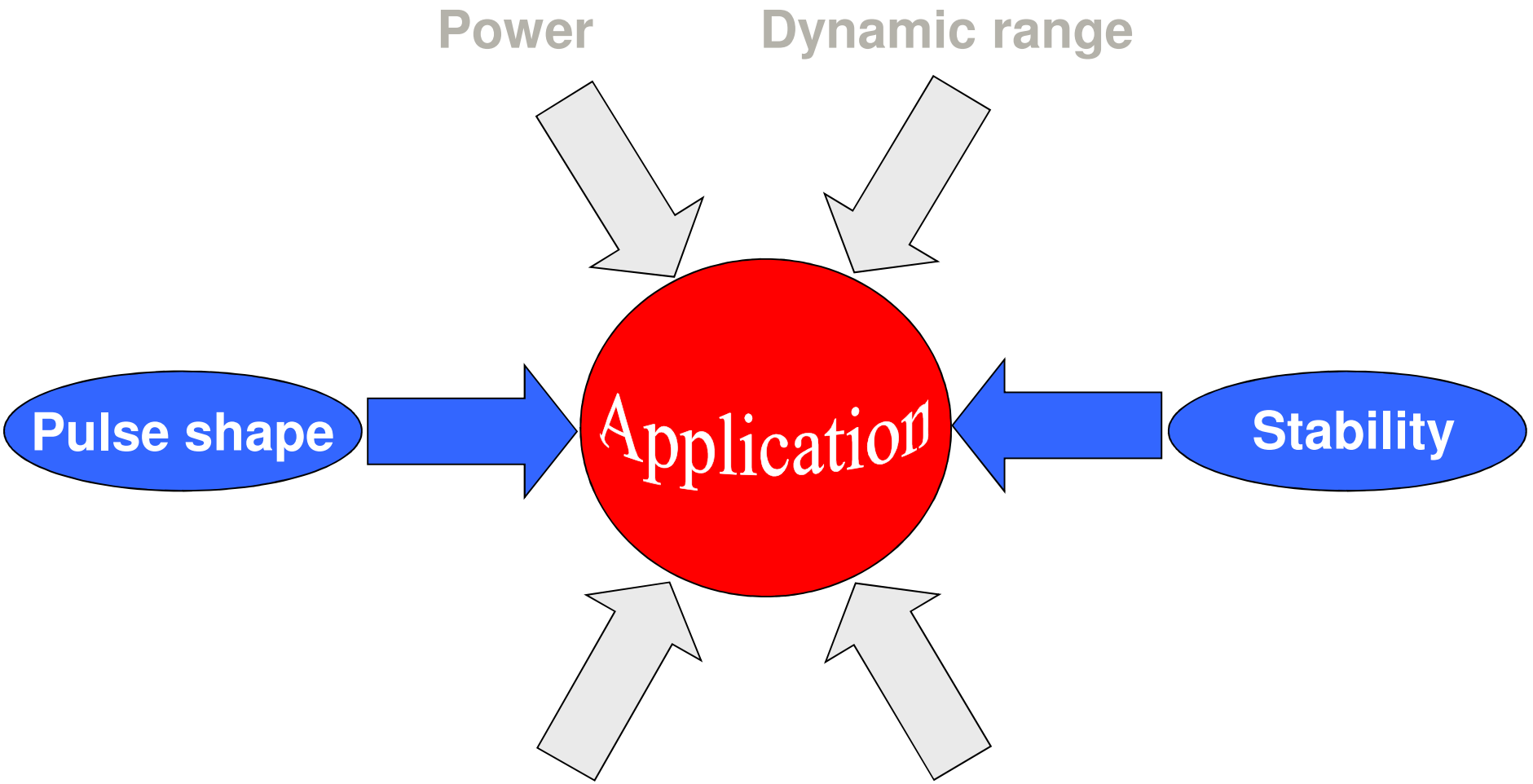
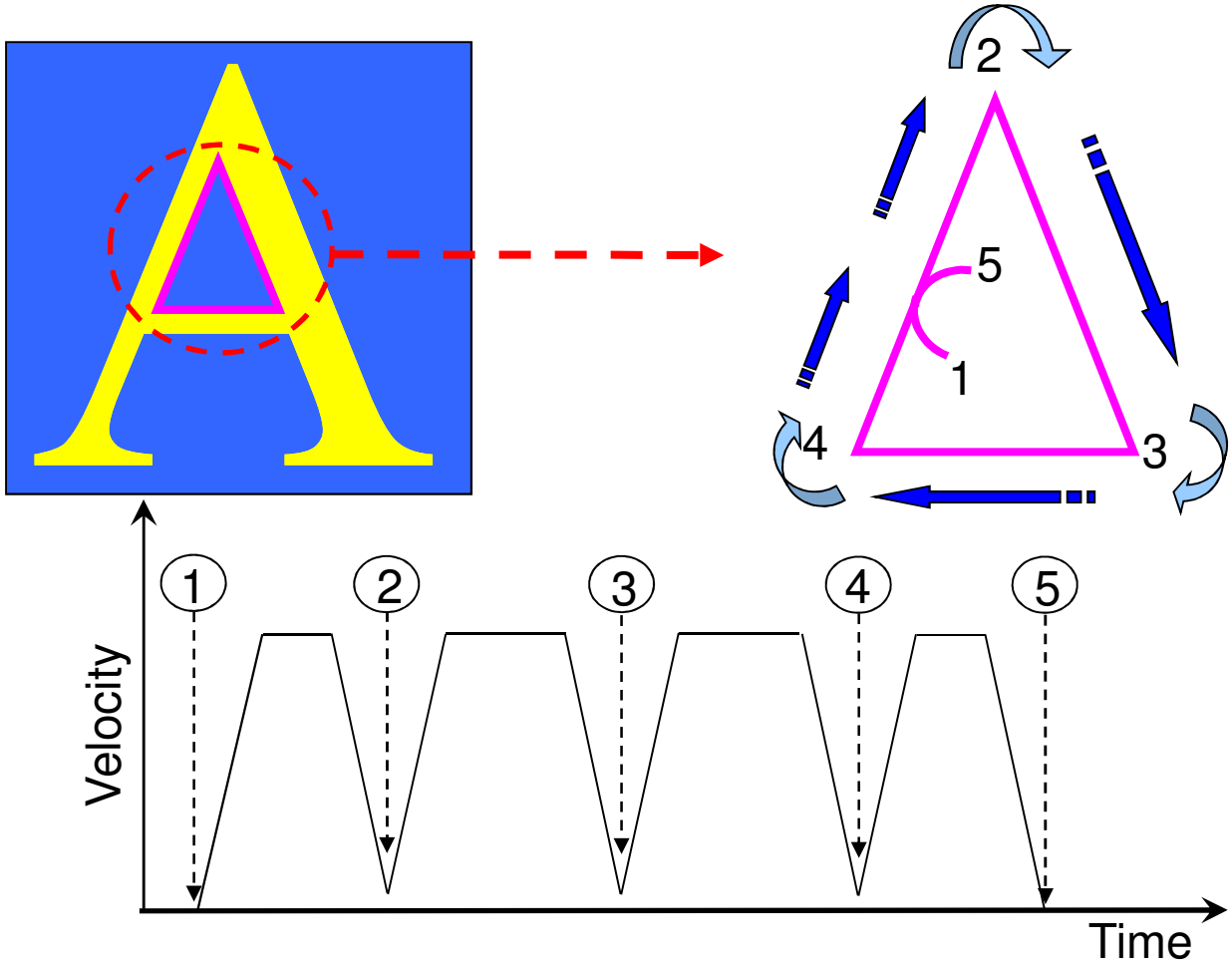
Process Dependencies

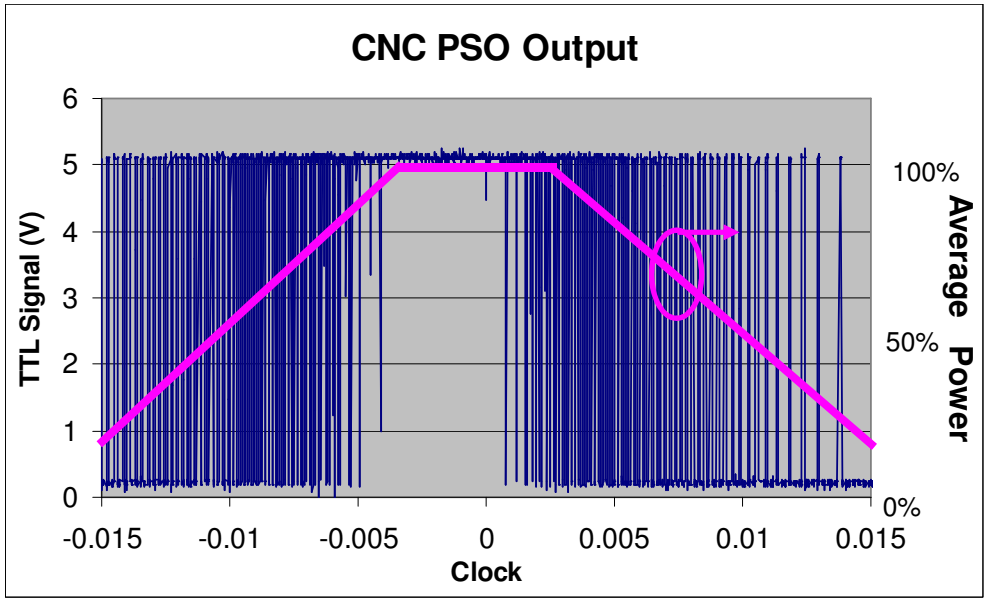


Detail cutting- HAZ control



- **Speed reduction in detail sections ⇨ requires management of heat input to limit heat affected zone (HAZ)**

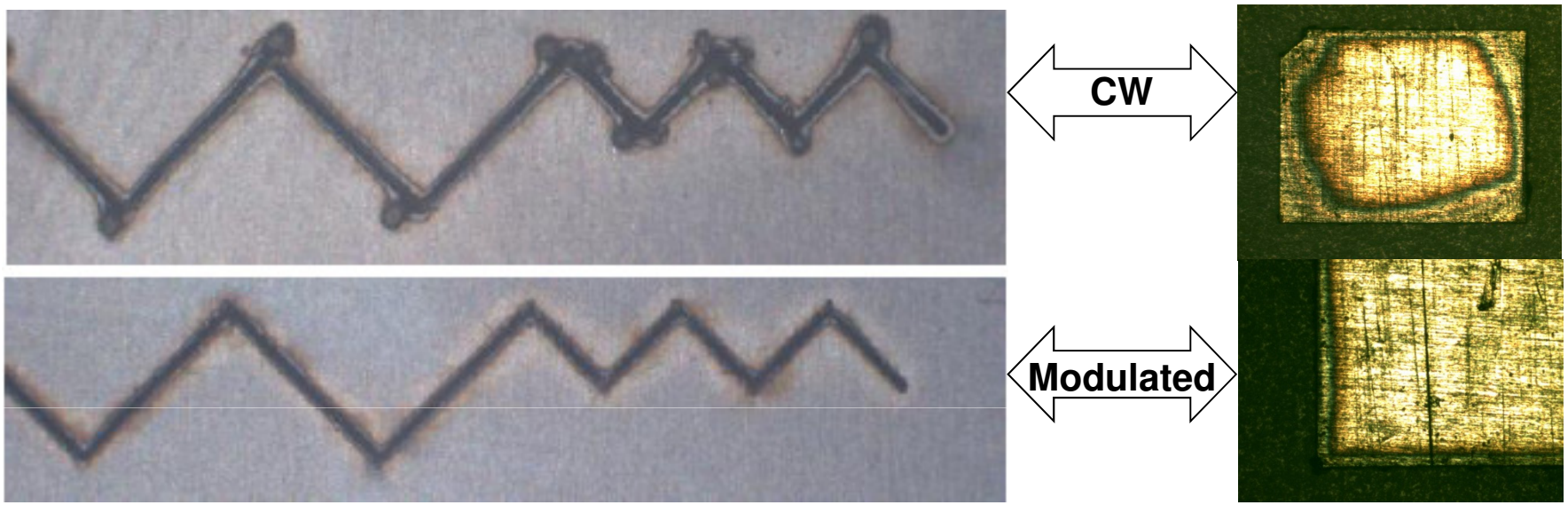
Precision cutting with HAZ control via PSO (Position Synchronized Output)



Position synchronized triggering controls HAZ at low speed.

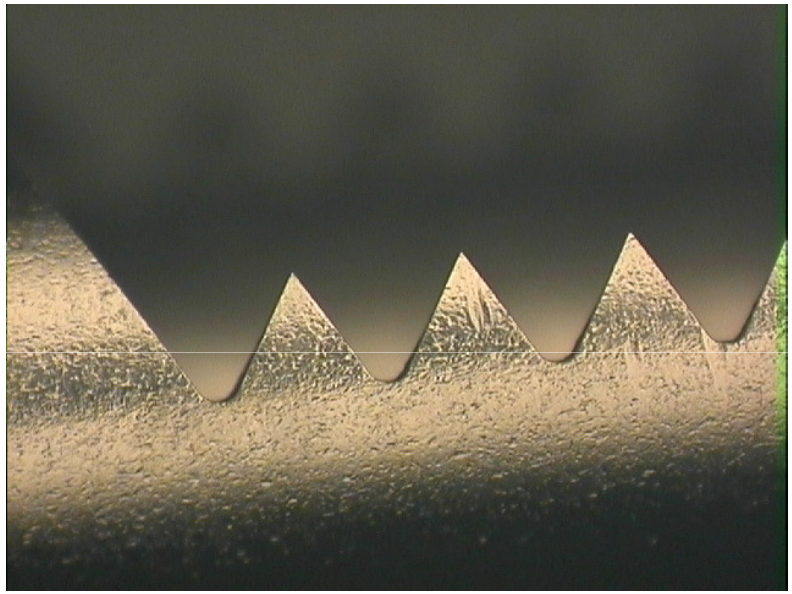
- Position Synchronized Output (PSO) :-
- Motion system detects Δx position change from encoder outputs ⇨ …
- TTL trigger signal with preset pulse width ⇨ …
- TTL pulse triggers laser output ⇨ …
- **Laser average power controlled by pulse frequency**.

Precision Contour Cutting & HAZ control: Power control via Modulation



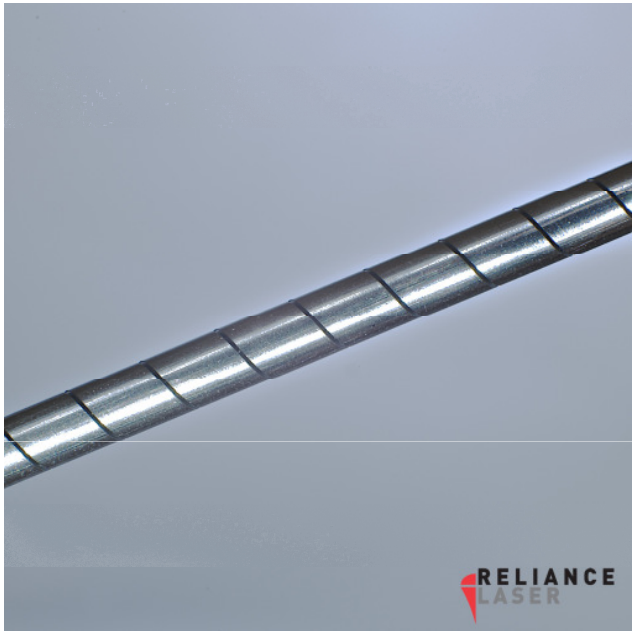
- Detailed contour cutting requires lower speed and lower average power to minimize HAZ around corners
- Modulation capability provides wide range of pulse widths <10us to CW allowing a wide process window
- Process control optimised using by fixed pulse width with variable modulation frequency controlled by speed or position reference of motion system

Precision Profile Cutting using PSO



Courtesy of Miyachi Unitek

Quality Improvements in Cutting / welding of precision medical tools



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Fiber Laser Cutting vs Electro-Discharge Machining

Laser-Cut Part **EDM Part**

- **Visual CMM showing fiber-laser cut part next to the original Wire EDM processed part**
- **Quality difference between the two.**
- **Function is improved: Clean, straight cut provides greatly superior column strength since it closes like a shut spring.**
- **Cost benefit: Laser cut part was much less expensive than the Wire EDM'd part. A great example of using fiber laser technology to solve a manufacturing problem.**

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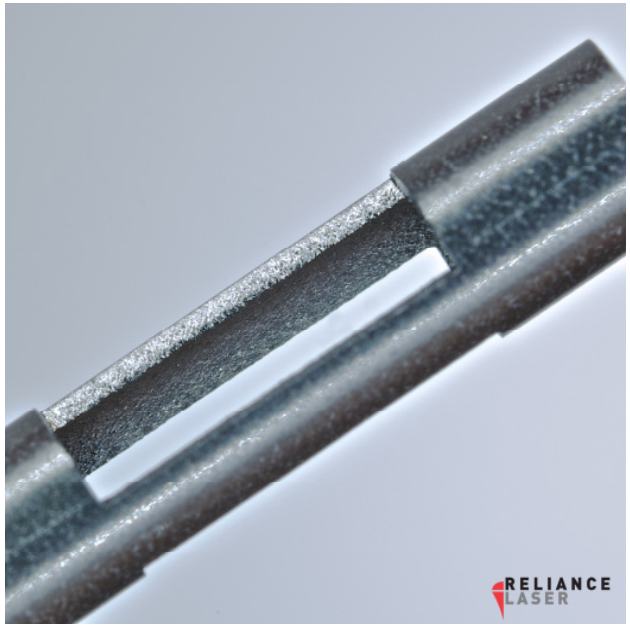
Thicker Tube Cutting: 1.25mm Stainless Steel



- Wall thickness of this tube >1.25mm
  - Cut with 200W CWM laser
- Cut speed for 1.25mm wall was same as for 0.125mm wall
- In cutting small scale parts most of the motion is tied up with acceleration and deceleration of rotation / traverse

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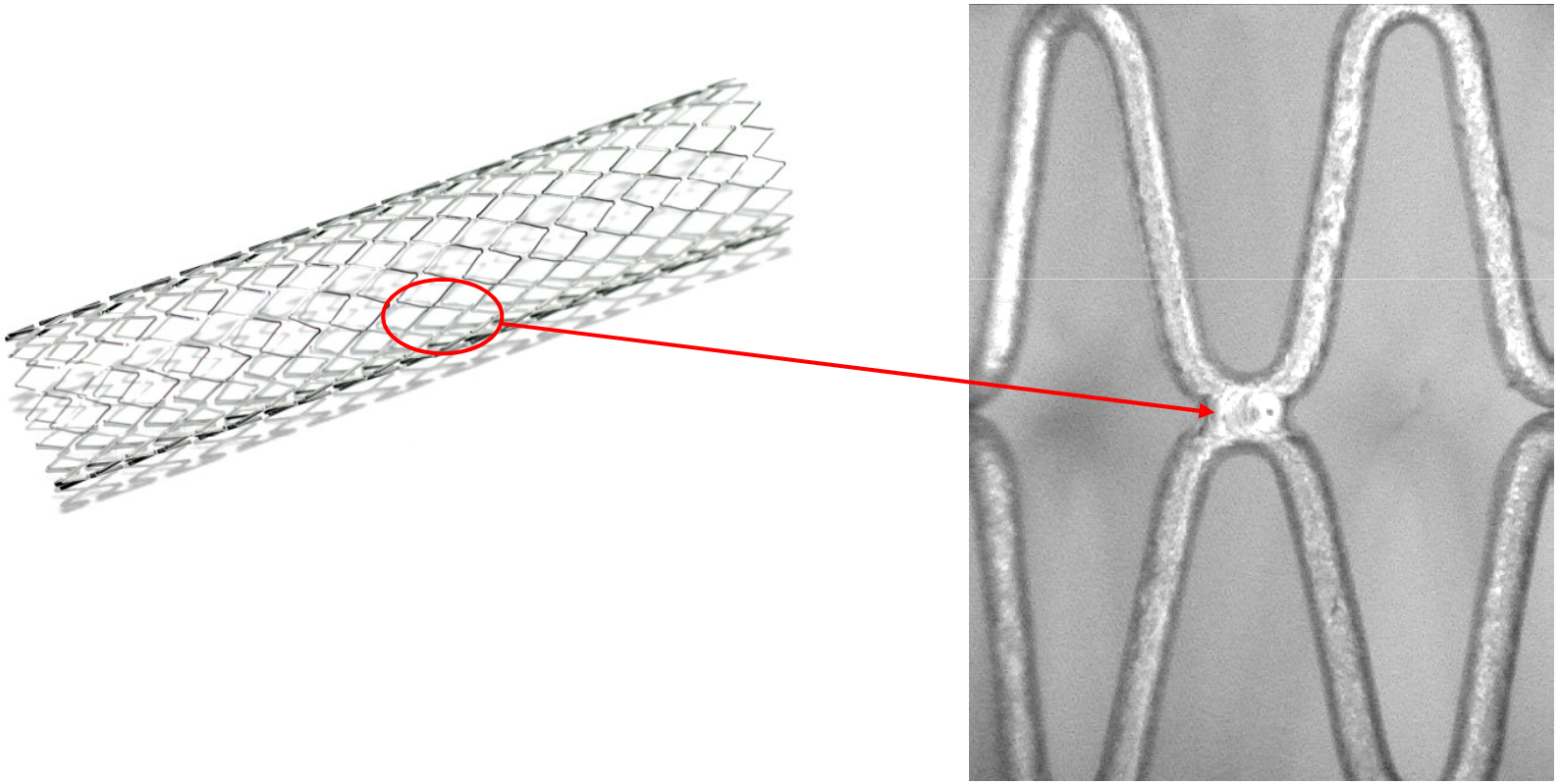
Welded-Wire “Crown” Stent

- **Manufacture of Welded Stents**

  - Wire rings are mechanically deformed into crowns
  - The wire “crowns“ must be accurately positioned and pushed together before welding with a precisely controlled laser pulse.
  - Typical power settings are in the range 40W - 50W with pulse durations in the range 5-10ms

Welded-Wire “Crown” Stent

- **Example: Welded Stent**

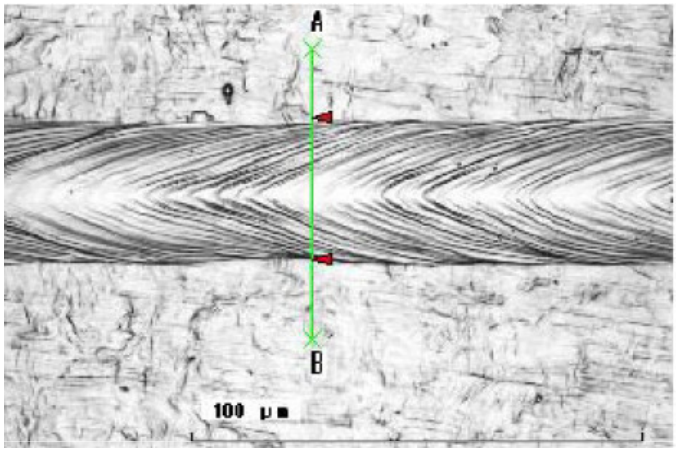


Medical Devices - *Weld quality is everything*

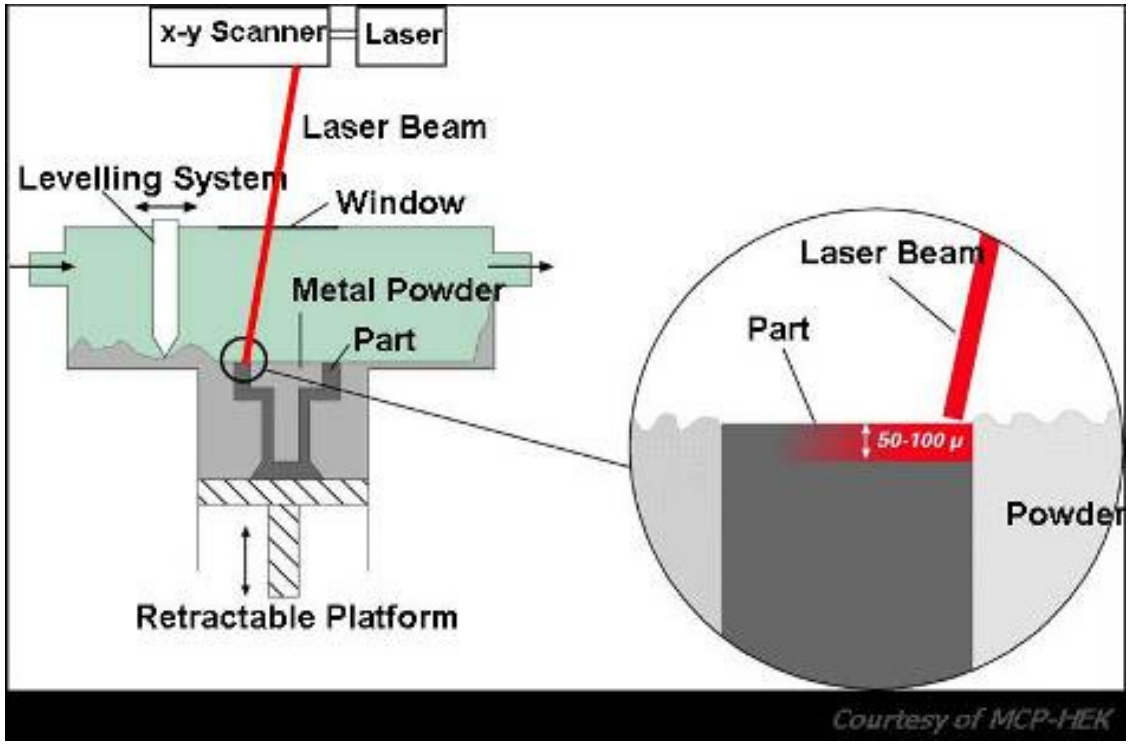
Weld approx. 0.1 mm wide

Weld smoothness is key

- ✓ Sterilizable



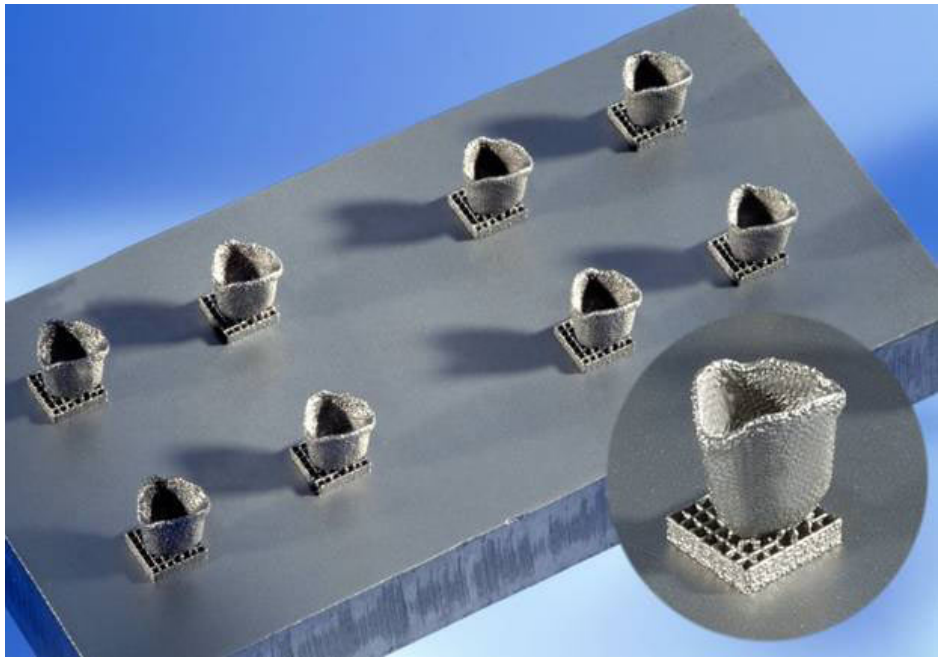
Selective Laser Melting (SLM) Rapid Manufacturing System: Medical



- To dramatically reduce lead times / produce high value and low volume parts
- To produce precision parts that could not be made or are very costly to be tooled due to constructional features

Example “Mainstream” Application for Generative Microprocessing / Manufacturing

One-off piece parts: Dental Caps!



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Titanium & Cobolt Chrome Medical Implants

High Value , bespoke (low volume) part production

Picture Courtesy of MTT UK

Replacement knee joint in
EOS CobaltChrome MP1

redPOWER and redPOWER DIODE for Medical

Pulse control

Higher brightness **redPOWER DIODE**

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Medical Lasers

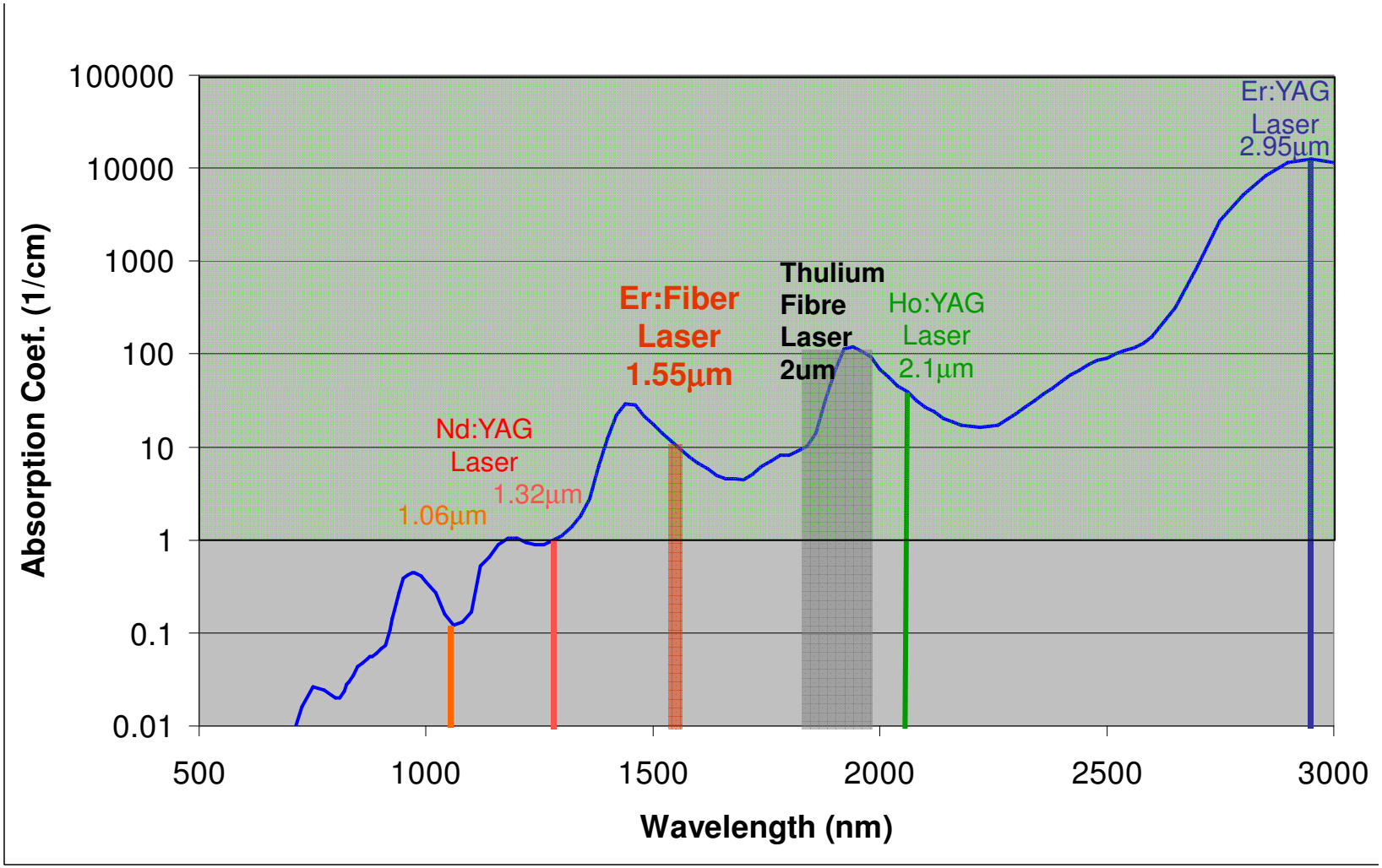
- **1550 nm wavelength is preferred to 1070nm**
  - 1550nm absorbed in water
  - Can be used to treat skin & subcutaneous layers without surgical procedures
  - Uses in:-
    - Dermatology (“Fraxel”) treatment
    - Vein Closure
    - Micro Surgery
    - Veterinarian Medicine
    - Hair removal

SPI® Lasers

nqa. ISO 9001 Registered UKAS 015

Water Absorption Spectrum

500nm to 3µm



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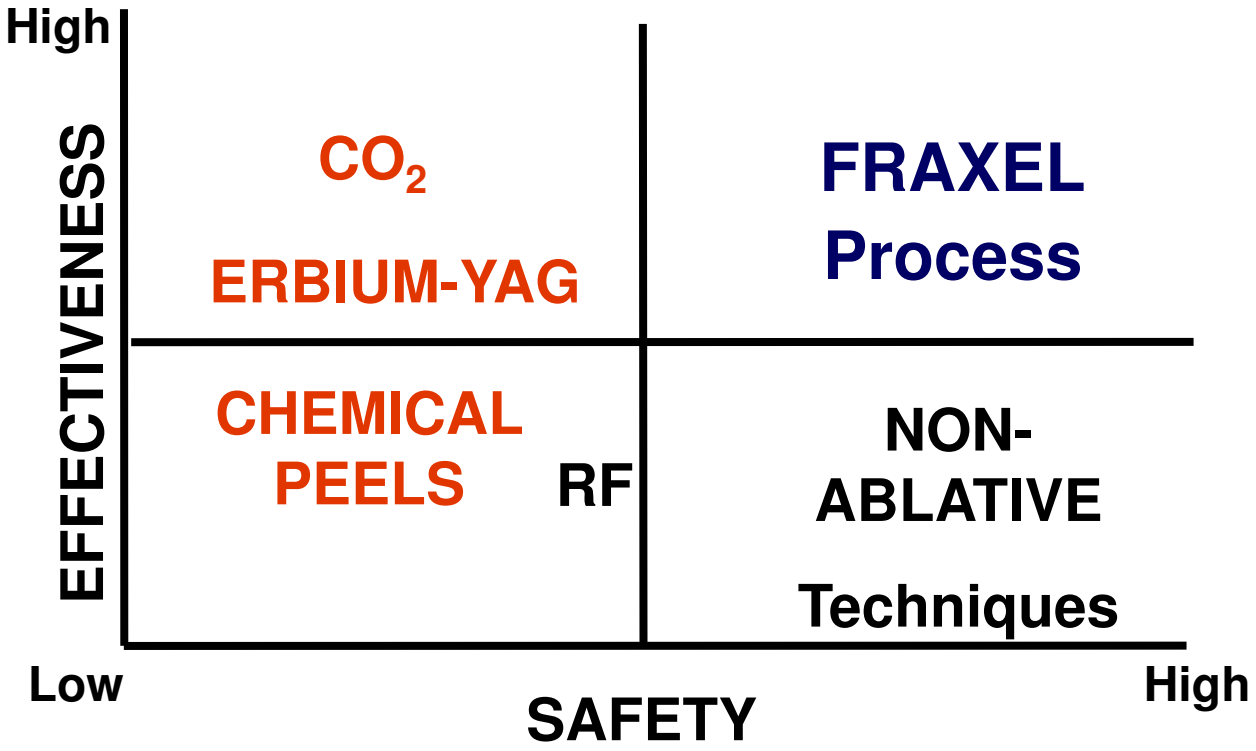
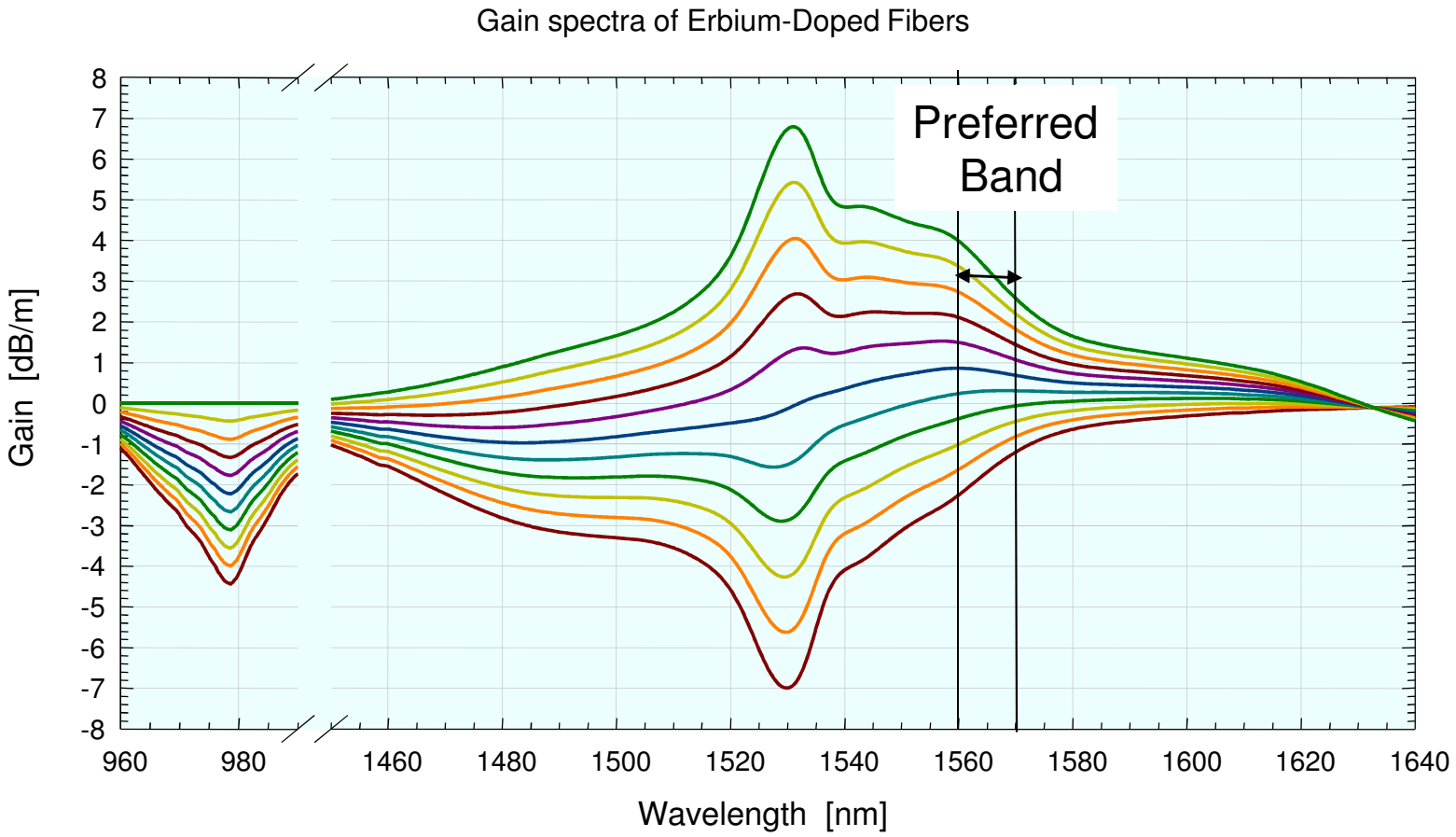
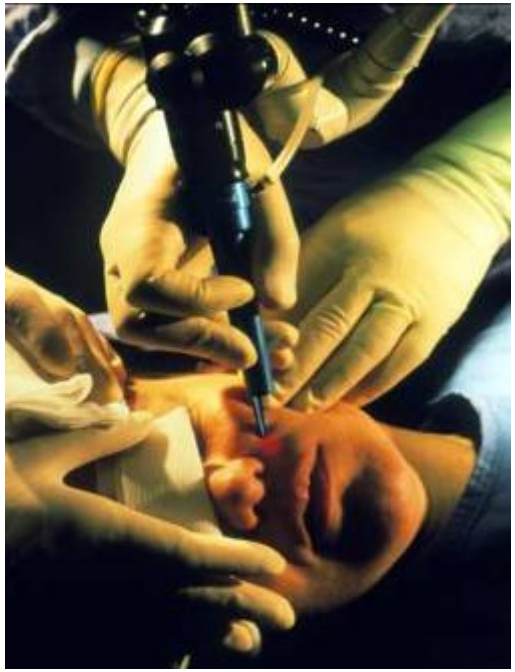
SKIN REJUVENATION



Er Fibers: Emission Spectrum

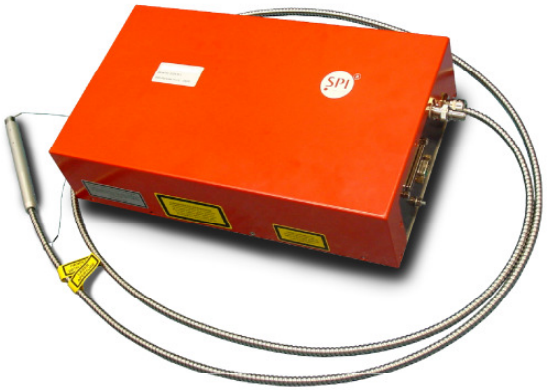


1550nm Fibre Laser For Medical Aesthetics
OEM Lasers for Skin Rejuvenation



Laser Treatment

1550nm / 1565nm OEM Laser



CW Power: 10W / 20W / 25W
Wavelength: 1550nm / 1565nm
Mode: CW and Modulated
Power Tuning: 10 – 100% (CW)
Max modulation speed: 3kHz
Linewidth FWHM: < 2nm

Output Beam Characteristics
Beam dia. : 5mm nom
Full angle divergence: <0.6mrad
M^2: <1.2

Courtesy of Sellas, Korea

SPI Lasers

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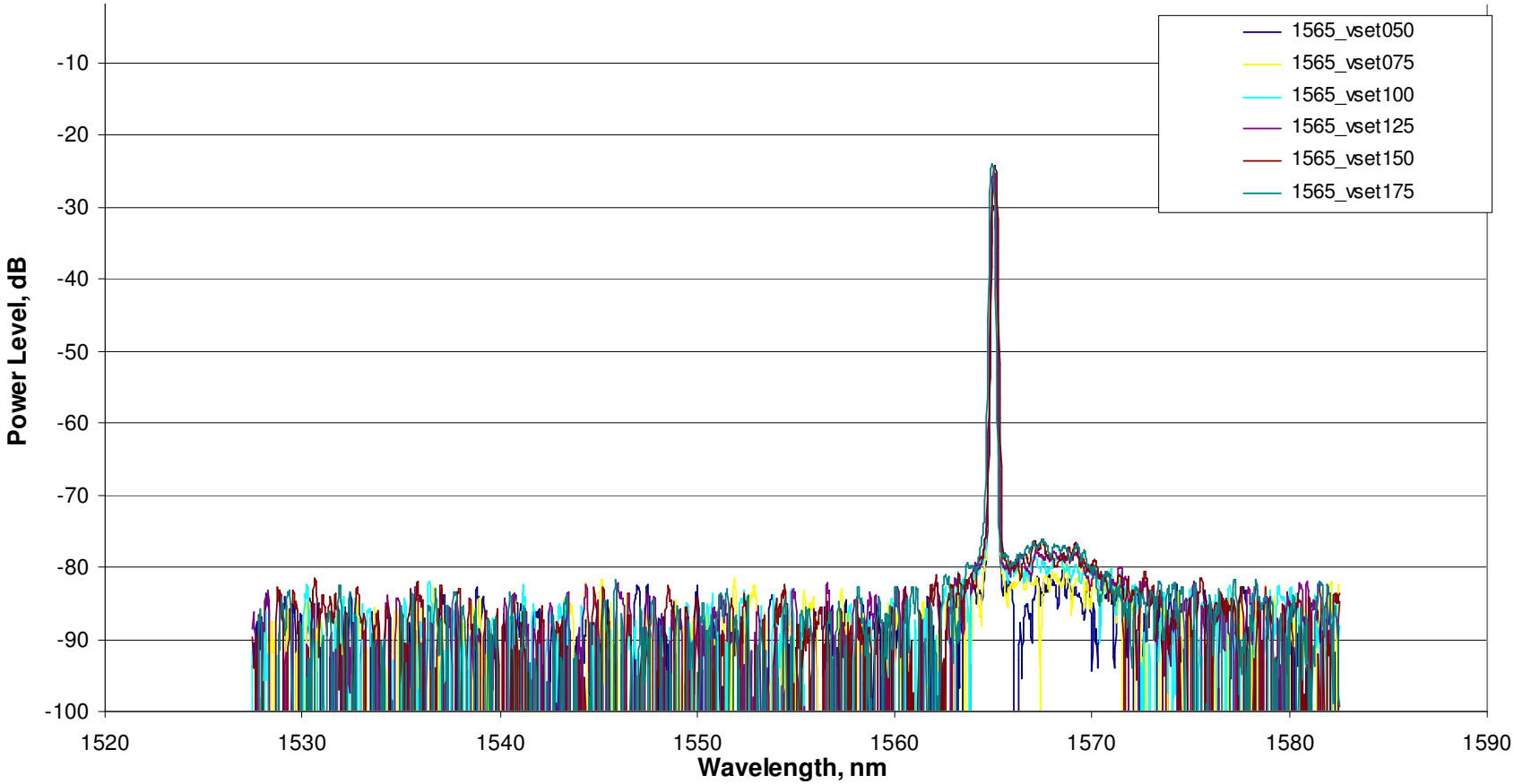
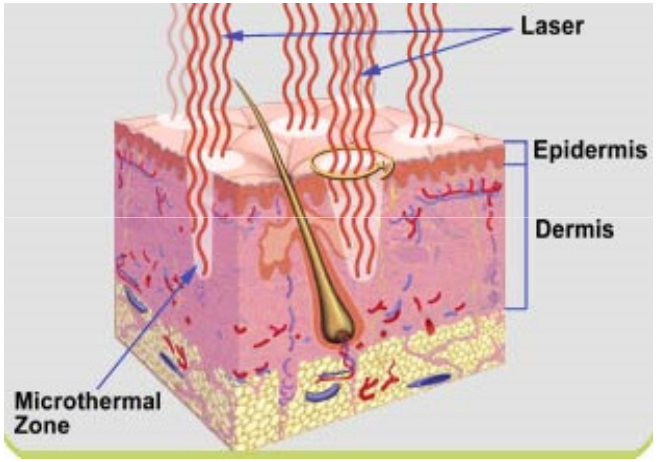
20W 1565nm Fibre Laser: Spectral Properties



Medical Laser Case Study:
Aesthetic Dermatology

- **Non-Ablative**
  - Lower risk of infection
  - Tissue is coagulated, not vaporized
  - The stratum corneum remains intact
- **Fractional**
  - Multiple 70-150 micron MicroThermal Zones (MTZs) surrounded by islands of viable tissue
- **Resurfacing**
  - Extrusion & replacement of damaged tissue
  - Rapid re-epitheliazation (within 24hrs)
  - Collagen denatured between 300-750 microns



Laser-based wrinkle removal!

SPI® Lasers

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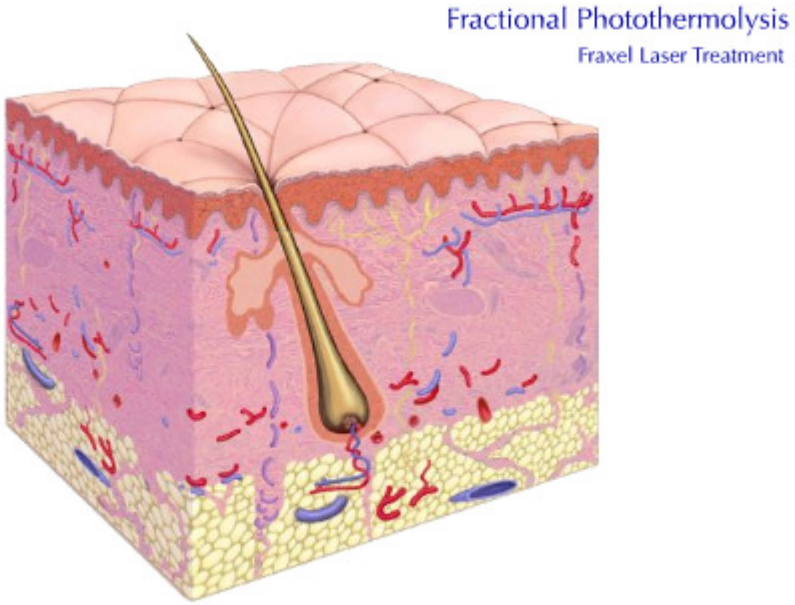
NON-ABLATIVE FRACTIONAL RESURFACING using 1550nm fiber lasers

- **Fraxel Technology:**
  - Treating the skin fractionally with pattern microscopic laser spots 100µm in diameter
  - Unique wound healing process results in:
    - **Rapid re-epitheliazatio the epidermis**
    - **Collagen remodeling t depths of 400-700 mic**



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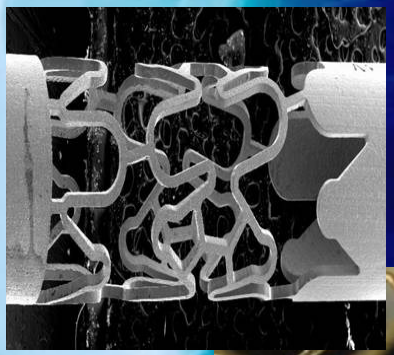

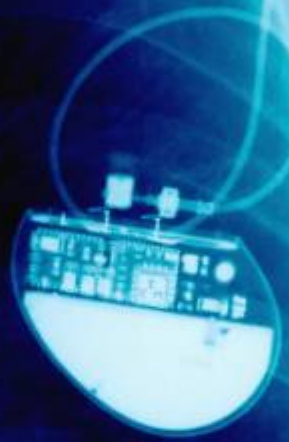

Fibre Lasers are Saving Lives

Fibre Lasers Rejuvenate the Body