

NEW HIGH-POWER, DIODE- PUMPED SOLID STATE LASER

InterOpto '95, Makuhari Messe, Japan



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OUTLINE

Introduction to SEO

Review of diode-pumped lasers

Prior SEO experience

Design goals

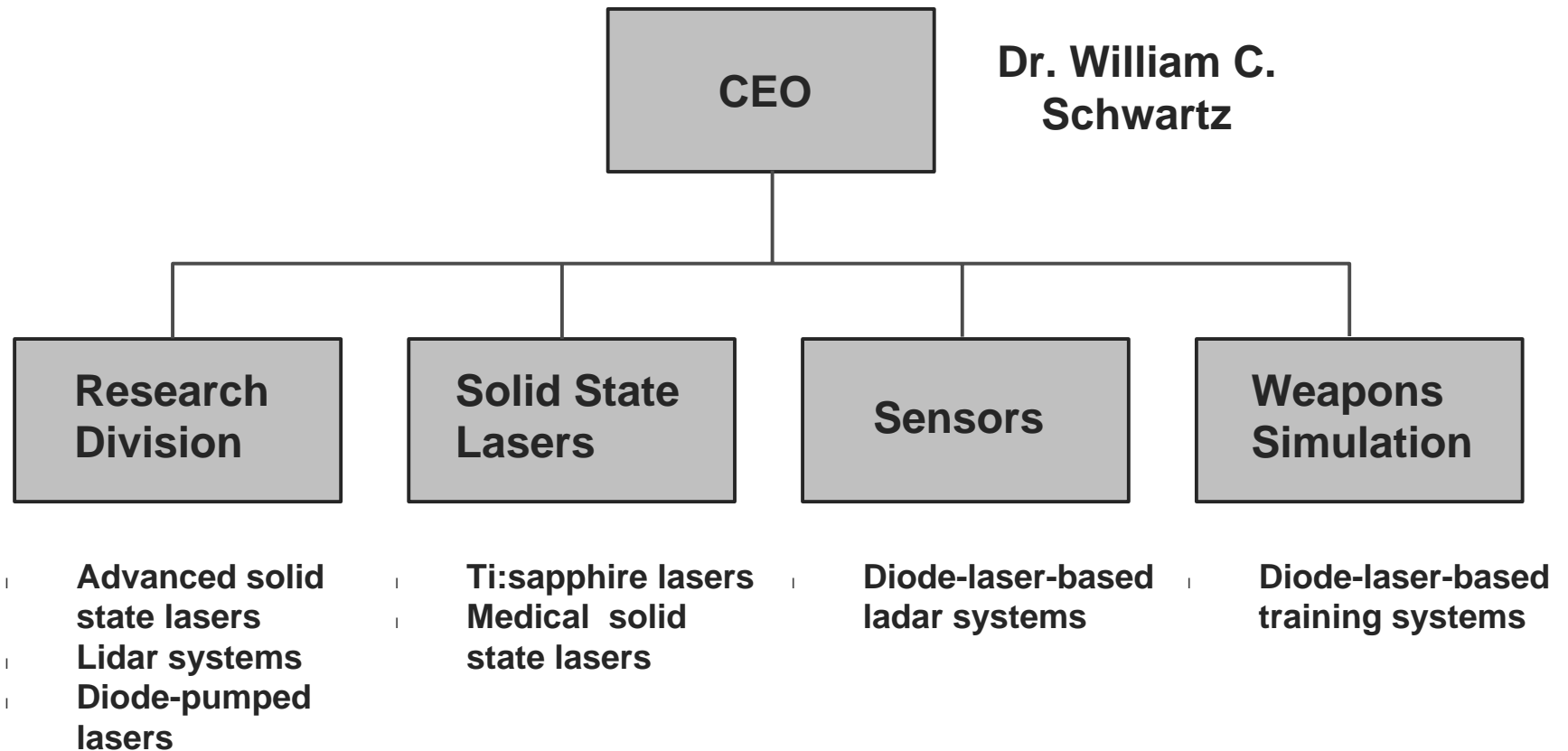
Laser performance

Product description



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SCHWARTZ ELECTRO-OPTICS (SEO) HAS FOUR DIVISIONS





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SEO HAS OFFERED COMMERCIAL LASER PRODUCTS SINCE 1987

n Laser 1-2-3

- **Multi-wavelength-capability, lamp-pumped solid state laser**
- **0.75, 1.06, 2.1, 2.9 μm wavelengths, others available**

n Titan-CW

- **Tunable CW Ti:sapphire laser, 680-1100 nm**
- **Standing-wave or single-frequency ring**

n Titan-P

- **Pulsed, 100-mJ, Ti:sapphire laser, Nd:YAG pump included**

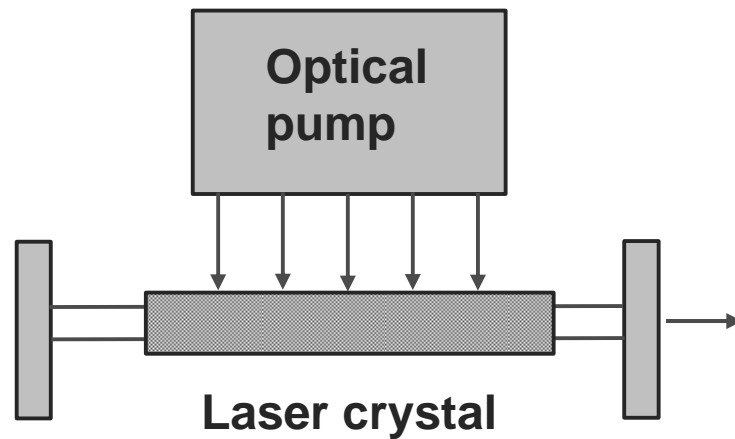
n Titan-ML

- **Mode-locked Ti:sapphire laser, 100-fs pulses**



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DIODE-LASER OPTICAL PUMPING SOURCES HAVE MANY ADVANTAGES



- n High power density
- n Precise control of pumped volume
- n Long lifetime
- n High efficiency
- n Low-voltage power supply
- n Reduced heat load in laser crystal



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SEO HAS BEEN BUILDING DIODE-PUMPED LASERS SINCE 1986

n Single-frequency sources

- **1-W, Nd:YAG ring laser**
- **50-mW, Tm,Ho:YLF laser at 2.06 μm**
- **40-mW, tunable Cr:LiSAF ring laser, 810-850 nm**

n Pulsed, Q-switched (2.5 mJ) miniature Nd:YAG laser

n Pulsed, 90-mJ Nd:YAG rod laser

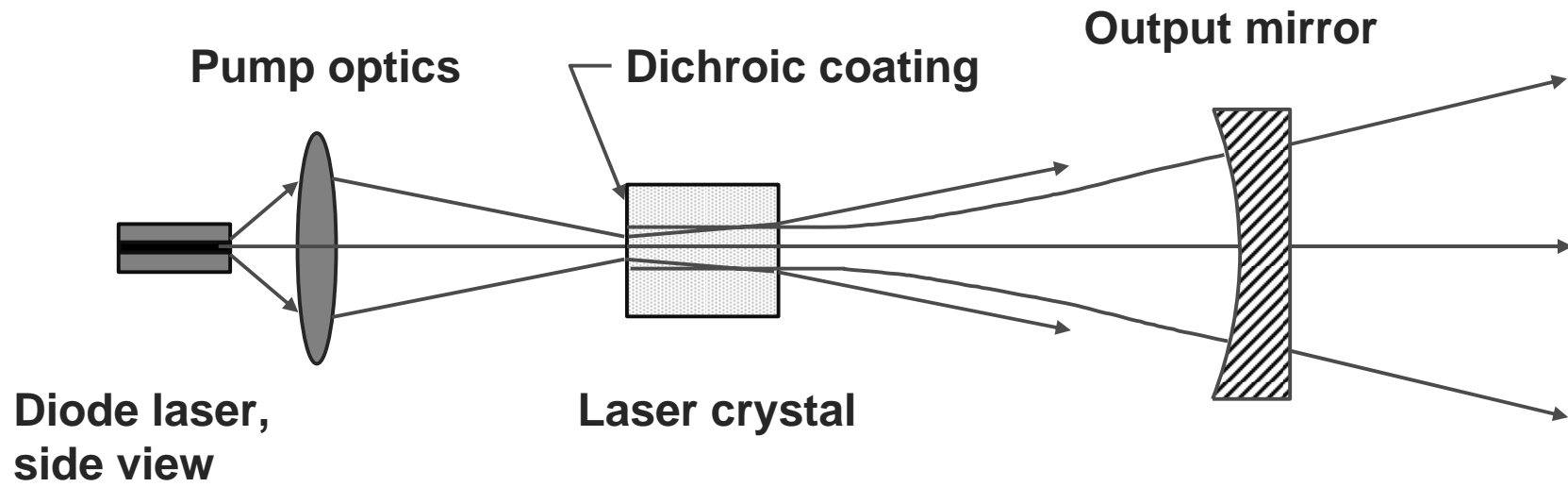
n High-power, bar-pumped cw lasers

- **1.6 W, 523-nm doubled CW Nd:YLF system**
- **6 W CW Nd:YVO₄ fiber-pumped laser**
- **Microlaser arrays in Nd:YAG, Tm,Ho:YLF and Er:YSGG**
- **4.5 W CW Tm,Ho:YLF laser at 2.06 μm**



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END-PUMPED LASER

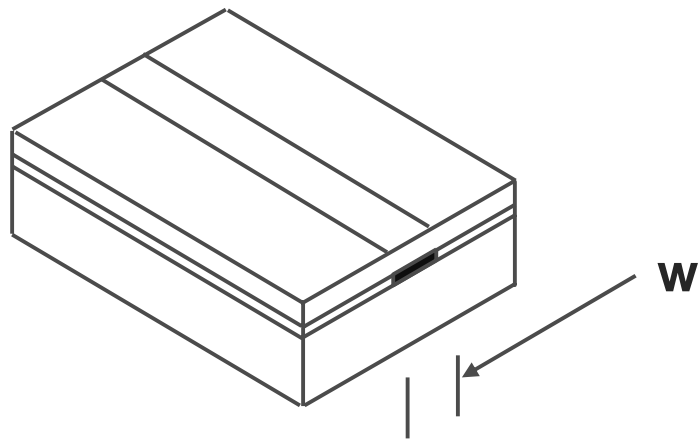




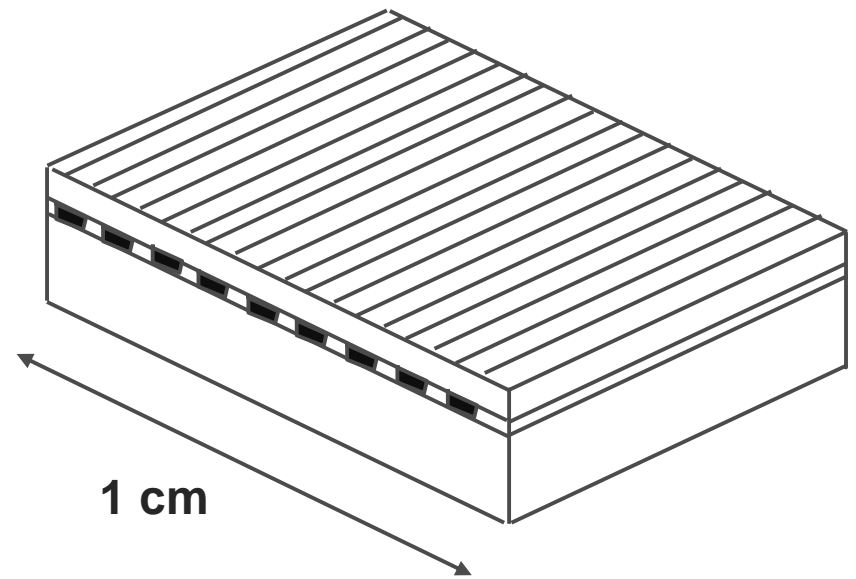
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HIGH-POWER DIODE LASERS ARE AVAILABLE IN SINGLE APERTURE AND LINEAR ARRAYS

Single aperture



Linear array



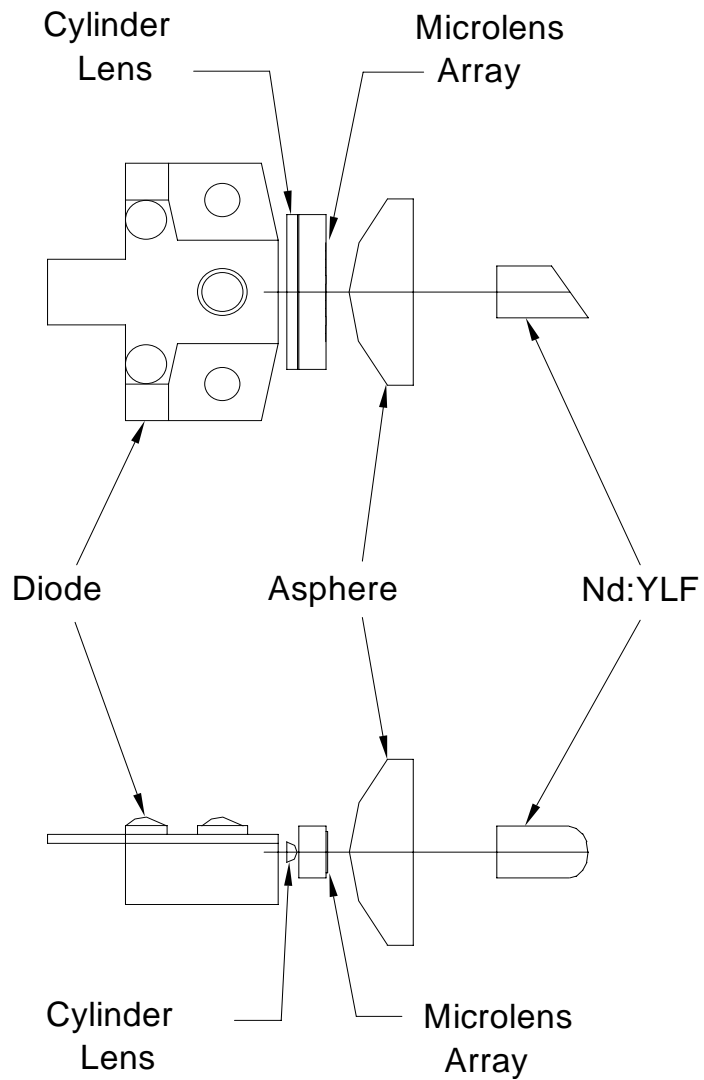
w, Aperture (μm)	Pout (W) 780-
3	0.2
50	0.5
100	1.2
200	2.0
370	3.0
500	4.0

Pout = 5, 10, 15, 20 W

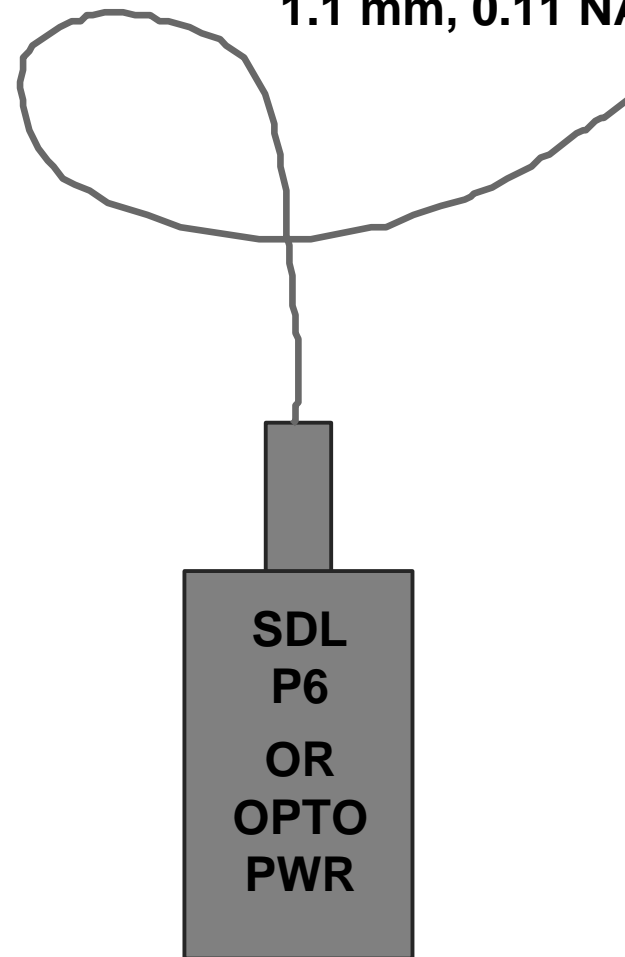


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OPTICS CONVERT LINEAR ARRAYS TO END-PUMPING SOURCES



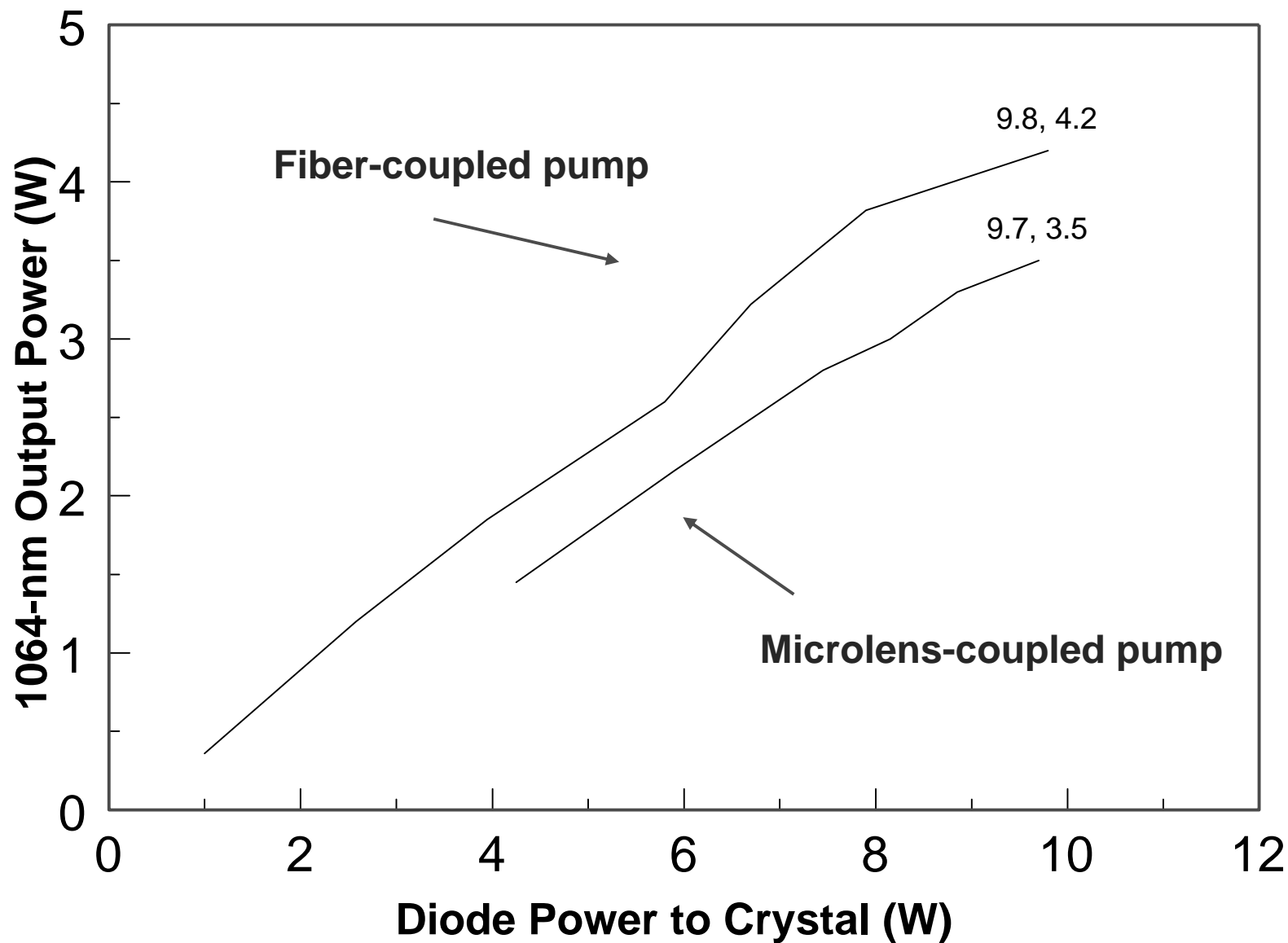
0.5 mm, 0.2 NA (SDL)
1.1 mm, 0.11 NA (OP)





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SEO HAS BUILT EFFICIENT END-PUMPED Nd:YVO₄ LASERS





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SEO SET DESIGN GOALS FOR THE NEXT LEVEL IN HIGH-POWER LASERS

- n **>10 W of power output**
- n **High TEM₀₀ -mode beam quality, $M^2 < 1.2$**
- n **Minimal effect of pump power on beam parameters**
- n **Polarized**
- n **High energies, peak powers in Q-switching**
- n **Low cost**
- n **No external cooling water**



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SEO THEN SET DESIGN APPROACHES

- n **High efficiency in TEM₀₀ mode**
 - **Reduces pump-power requirements, cost**

- n **Simple optics for coupling bars to laser crystal**
 - **More reliable**
 - **Lower cost**

- n **High gain**
 - **More tolerant to cavity losses**
 - **Generates short Q-switched pulses**



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THREE LASER HOSTS ARE AVAILABLE

Crystal	Wavelength (nm)	Gain cross section (10 ⁻¹⁹ cm ²)	Lifetime (μs)	Peak absorption (cm ⁻¹)
YAG	1065	3.3	240	10
YLF (π) YLF (σ)	1047 1053	1.9-2.3 π / 1.5	480-520	11
YVO4 (π)	1064	9.8-15.6	97	40

Crystal	Thermal conductivity (W/m K)	Expansion coeff. (10 ⁻⁶)	Thermal shock (W/m)	dn/dT (10 ⁻⁶)	Lensing
YAG	13	6.7	1450	+7.3	moderate
YLF	5.8 (c) 7.2 (a)	8 (c) 13(a)	240	-4.3 (e) -2.0 (o)	weak
YVO4	5.2	7.3 (a) ?? (c)	?	+2.9 (e) +8.5 (o)	strong



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SEO CHOSE YLF AS THE LASER CRYSTAL

Advantages

- **Weak thermal lensing reduces connection between beam properties and pump power**
- **Natural birefringence eliminates depolarization from stress-induced birefringence**
- **Long lifetime maximizes energy in Q-switched pulse**

Challenge

- **Fracture a greater concern than with YAG**



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SEO HAS DEVELOPED A SIDE-PUMPED, MULTIPASS GAIN ELEMENT

**Nd:YLF right parallelepiped, transversely pumped
by a pair of 20-W diode-laser bars.**

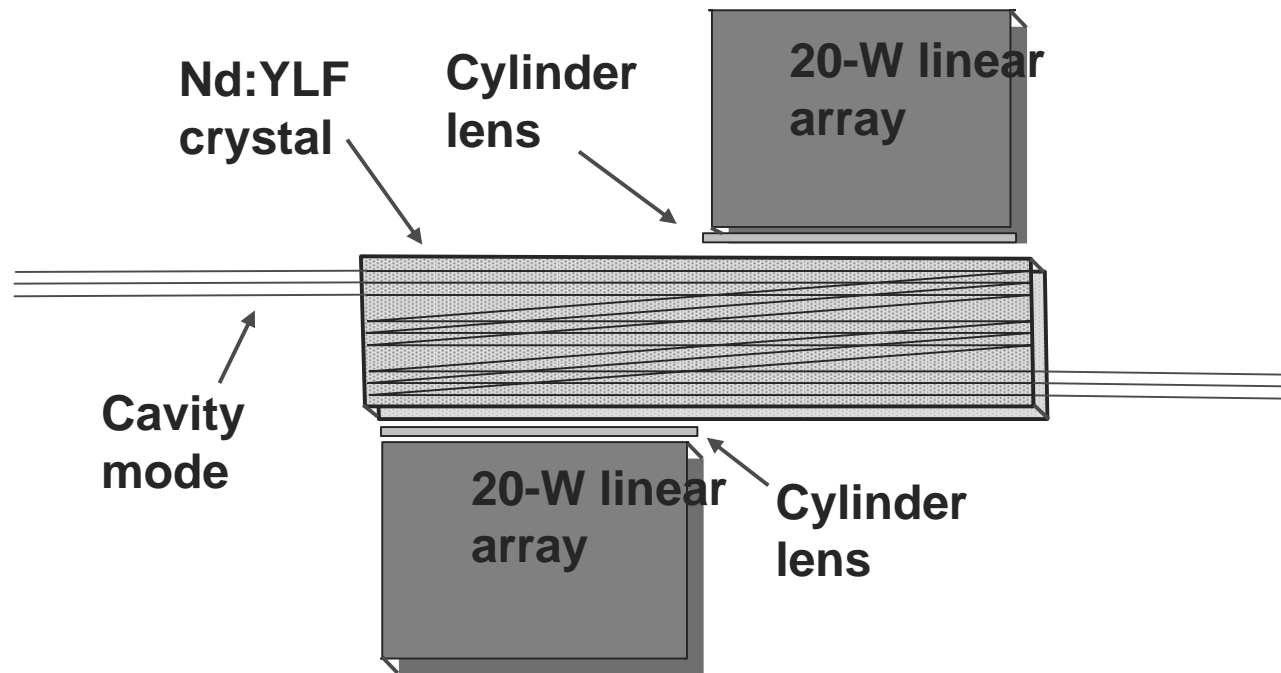
**Bars (coupled through fiber lenses) to establish
planar gain region.**

**Segmented coatings or external mirrors for multiple
passes through gain region.**

**1047 nm, linear polarization (c-axis perpendicular to
plane of propagation)**



MULTI-PASS SLAB DESIGN IS SIMPLE

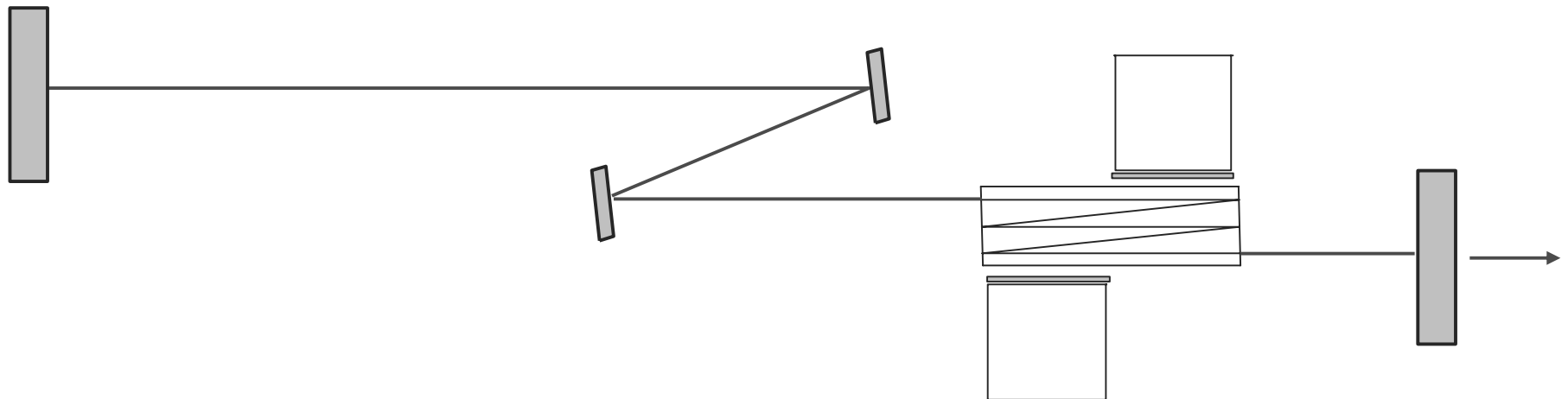


- | Multi-pass design extracts large fraction of available power in TEM₀₀ mode, has high gain
- | Low average excitation density minimizes stress, beam distortion
- | Simple, single-element pump optics



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CAVITY DESIGN FILLS GAIN REGION WITH TEM₀₀ MODE

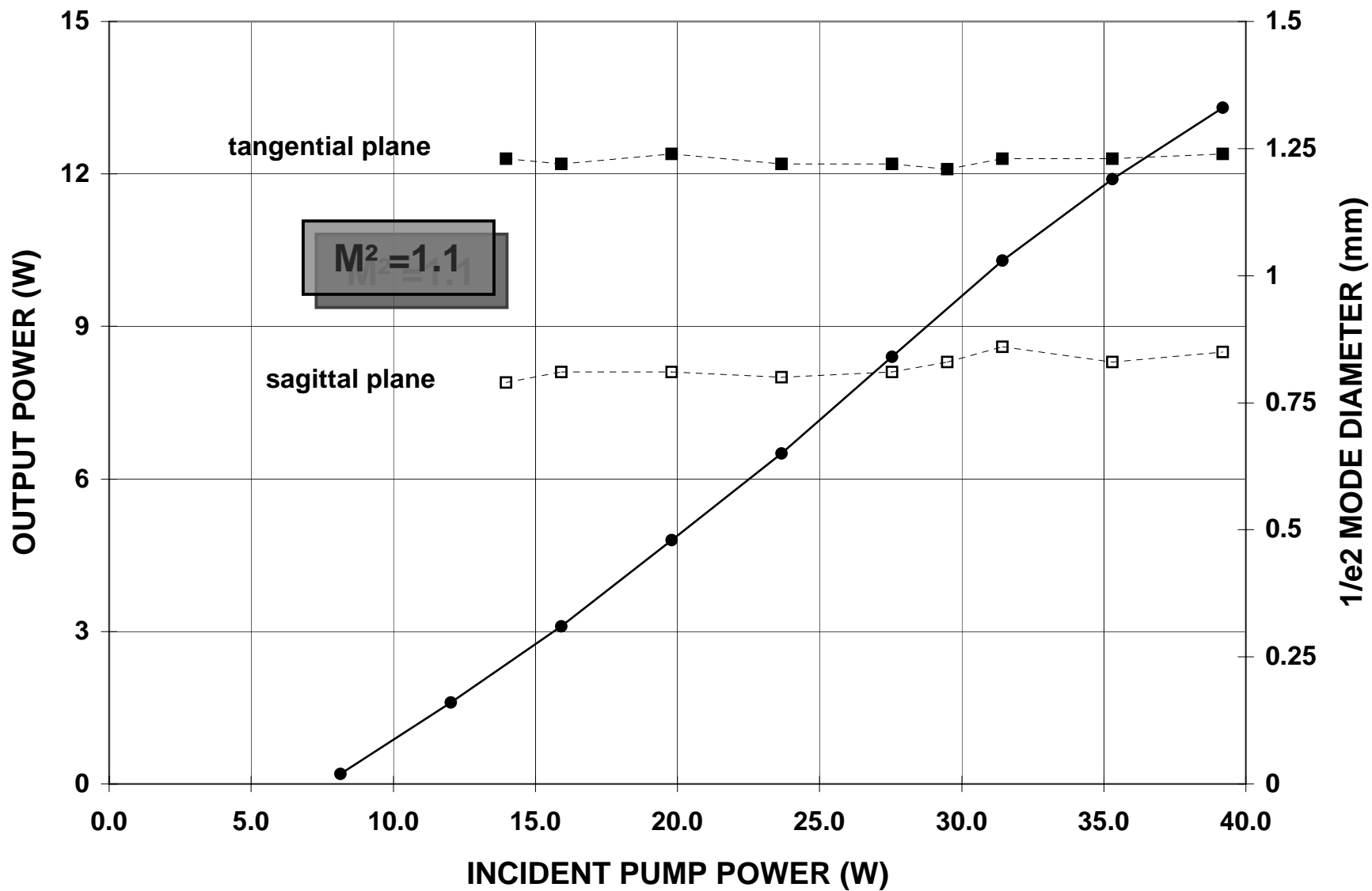


50% R
Output
mirror



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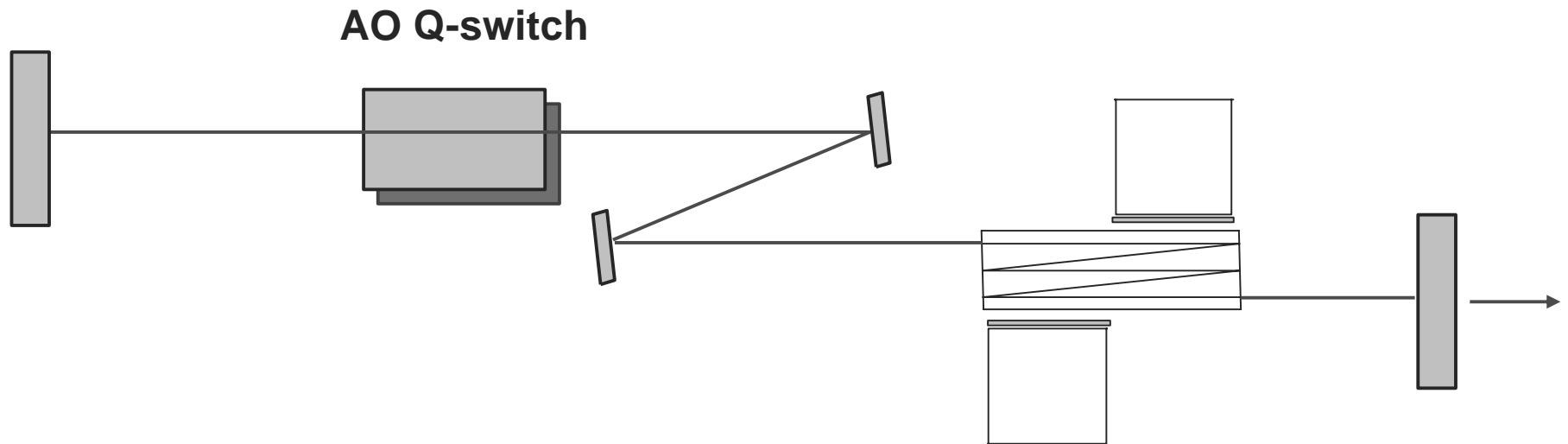
LASER OUTPUT EXCEEDS 10 W IN A HIGH-QUALITY BEAM





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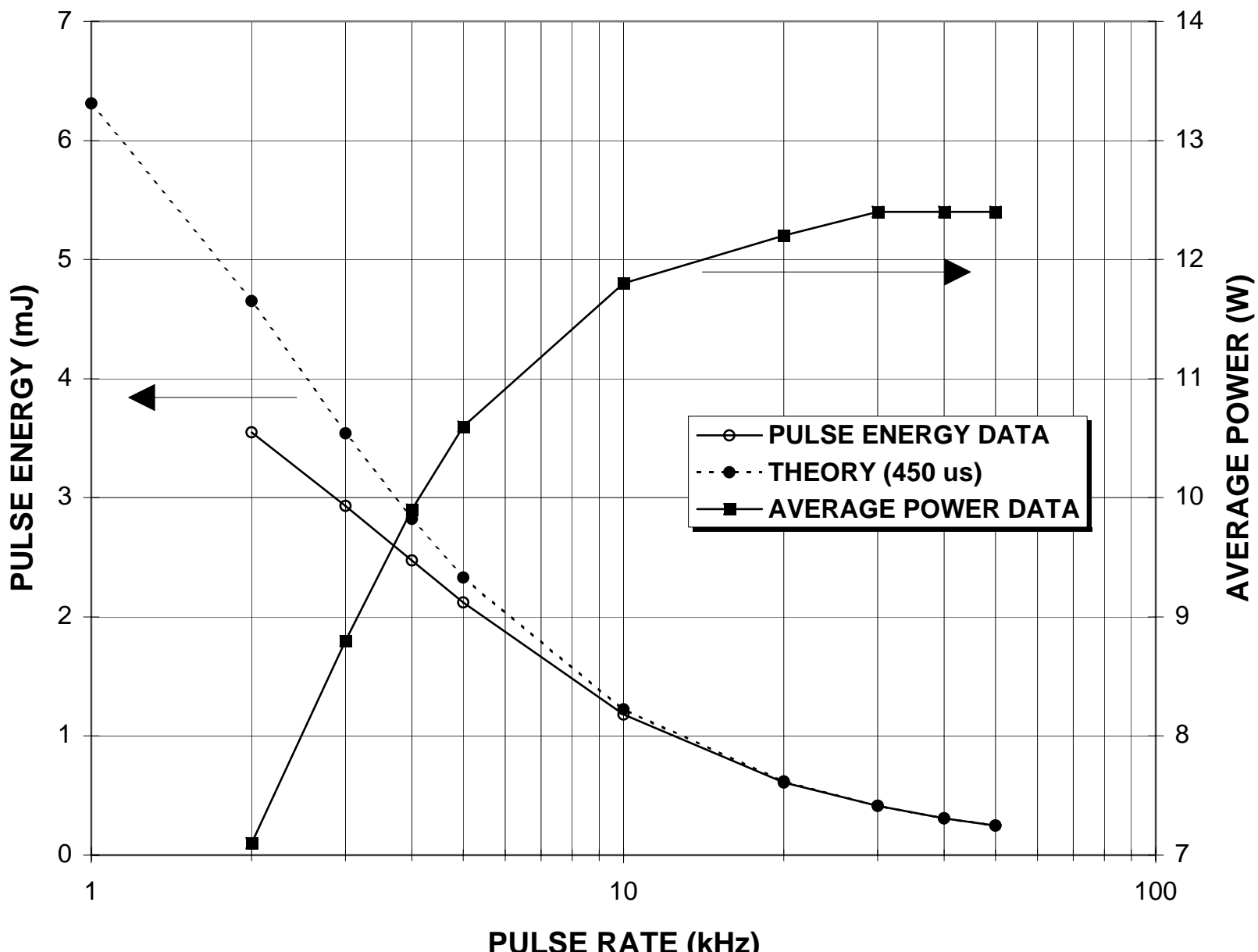
AN ACOUSTO-OPTIC Q-SWITCH CAN BE ADDED TO THE SYSTEM





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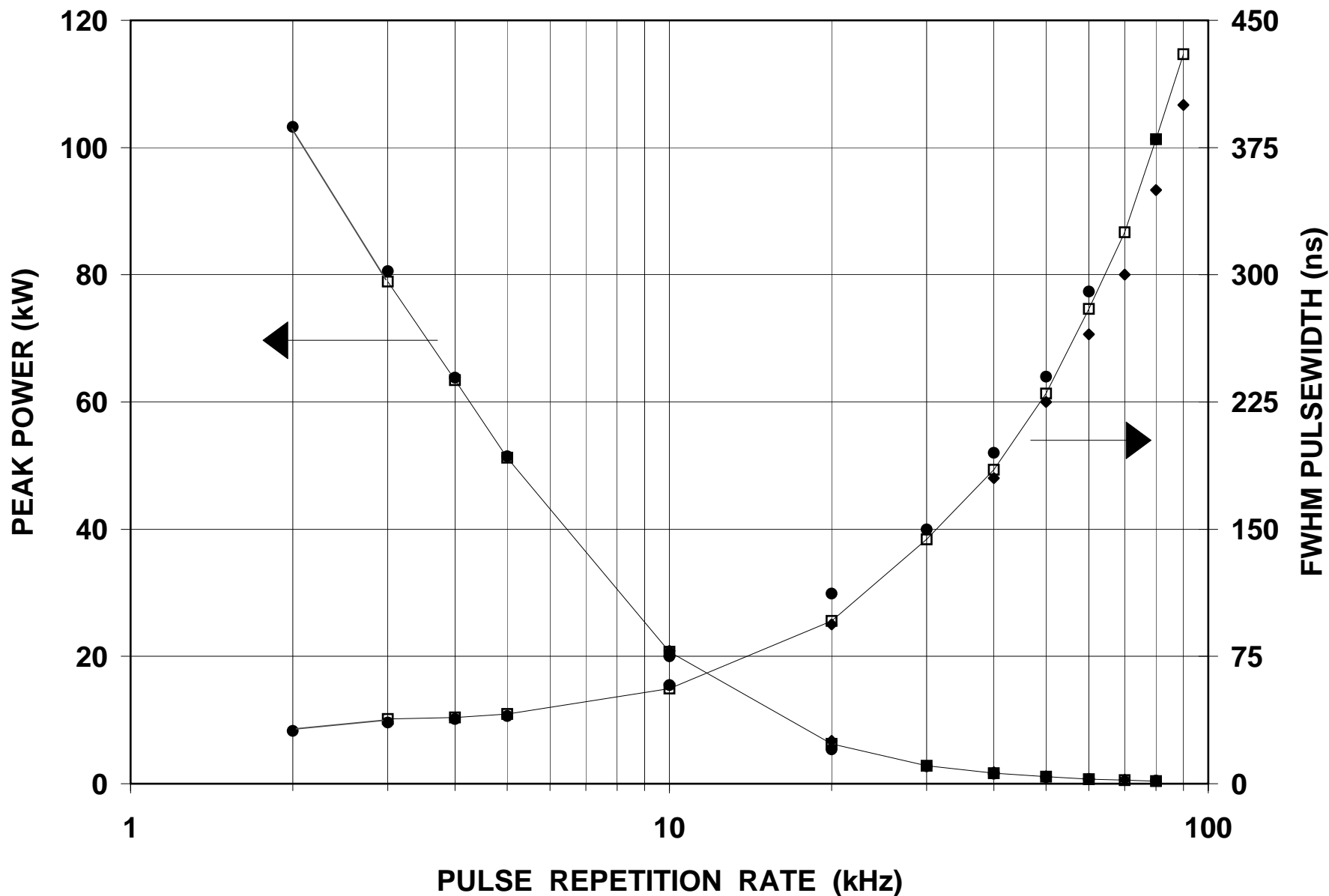
Q-SWITCHING PRODUCES >3 mJ PULES AT 2 kHz, >10 W AVERAGE POWER





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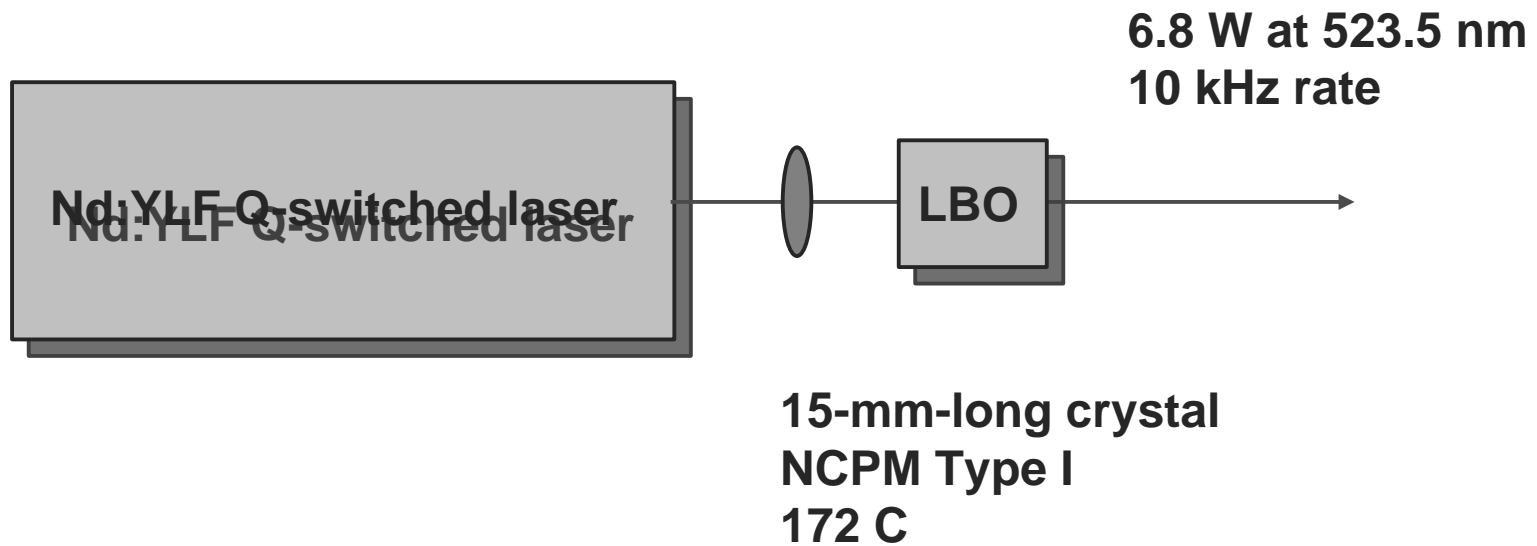
Q-SWITCHING GENERATES 100 kW OF PEAK POWER, < 40 ns PULSEWIDTH





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EXTERNAL DOUBLING OF Q-SWITCHED LASER PRODUCES 6.8 W AVERAGE POWER





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SUMMARY OF LASER PERFORMANCE

Typical performance (5-pass, 1047 nm): 13 W, $M^2 = 1.1$.

70% of theoretical slope efficiency with $M^2 < 1.2$.

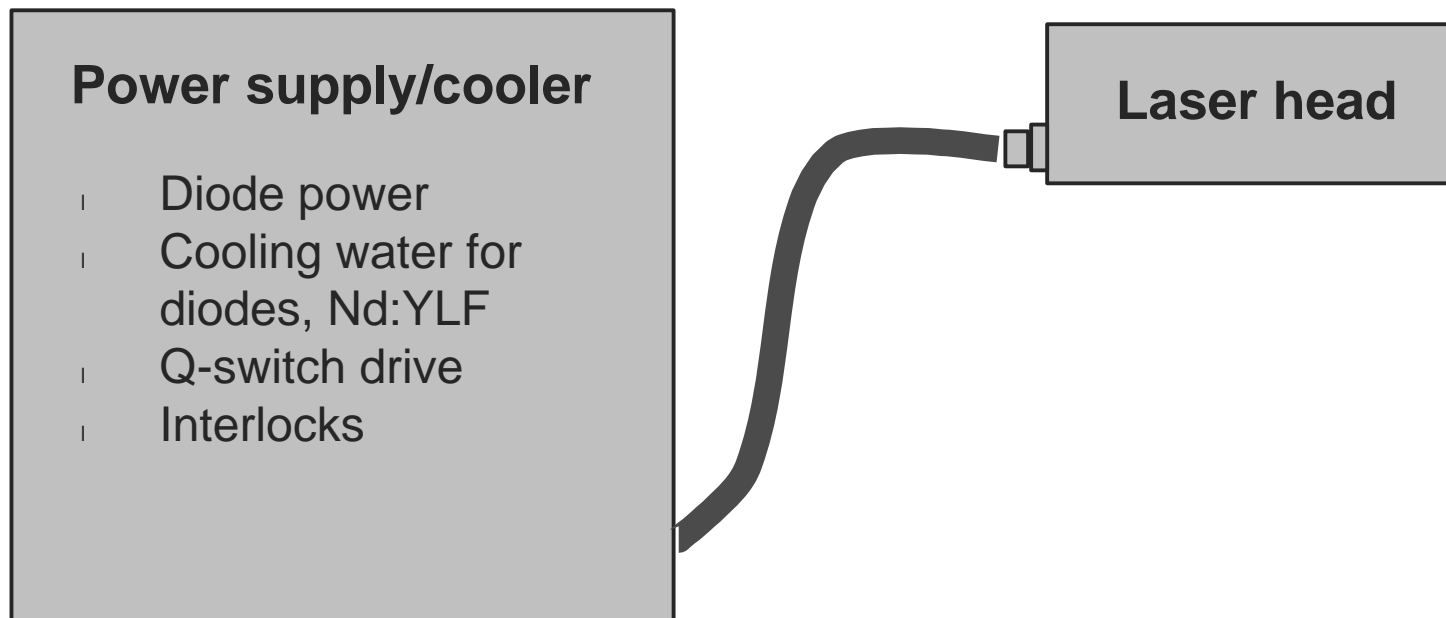
>3 mJ (>100 kW) Q-switched at 2 kHz.

SHG demonstration (523.5 nm): 6.8 W (61%) at 10 kHz.



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SEO HAS DEVELOPED A POWER SUPPLY/ COOLING SYSTEM FOR LASER HEAD





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DESIGN GOALS FOR POWER SUPPLY/COOLER

- n **Reliable**
No mechanical refrigerator

- n **Compact**

- n **Universal-voltage operation**

- n **Constant-temperature cooling**
Maintain stable operating point for laser



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SEO USES SWITCHING POWER SUPPLIES AND THERMOELECTRIC COOLING

- n **Switching power supplies**
 - **Universal power (90-250 VAC, 47-63 Hz)**
 - **Power-factor corrected**
 - **Lightweight**
- n **Thermoelectric coolers for water**
 - **Solid state, no compressor**
 - **Excellent water temperature control, no cycling**
 - **Hot side of thermoelectric cooler is forced-air cooled**
- n **DC motor on water pump, cooling fans**
 - **Powered by switching supply**



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PRODUCT SPECIFICATIONS

MPS-1047 Laser Head

- CW power output : > 10 W
- Mode: TEM₀₀ , M² < 1.2
- Wavelength: 1047 nm
- Linear polarization: > 100:1

SSC-40 Controller

- Operating voltage: 90-235 VAC at 47-63 Hz
- Power consumption: 1 kW for 25 C ambient

MPS-1047Q Laser Head

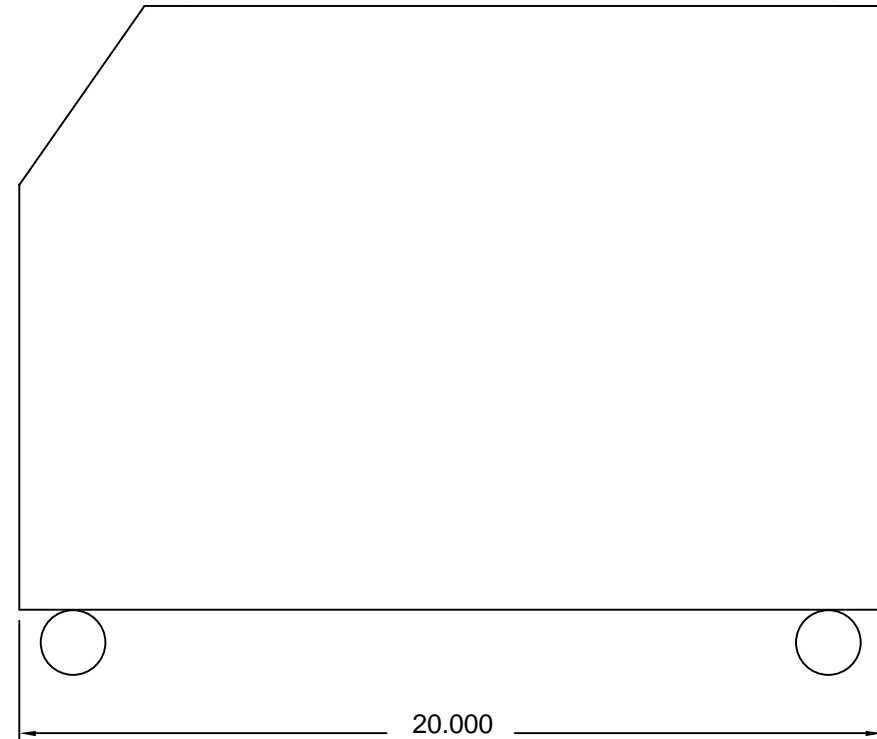
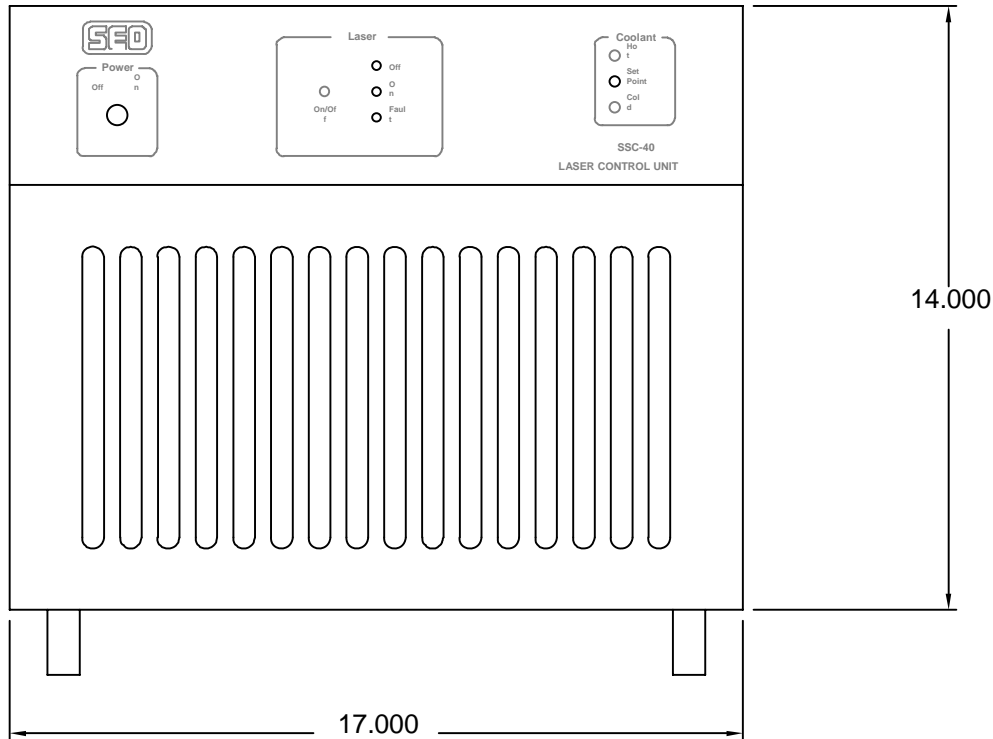
- Pulse rate: 2 - 100 kHz
- Pulse energy:
 - > 3 mJ at 2 kHz
 - > 1 mJ at 10 kHz
- Pulseswidth:
 - < 40 ns at 2 kHz
 - < 75 ns at 10 kHz

Note: Specifications subject to change without notice



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DRAWING OF SSC-40 CONTROLLER/COOLER



Dimensions in inches
Specifications subject to change without notice



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OEM VERSIONS

SEO will be happy to discuss custom versions of this laser systems and other diode-pumped lasers in general with interested customers. Please contact us with your requirements.