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Fibre Lasers for Precision Micromachining and Engraving

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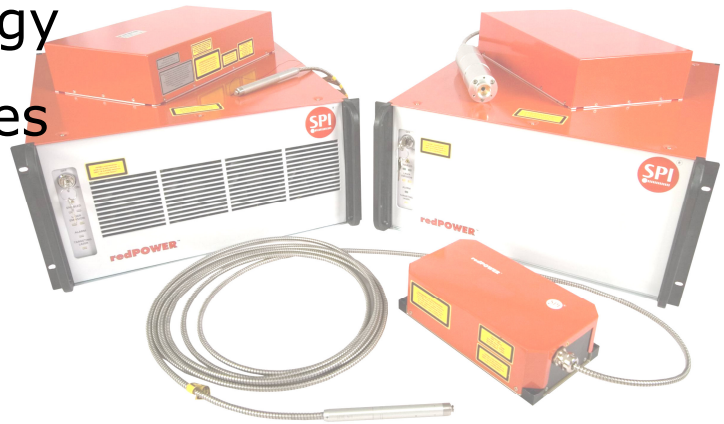
Agenda

- High Average Power CWM Lasers
  - Fiber Laser technology
  - Applications examples
- High Peak-Power ns Pulsed Lasers
  - Fiber Laser technology
  - Applications examples
- Summary & Conclusions

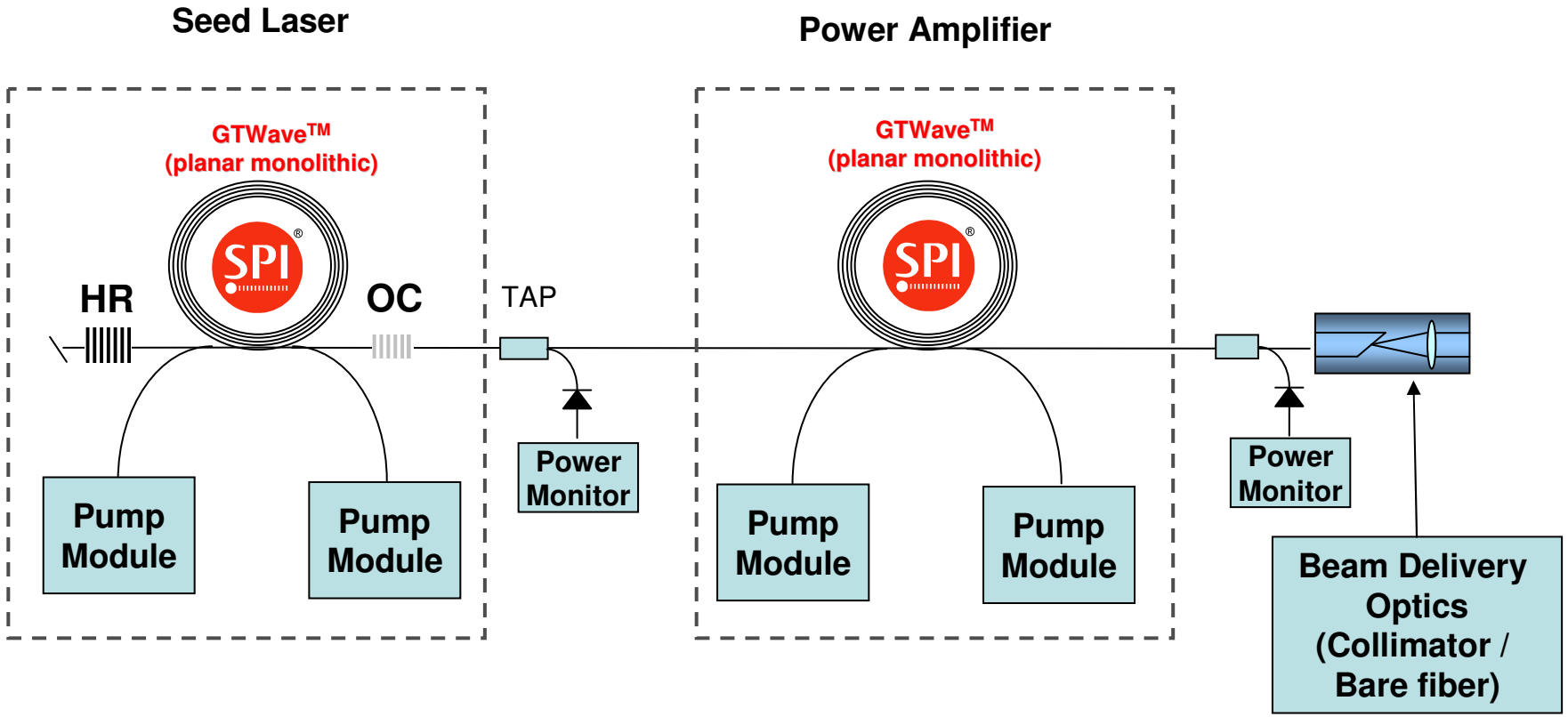


CWM Lasers for Micromachining

- 50W – 200W Air-cooled
- 100W - 400W Water-Cooled

- *Unique design features optimised for high-speed processing*

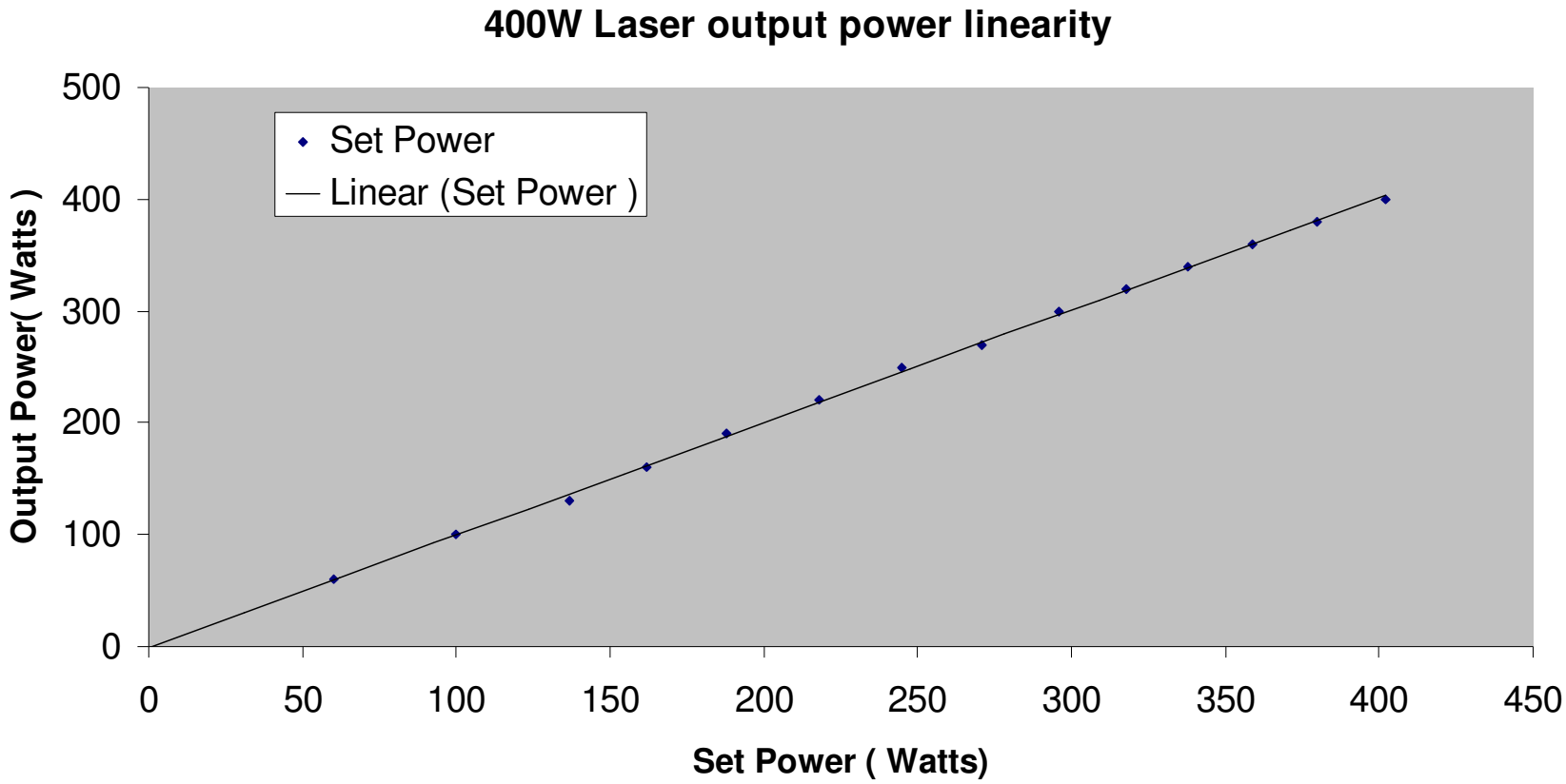
CWM Lasers: Flexibility in Power Control: 400W "R4" System Architecture



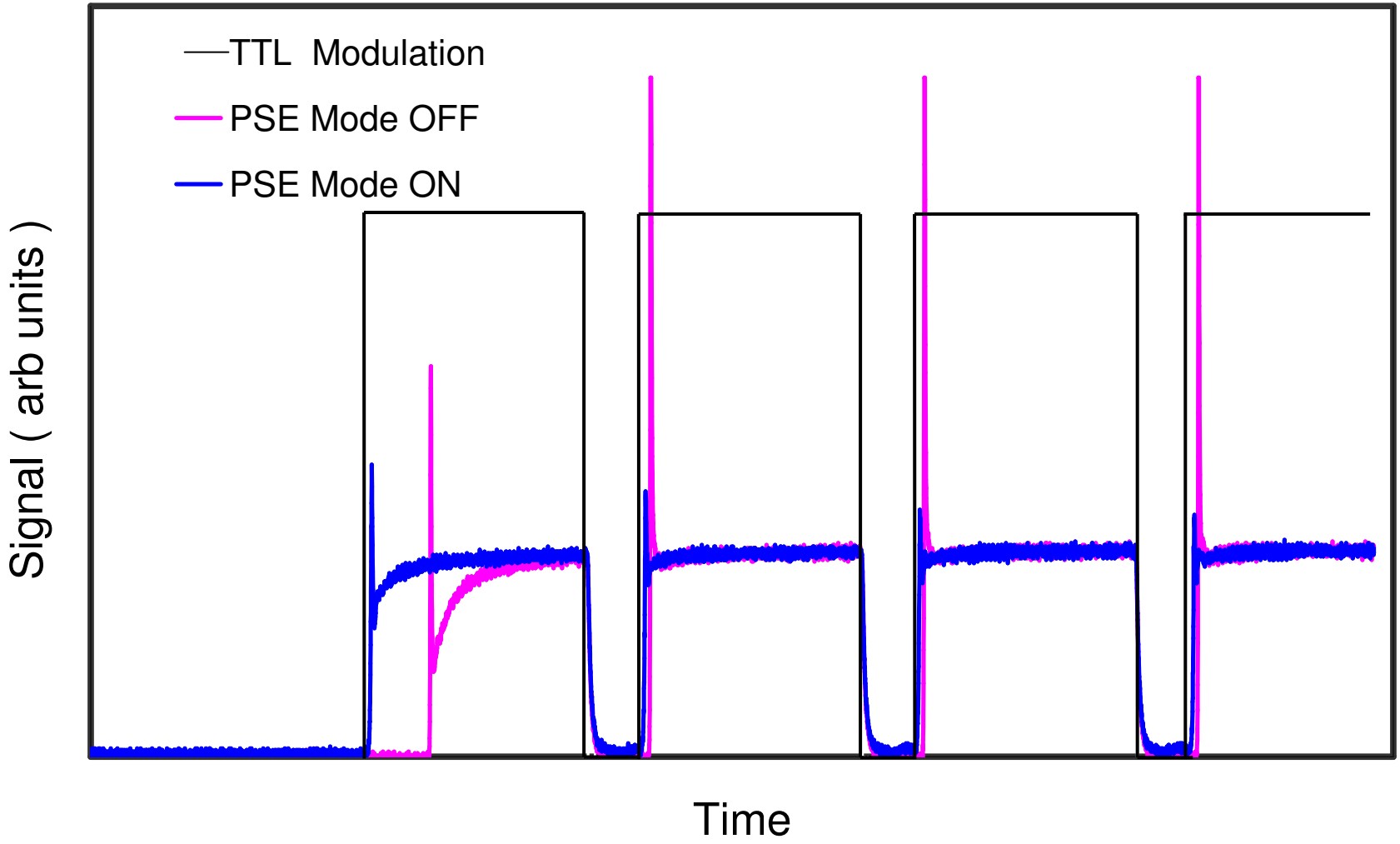
Single-emitter pump diodes can operate from DC to >100kHz - Laser output can be modulated correspondingly

Operating Modes: CW Laser ("DC" source) Power Linearity

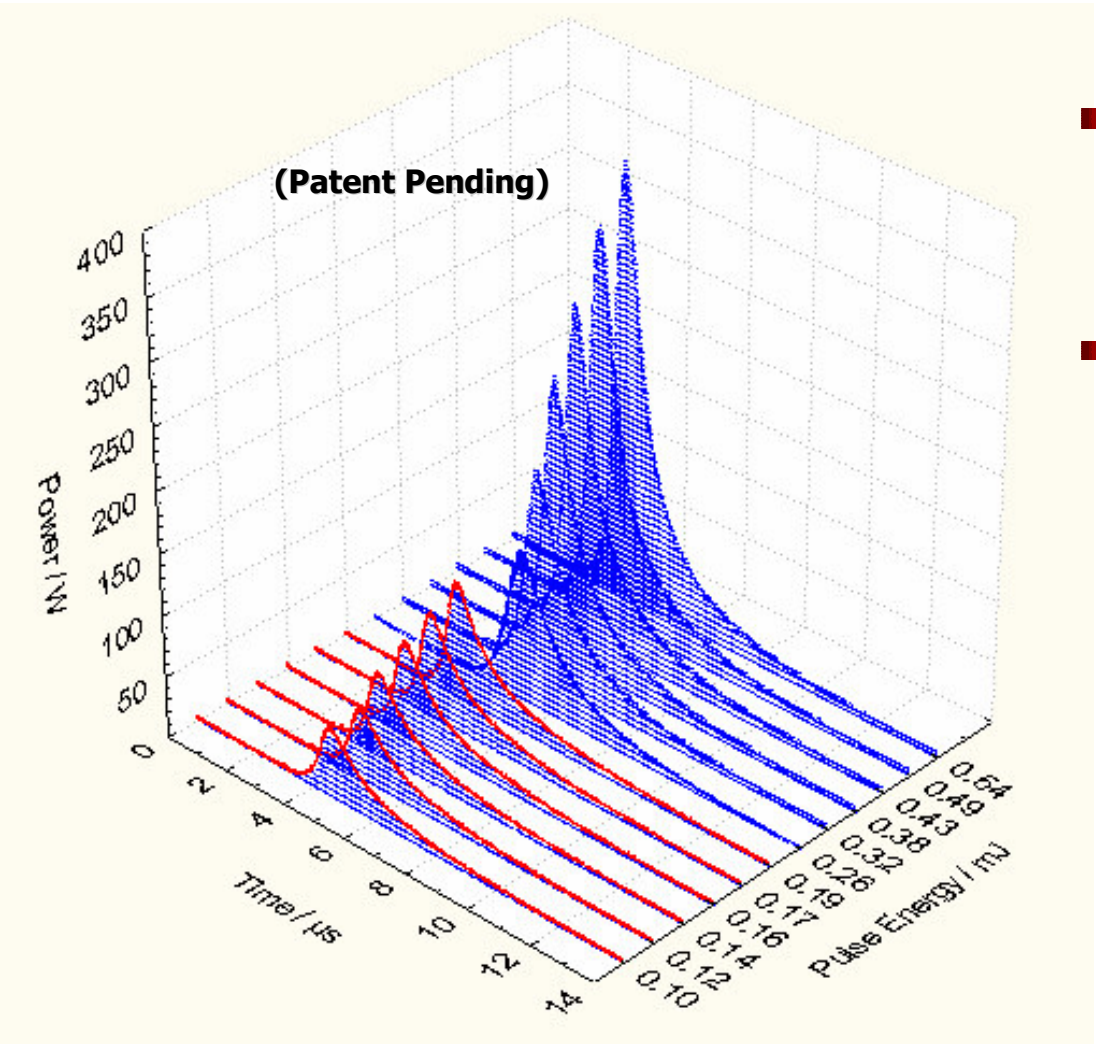
- **Linear output power characteristic**
  - No change in the output linearity as laser power is increased
  - Closed loop operation under modulated conditions



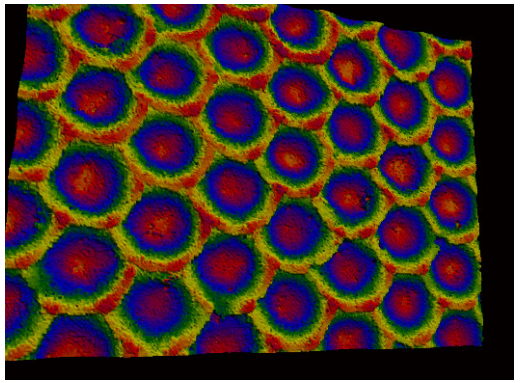
Pulsed-Mode Operation for Micromachining Applications



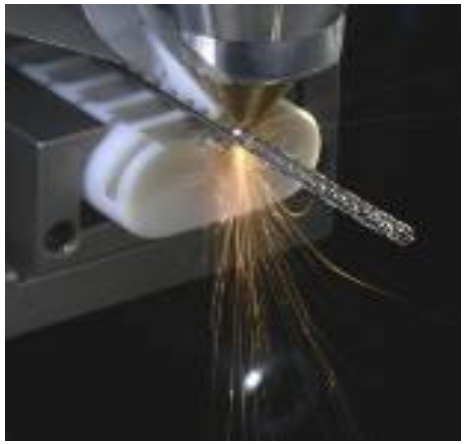
High-Speed Pulsed Mode Modulation of CWM Lasers: Pulse Waveforms @ 70kHz



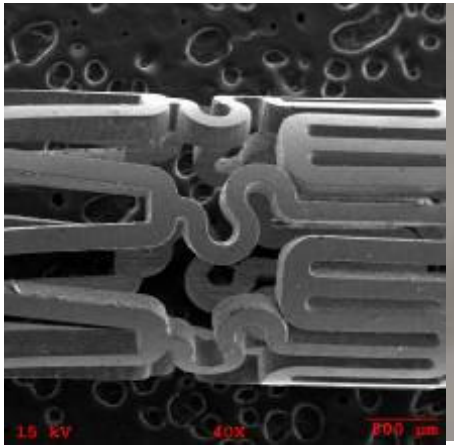
- 70kHz Pulse Profiles at controllable power / pulse energies
- Examples Applications: Fine Engraving: <20um Feature Size using pulse energies down to 0.2 mJ / pulse



Application Case Study I: Medical Devices Micromachining / Fine tube cutting



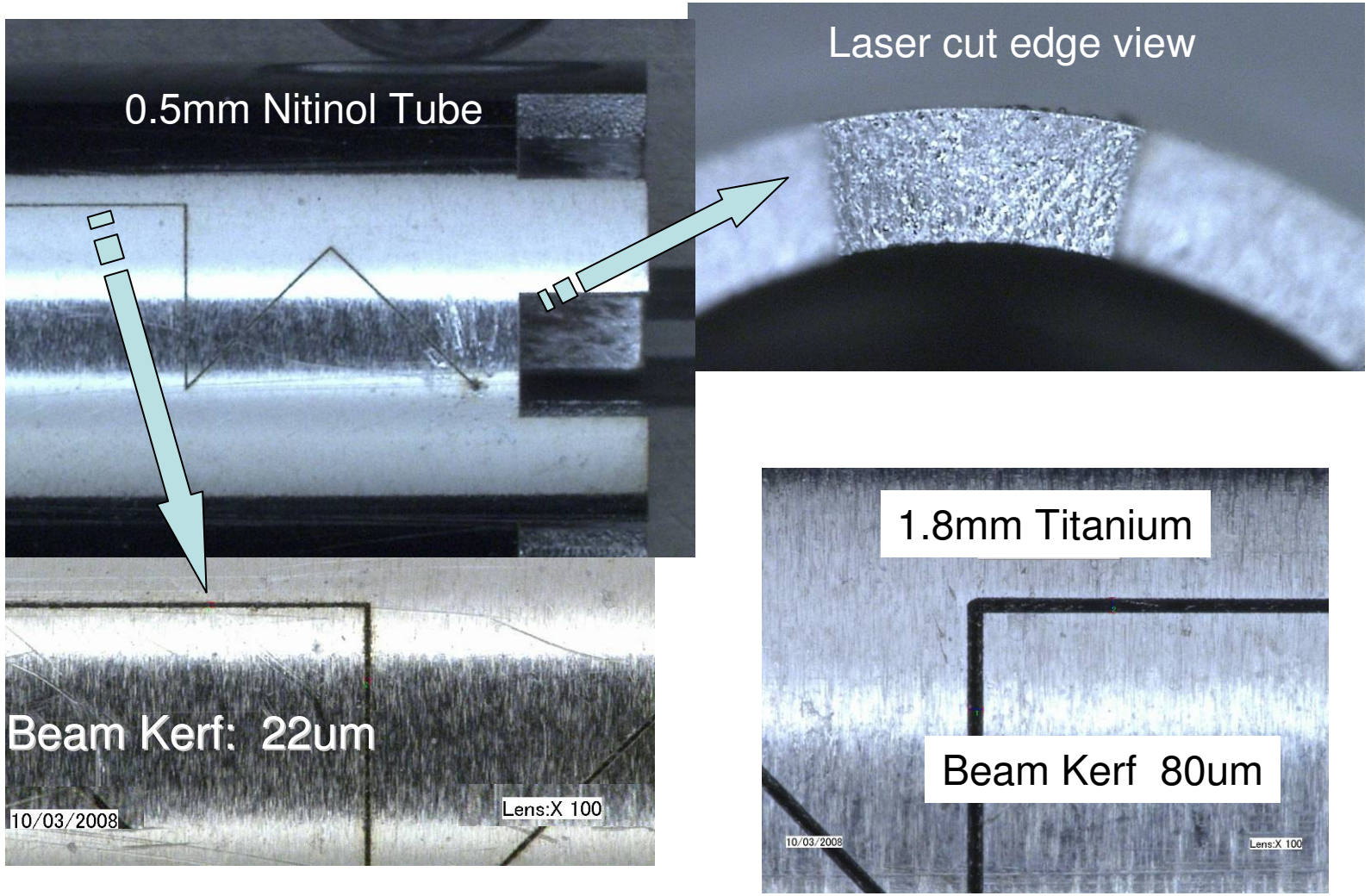
Cutting high precision Tubes



Cutting Nitonol Coronary Stents

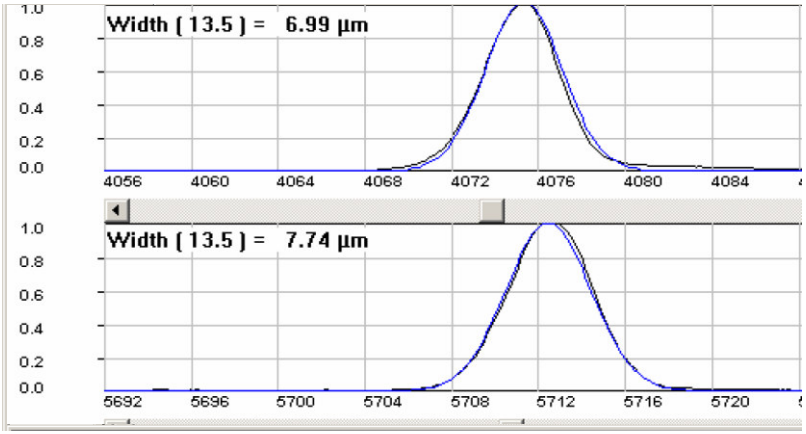
- Well-proven, widespread applications with 50W / 100W / 200W lasers
- $M^{2\sim}1.1$ beam quality allows very fine kerf as low as 15um width
- Cutting speeds with conventional solid state lasers are limited by repetition rates of a few kHz
  - **Productivity improvements >5x in cutting speeds achieved**

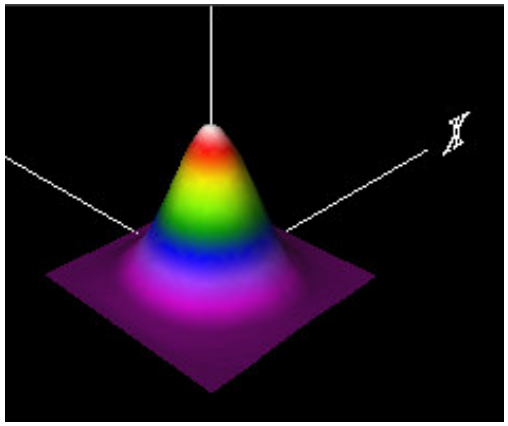
Thicker-Wall Precision Cutting: Medical Devices (using a 400W CWM laser)



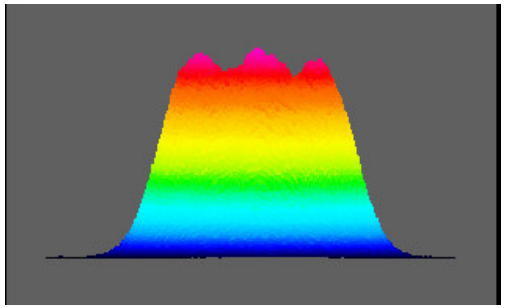
Case Study II, Micro-Welding: Beam Quality Choices

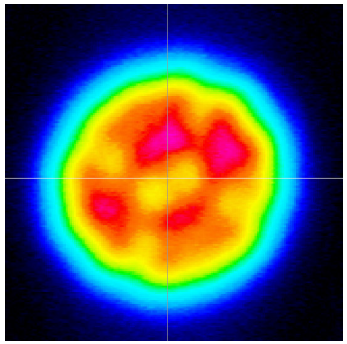
- **Gaussian Beam: Single-mode beam source ($M^2 < 1.1$)**





- **Micro-Welding: "Flat-Top" Profile Option ($M^2 \sim 4$)**



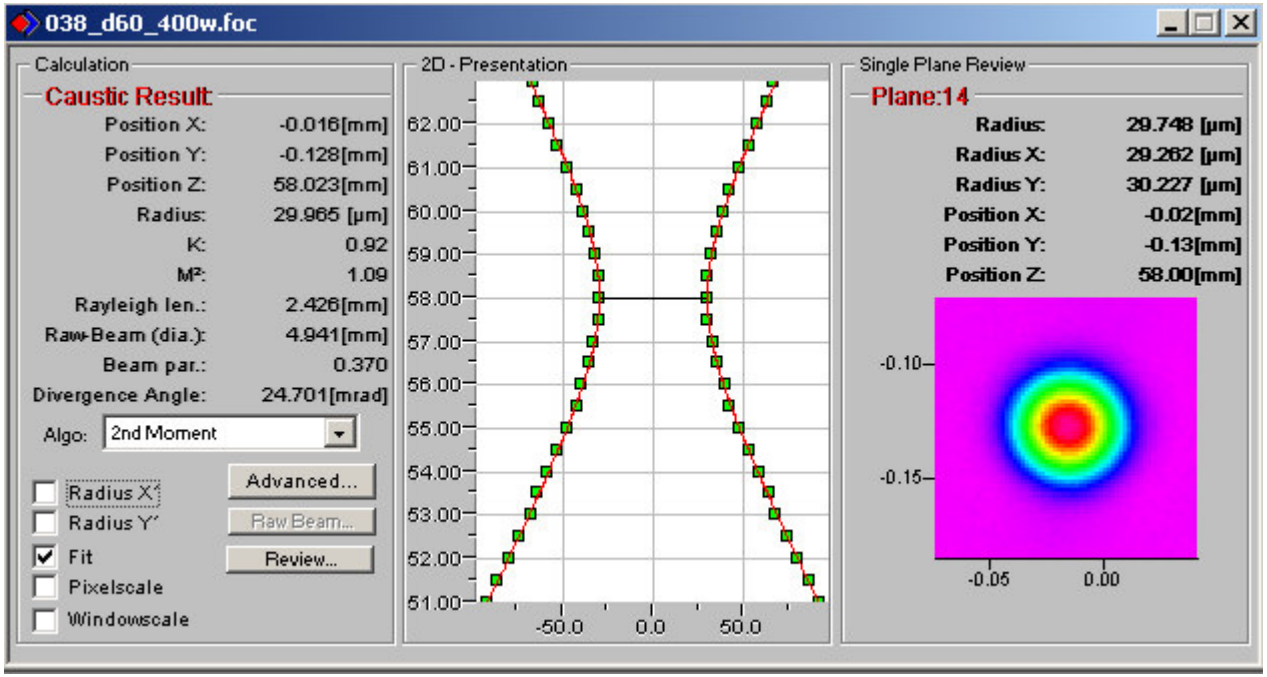


- Micro-welding of thin metals: non-Gaussian "flat-top" beam profile can improve coupling and weld uniformity

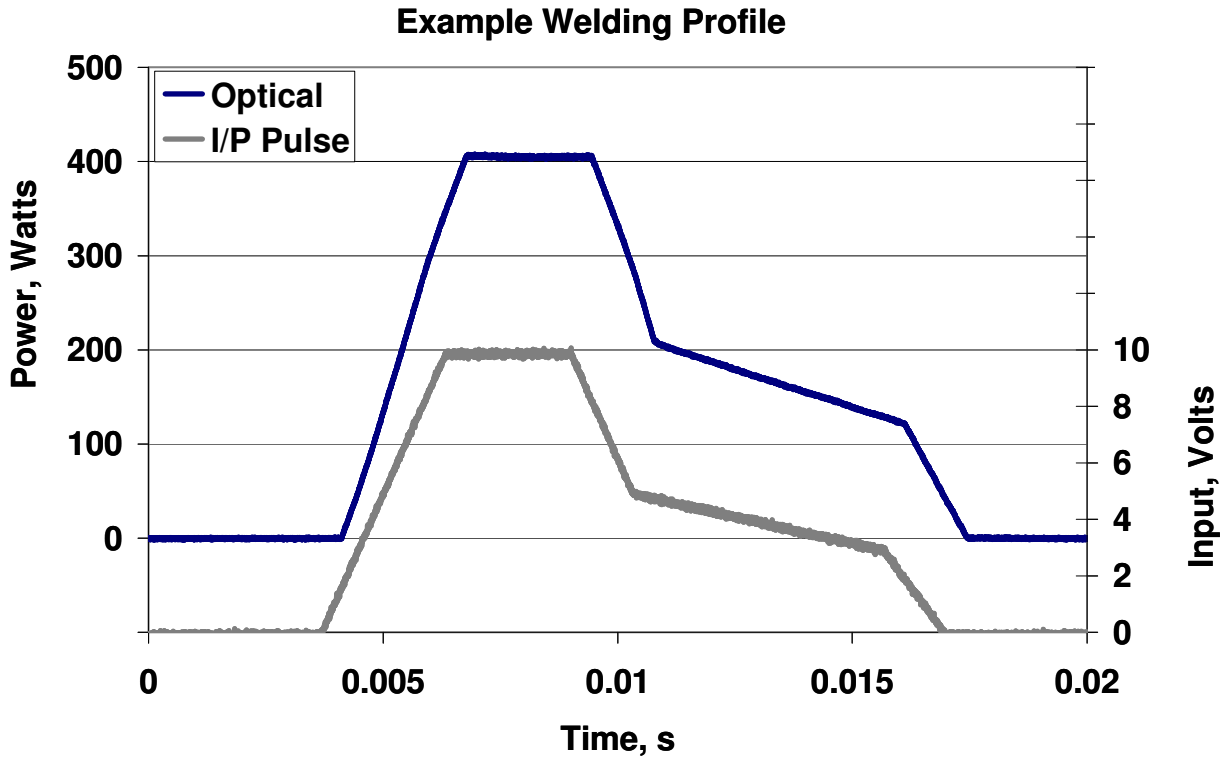
Micro-Welding: Spot Size Management

MICRO WELDING: BEAM DIAMETER CONTROL

BEAM OPTICS	SPOT SIZE, um		
	Calculated	Measured	
		@ 50W	@ 400W
Collimator + 0.5BET + f200 Lens	120	122	128
Collimator + f200 lens	60	59	60
Collimator + f100 lens	30	28	34
Collimator+2x BET + f100 lens	15	20	19

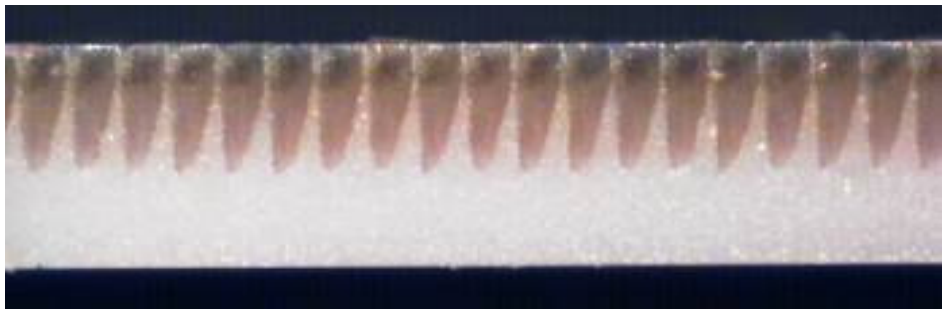


Micro-Welding: Temporal Beam Shaping



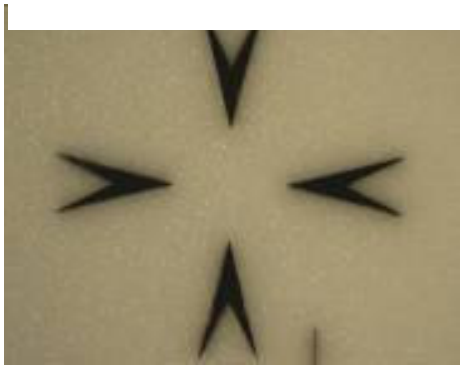
- Waveform can be PROFILED TEMPORALLY
  - "Tailored energy" for Micro-Welding applications
  - Degrees of freedom: Pulse Rate / Peak Power / Pulse Energy / Energy Profile

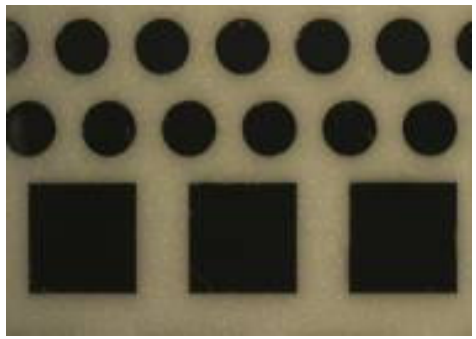
Application Case Study III: Ceramic Scribing / Cutting

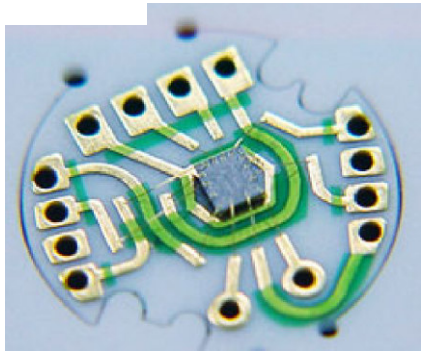


Alumina scribed with fiber laser
400um thick alumina
250mm/s, 75um centres,
250 um deep

High precision alumina substrates cut with CW-M fiber laser







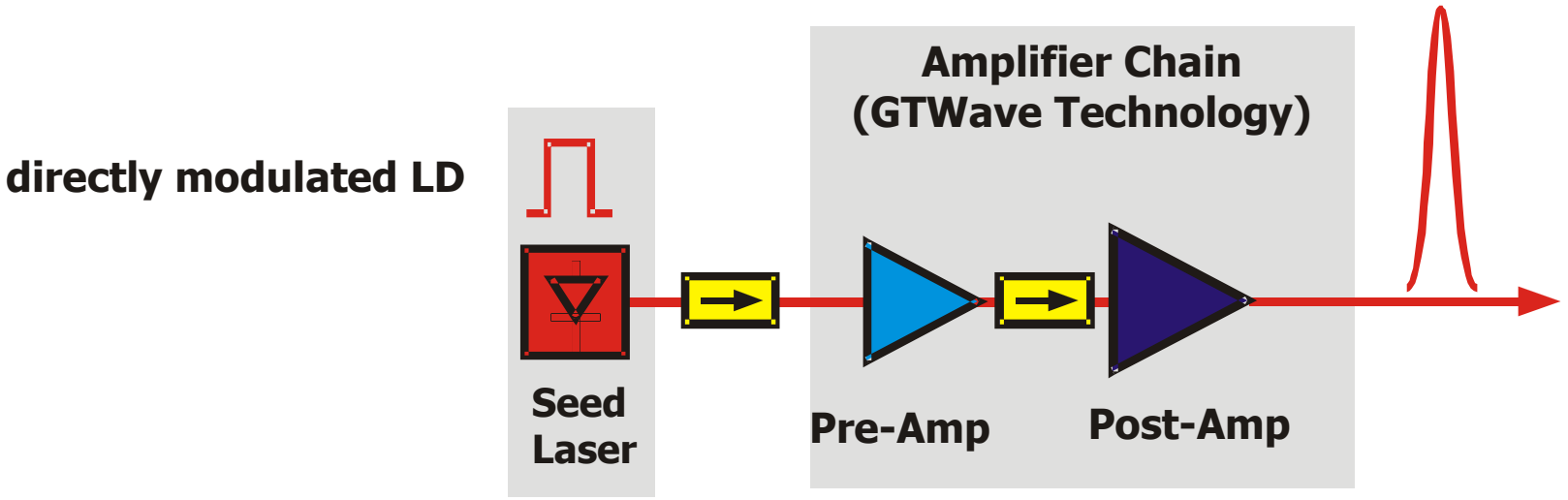
Ceramic substrate images Courtesy of Synchron Laser

Micromachining with ns Pulsed Lasers

Processing Applications

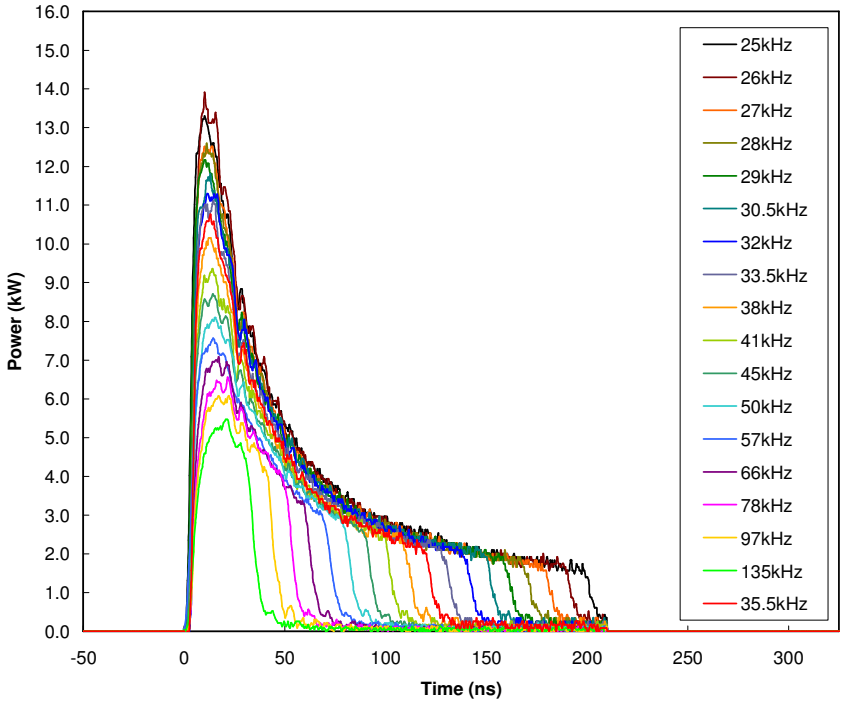
- The majority of materials processing applications are governed by:-
  - **Peak pulse power** - which is typically required to overcome processing thresholds.
  - **Pulse energy** - which governs the amount of thermal energy available to effect any material processing.
  - **Pulse duration** - which impacts the beam material interaction time.
  - **Power Density** – 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 pulsed laser materials processing applications.

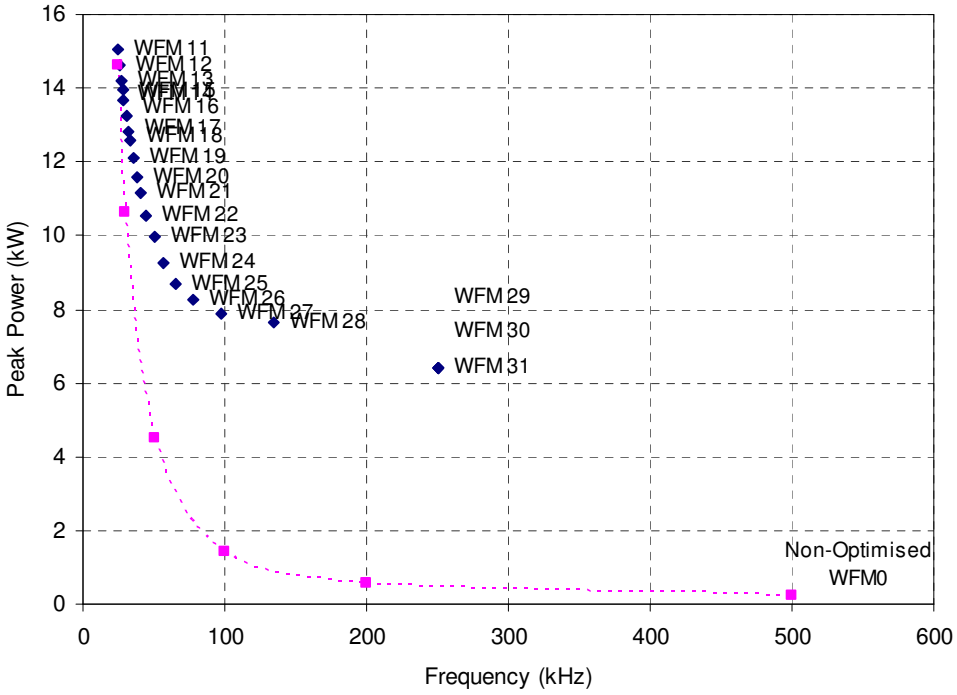
SPI Pulsed MOPA Fiber Laser



- Advantages of MOPA architecture:
  - Pulse parameters can be controlled independently at different stages
  - Extensive pulse energy and peak power parameter space

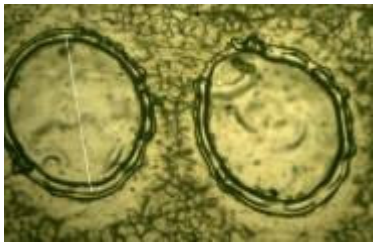
20W Pulsed Laser Waveforms





Process optimisation via Peak power / pulse energy control via Waveform selection

Spot Overlap: Marking quality up-close
(one of several quality measures)



No Spot Overlap
- ***visible mark***
- ***poor resolution***
- ***dotted-line***

<5% Spot Overlap
- ***improved mark***
- ***low resolution***
- ***"scallop" edge***

>60% Spot Overlap
- ***desired mark***
- ***high resolution***
- ***smooth line edge***

Spot overlap is a key visual factor in determining mark quality

- Greater overlap produces a more continuous mark appearance
- >60% overlap desired for many marking applications

Metal Marking
(Color Marking on Stainless Steel)

- Niche application but potentially high volume
- High repetition rates gives better contrast colours
- Higher repetition rate allows better control

* Image courtesy of A&P Instruments Co Ltd

* Image courtesy of Electrox

Metal Engraving using ns Pulsed Lasers

- Operation from CW-500kHz gives total control of peak power and pulse energy giving fine processing control
- Engrave:
  - 25kHz Waveform 0
- Smoothing / Polishing / Finishing:
  - High-speed low-energy pulses, e.g. 250kHz Waveform 3
  - Single pass "cleans" mark & smoothes engraved surface

EXAMPLES

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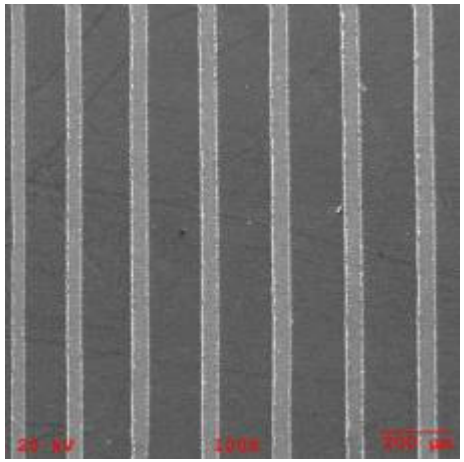
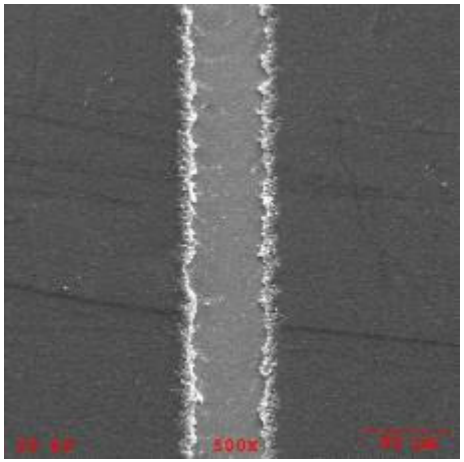
* Images courtesy of LMco

Solar Energy/Display Technology

- Scribing Molybdenum Films
  - The P1 scribe for thin film solar cells
  - Requires the selective removal of the molybdenum from the glass substrate.
  - Careful control of the pulse energy is crucial in order to;
    - completely remove the film,
    - produce minimal burr to the patterned edge,
    - lack of cracking/delamination of the Mo film
    - no damage to the glass substrate.



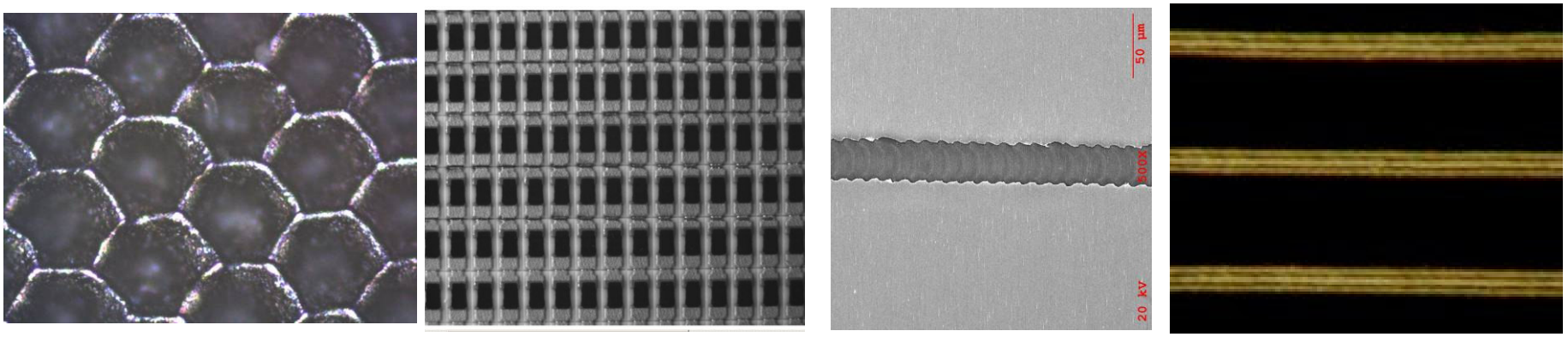


20W; 125kHz WF2
4m/s scan speed
40µm scribe width

In Summary

- CWM Lasers have exceptional dynamic range for a wide range of micromachining applications
  - Ultra-fine cutting
  - Engraving
  - Micro-Welding
  - Thicker section cutting with fine kerf width

- MOPA high peak energy lasers:
  - Tailored Pulse characteristics give processing flexibility for application / materials / targeted features
  - Marking / engraving / cutting
  - Diamond / Metals / Thin-film oxides / Plastics



10kHz — **500kHz**

Performance, Versatility, Stability, Repeatability

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