
High Average Power, High Repetition Rate Nd:YVO₄ MOPA Laser System

CLEO '99 Postdeadline Paper CDP-1

Kevin J. Snell, Dicky Lee, Jeffery G. Manni*

Q-Peak, Incorporated
135 South Road
Bedford, MA 01730
Tel: (781) 275-9535
www.qpeak.com

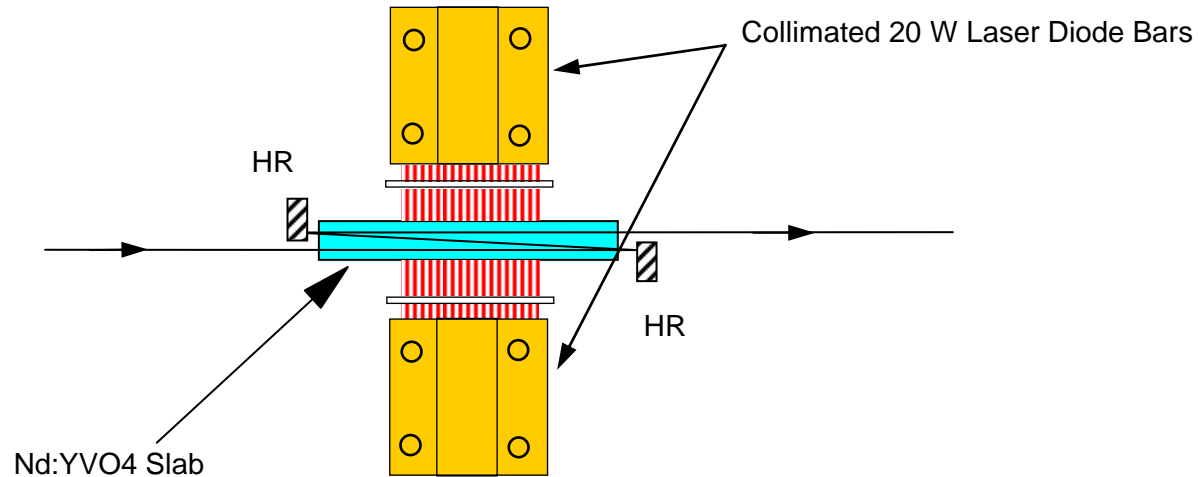
*JGM Associates Inc., 5 New England Executive Park, Suite 400,
Burlington, MA 01803



Introduction

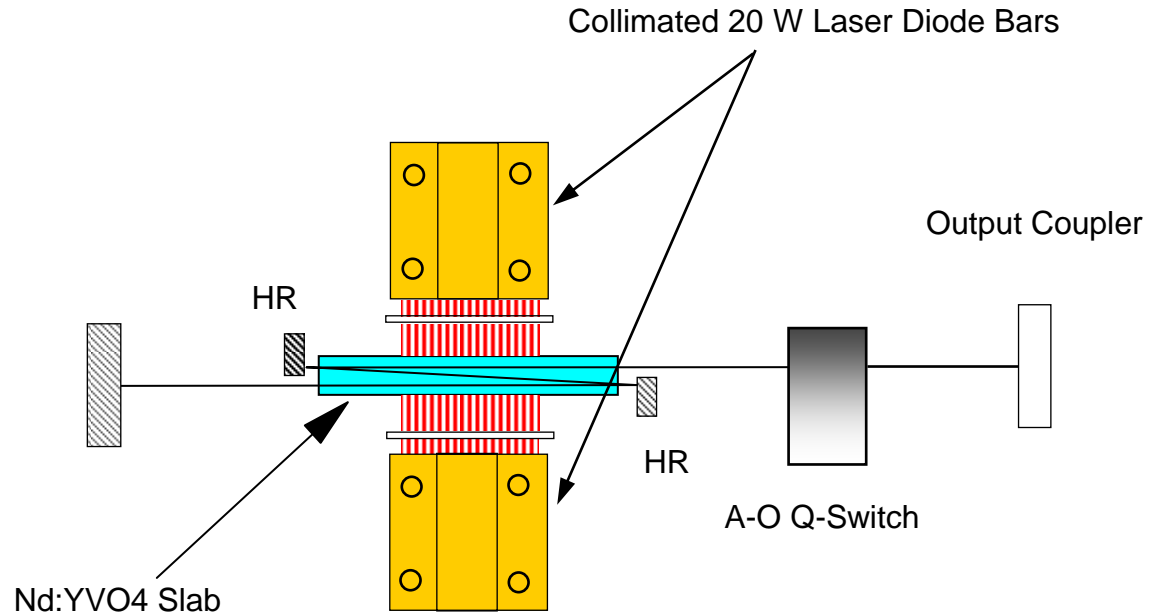
- Need high average power and high repetition rates with high brightness for efficient frequency conversion to other wavelengths.
 - Near-IR (1.5-2 μm) and Mid-IR (3-5 μm) for remote sensing.
 - Visible sources for displays and medical applications.
 - UV sources for materials processing and stereolithography.
- Nd:YVO₄ has a high emission cross-section (3-5 x Nd:YAG) short fluorescence lifetime for high peak power, high repetition rate operation.
- Excellent 1.34 μm performance due to high cross-section; 50% of 1.06 μm performance can be achieved.
- Natural birefringence eliminates depolarization from stress-induced birefringence.
- Strong thermal lensing makes efficient TEM₀₀ mode extraction difficult.

Nd:YVO₄ Gain Module



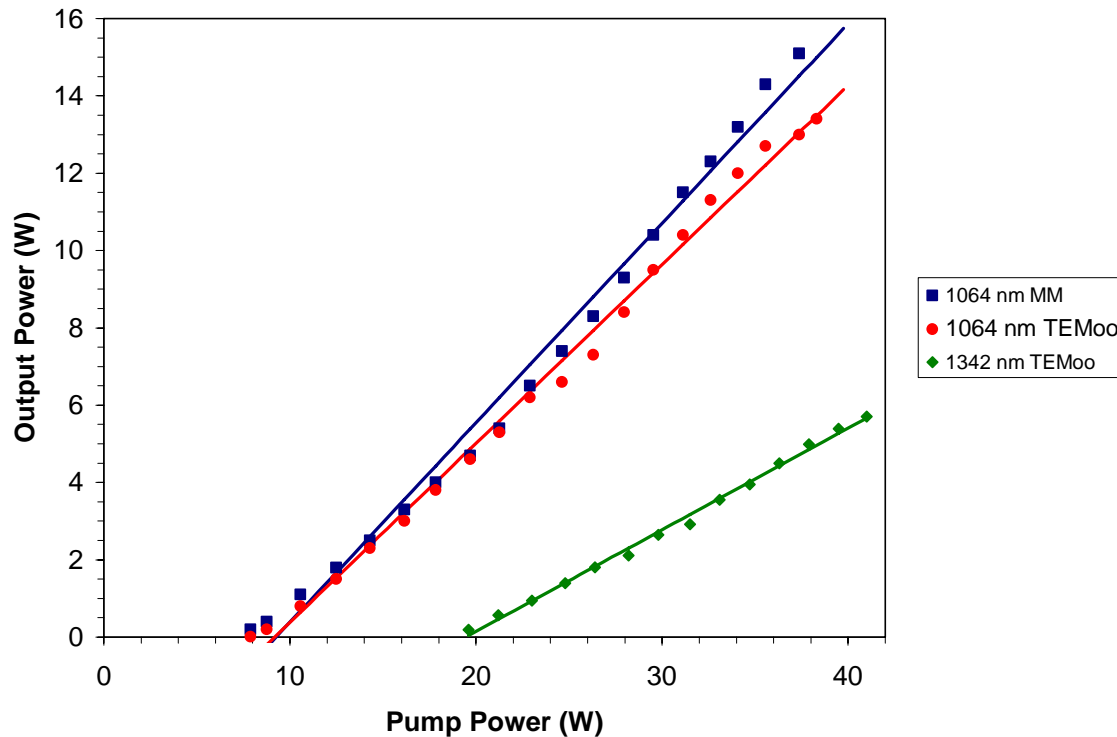
- ❑ Patented, side-pumped, multi-pass slab technology for efficient TEM₀₀ mode extraction.
- ❑ Can be used either as an oscillator or power amplifier for scaling power output.
- ❑ Simple, low cost collimated diode laser bar pump source.

Nd:YVO₄ Slab Master Oscillator



- Convex cylindrical HR, Plane Output Coupler, A-O Q-Switch.
- Same design for both 1064 nm and 1342 nm.

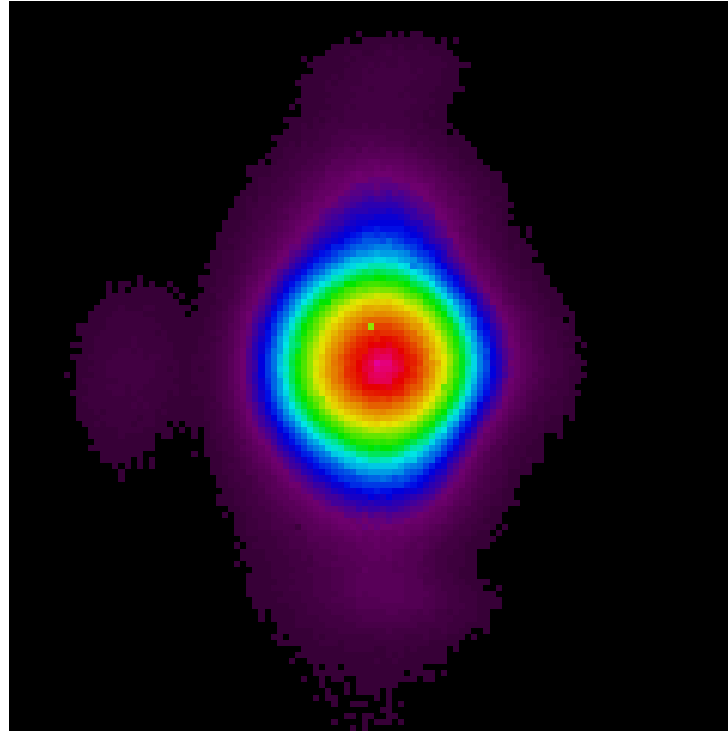
Nd:YVO₄ Slab Oscillator CW Efficiency



□ 1064 nm, >15 W multimode, >13 W TEM₀₀, 46.3% slope, 35.0% optical and 13% electrical efficiency.

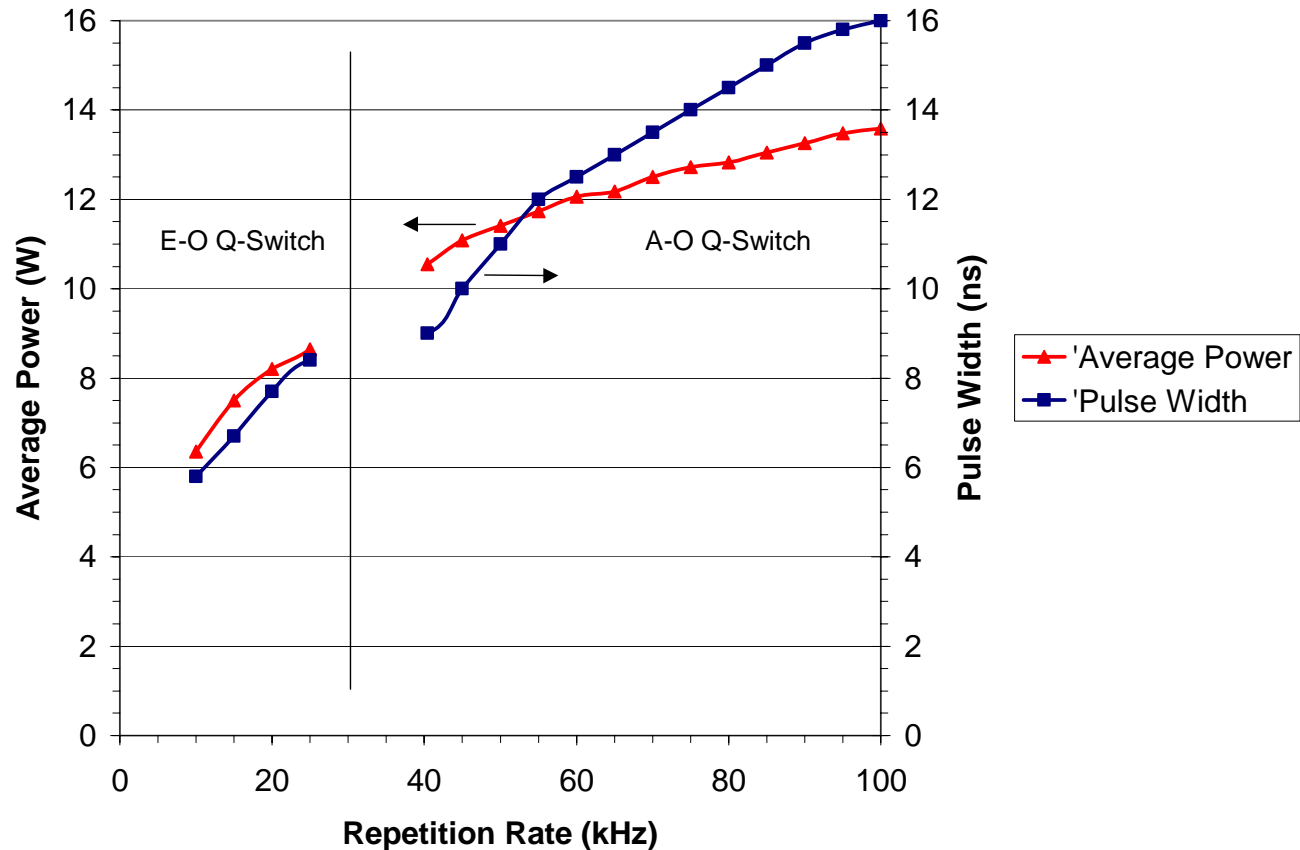
□ 1342 nm, >6 W TEM₀₀, 26% slope, 15% optical and 6% electrical efficiency.

1064 nm Nd:YVO₄ Slab Master Oscillator Beam Profile



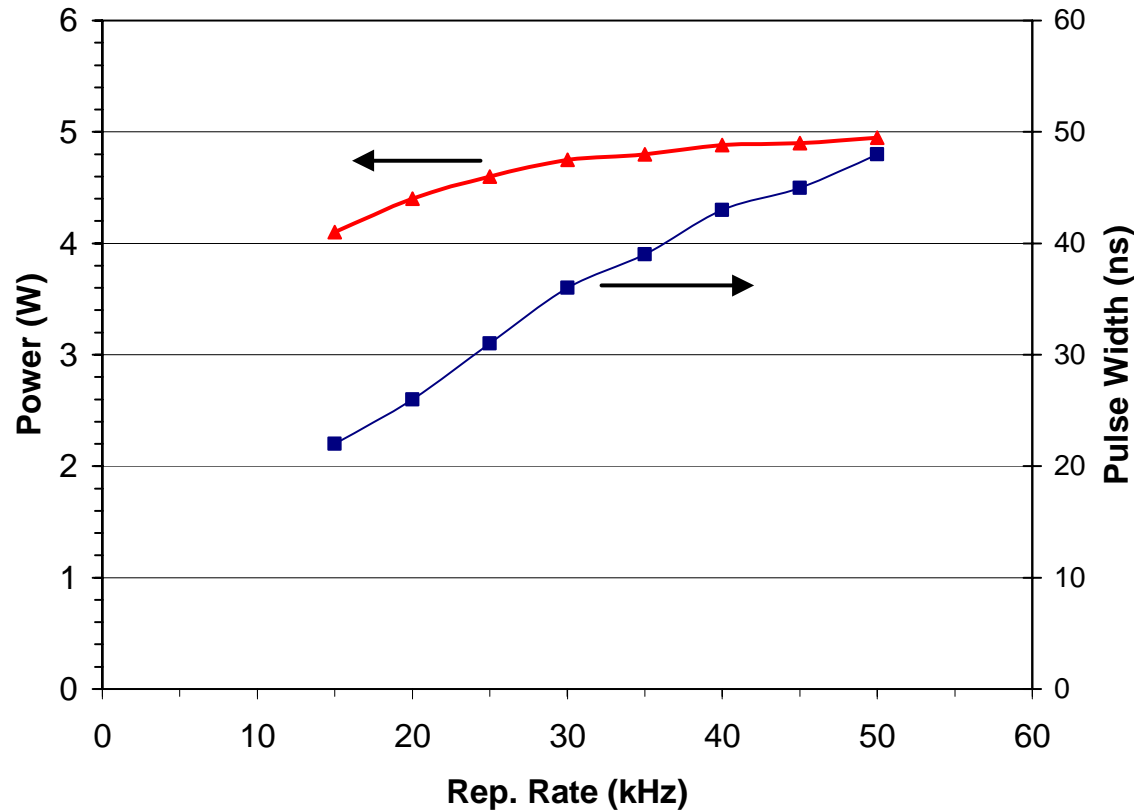
- TEM₀₀ mode operation from 7 to >13 W (full power).
- $M^2_v < 1.1$, $M^2_h < 1.2$, beam diameter 0.5 mm (v) × 0.8 mm (h).

1064 nm Nd:YVO₄ Oscillator Q-Switched Performance



□ >11.4 W average @ 50 kHz (>0.22 mJ/pulse), <11 ns pulse width (20 kW peak).

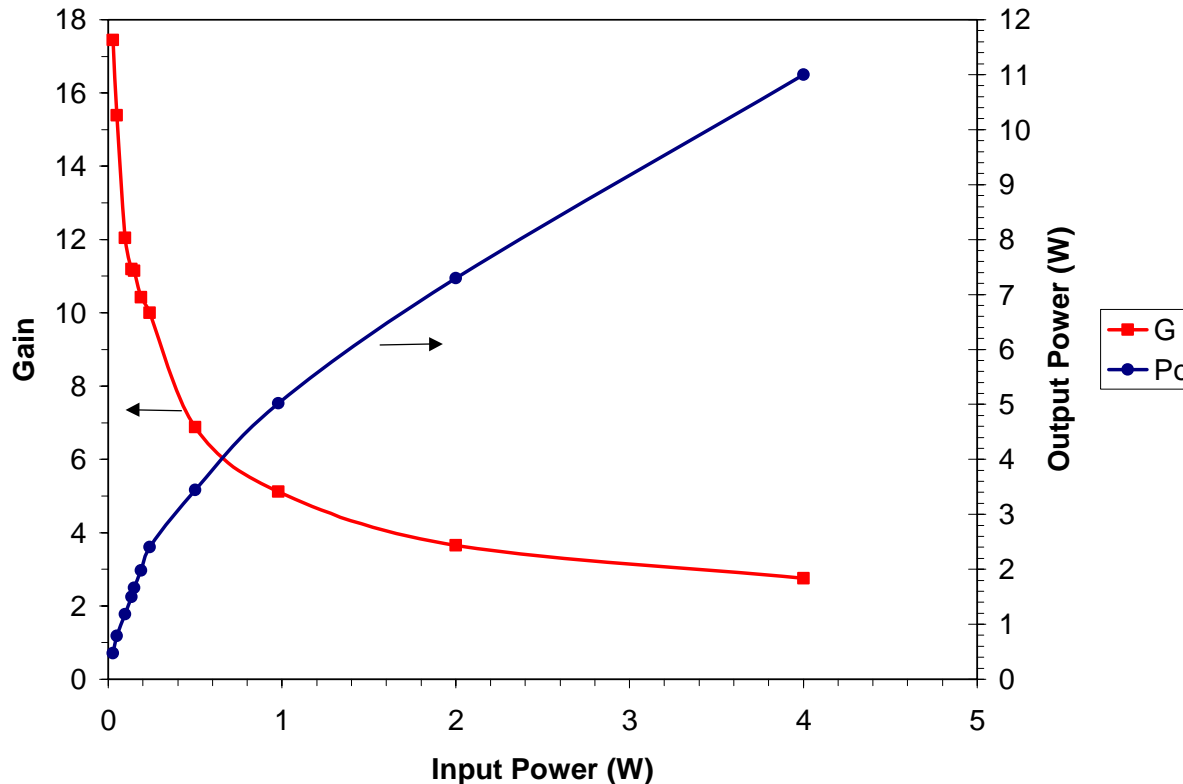
1342 nm Nd:YVO₄ Oscillator Q-Switched Performance



- >5.0 W Average power @ 25 kHz (0.2 mJ/pulse), < 28 ns pulse width (7.1 kW peak).

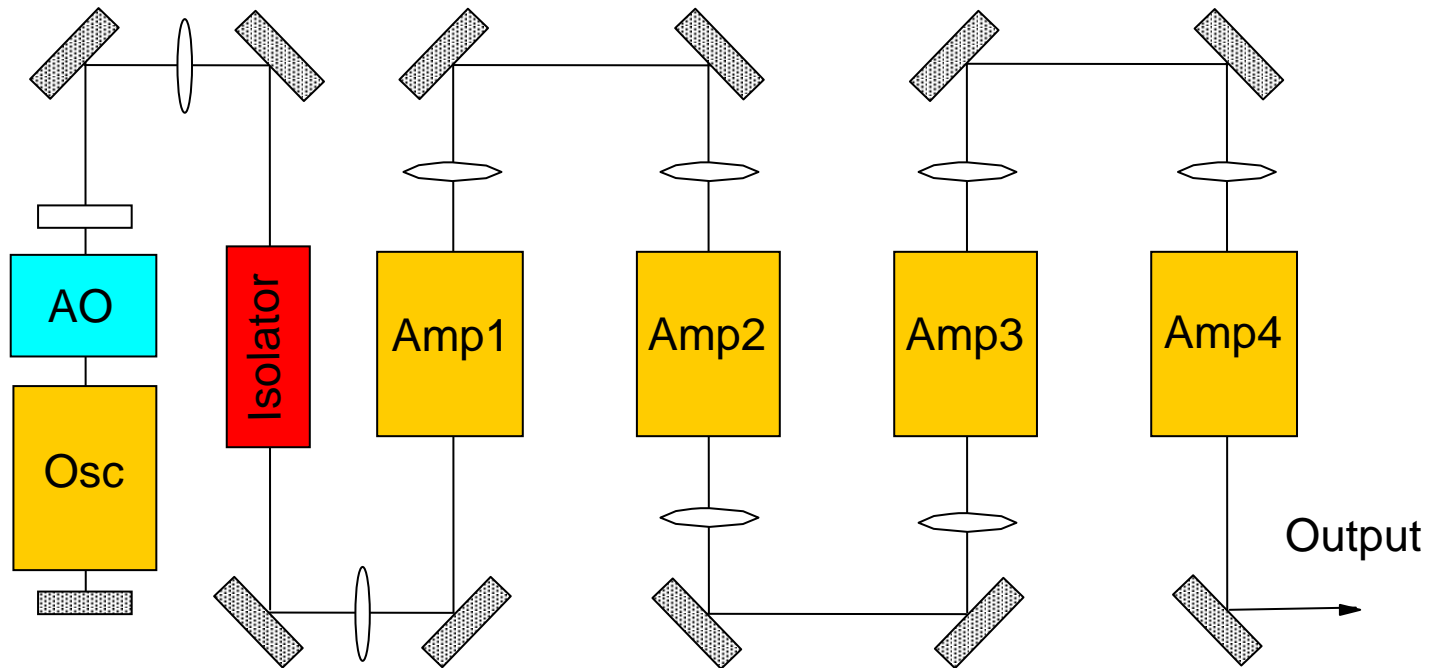


Nd:YVO₄ Slab CW Amplifier Performance



- Gain of 17 with 27 mW input at a pump power of 38.7 W. 3-pass small signal gain of 24 based on single-pass measurements.
- Extraction of 11.0 W CW with 4.4 W signal in (15.4 W out), 10.4 W Q-switched with 4.0 W signal in at 50 kHz (14.4 W out).

Nd:YVO₄ Slab MOPA System



- 5 Gain Modules; 1 Oscillator, 4 Power Amplifiers. Same design for both 1064 nm and 1342 nm.
- Relay-imaged between master oscillator and amplifiers to preserve optimum beam size throughout the MOPA chain.

Nd:YVO₄ MOPA Results

1064 nm

- Outputs CW/Q-Switched @ 50 kHz

Oscillator: 11.4 W / 10.5 W, 10 ns FWHM

Output: 53.5 W / 50.7 W, 10 ns FWHM, 1.01 mJ/pulse
101.4 kW Peak

- 200 W pump power → >25% optical, >10% electrical efficiency.

1342 nm

- Outputs CW/Q-switched @ 25 kHz

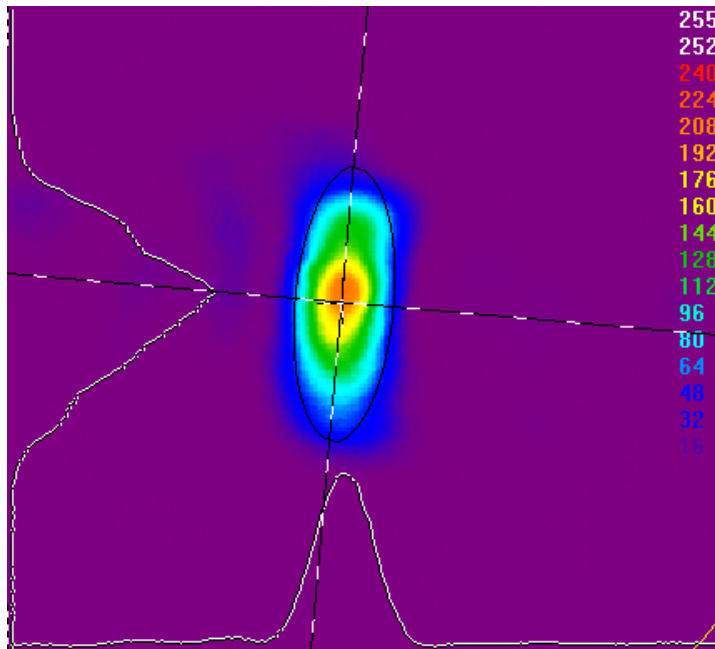
Oscillator: 7.0 W / 6.3 W, 28 ns FWHM

Output: 24.5 W / 22.0 W, 28 ns FWHM, 0.88 mJ/pulse
31.4 kW Peak

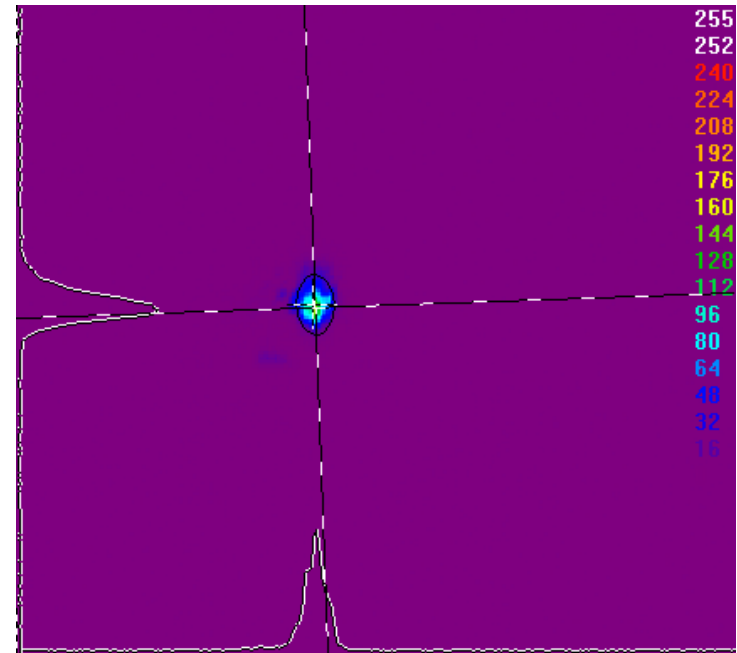
200 W pump power → 12% optical, 5% electrical efficiency.

1064 nm MOPA Beam Profiles

Near Field

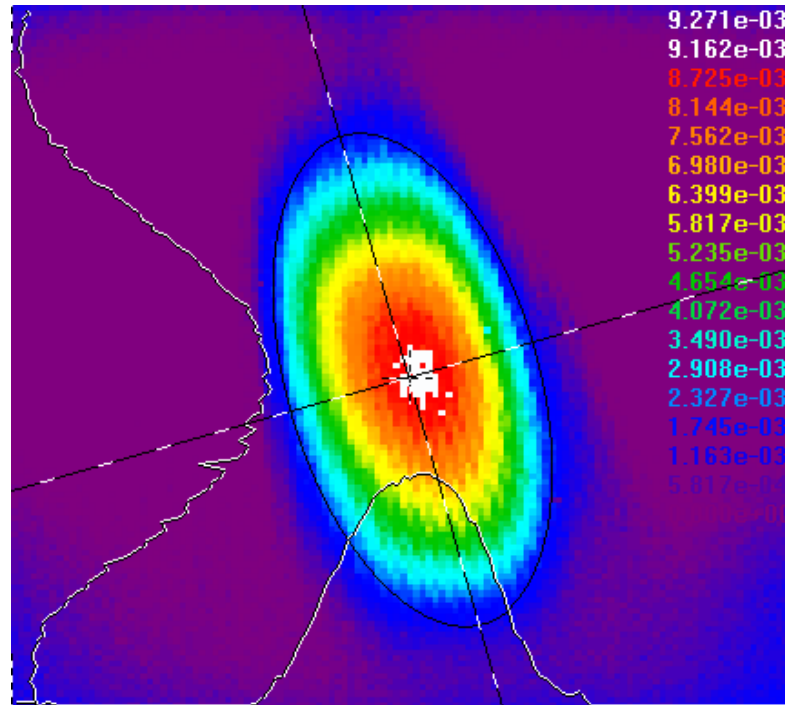


Far Field



- Single-lobed, Gaussian, near diffraction-limited output.
- $M^2_h < 1.7$, $M^2_v < 1.2$

1342 MOPA Near-Field Beam Profile



- Single-lobed, Gaussian, near diffraction-limited output.
- $M^2_h < 1.2$, $M^2_v < 1.2$

Conclusions

- Highest average powers ever achieved in a Nd:YVO₄ laser system:
 - 53.5 W CW, 50.7 W Q-switched at 1064 nm;
 - 24.5 W CW, 23.5 W Q-switched at 1342 nm.
- High peak power/short pulse width Q-switched operation:
 - >100 kW @ 50 kHz, 10 ns FWHM pulse width at 1064 nm;
 - >30 kW @ 25 kHz, 28 ns FWHM pulse width at 1342 nm.
- Near-diffraction limited beam quality:
 - $M^2_h < 1.7$, $M^2_v < 1.2$ at 1064 nm;
 - $M^2_h < 1.2$, $M^2_v < 1.2$ at 1342 nm.
- Ideal source for high repetition rate non-linear frequency generation:
 - 1064 nm SHG efficiency of 60% (30 W, 1064 nm → 18 W, 532 nm);
 - 1342 nm SHG efficiency of 63% (20 W, 1342 nm → 12.6 W, 671 nm).
- Scalable in power from 10-50 W.
- Can be power scaled to 100 W using 40 W pump diode bars.