
400-W Cryo-cooled Yb:YAG Laser with 56% Efficiency

Authors:

Bhabana Pati and Kevin F. Wall

Q-Peak, Inc., 135 South Road, Bedford, MA 01730

www.qpeak.com

Acknowledgments:

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Outline

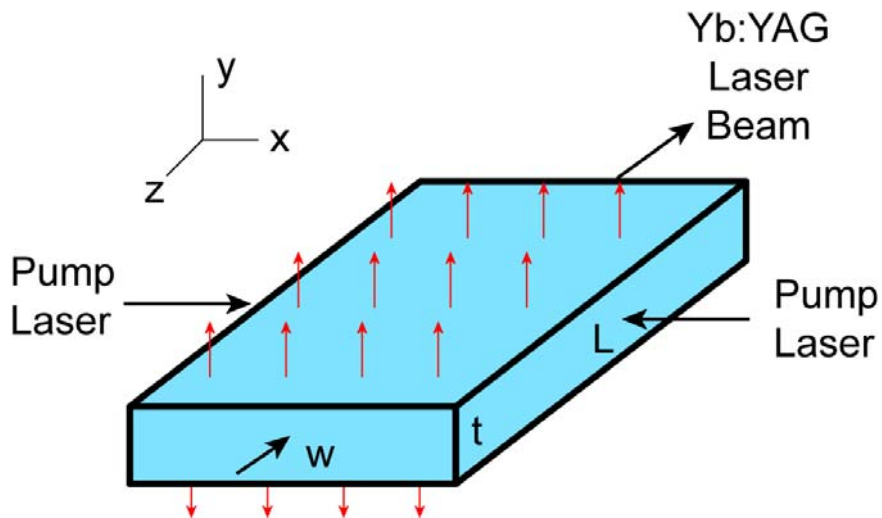
1. Objective
2. Laser performance in a prism-pump design
3. Conclusions and improvements

Objectives

- Build a highly efficient, cryogenically-cooled, Yb:YAG laser at 1030 nm.
- Produce >250 W, Q-switched, TEM₀₀ output power from an side-pumped slab laser.

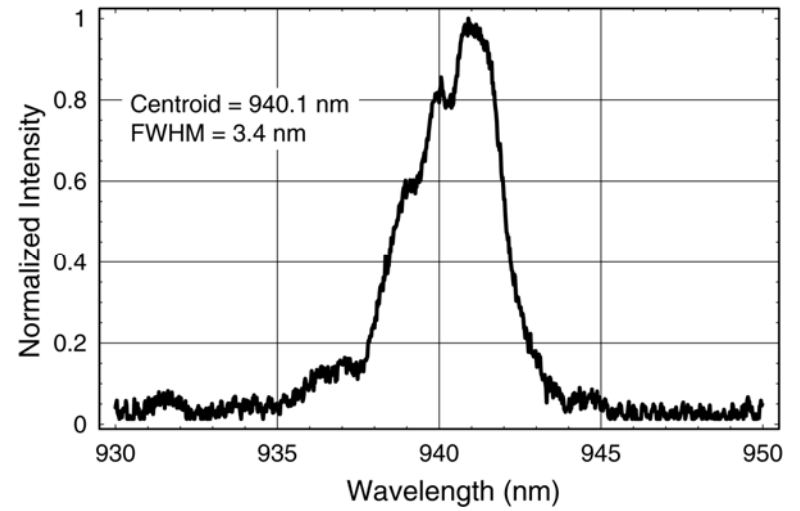
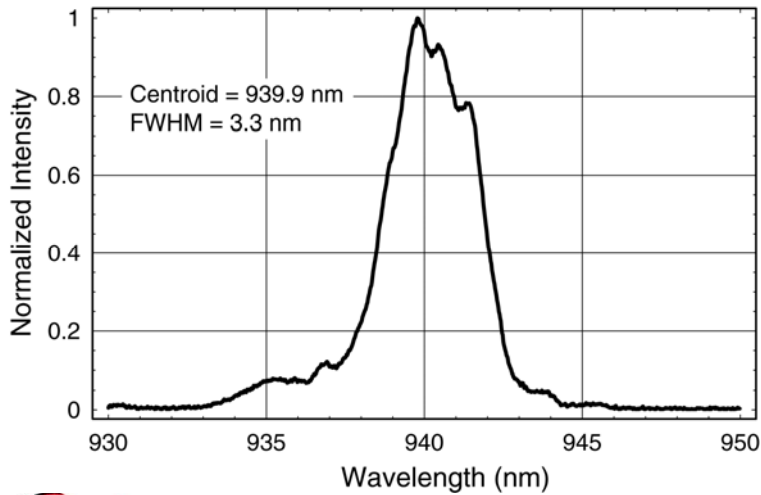
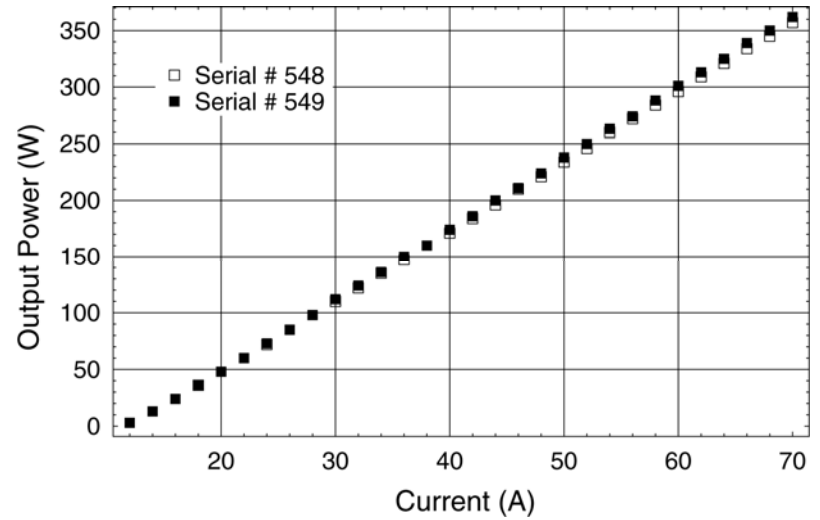
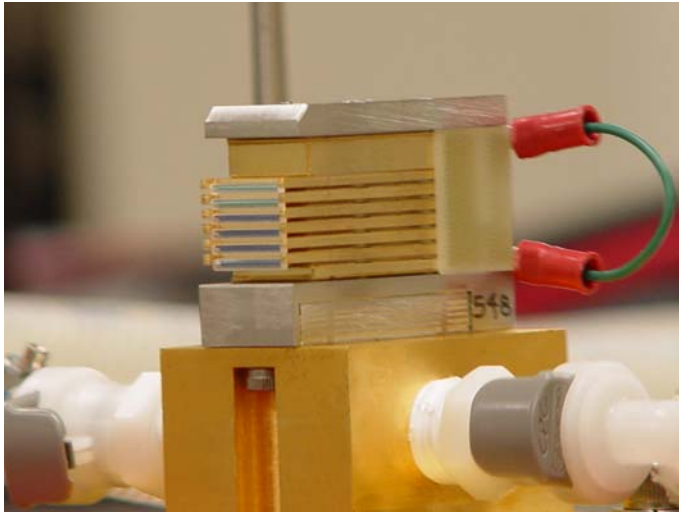
Show MPS design

Specific Yb:YAG design



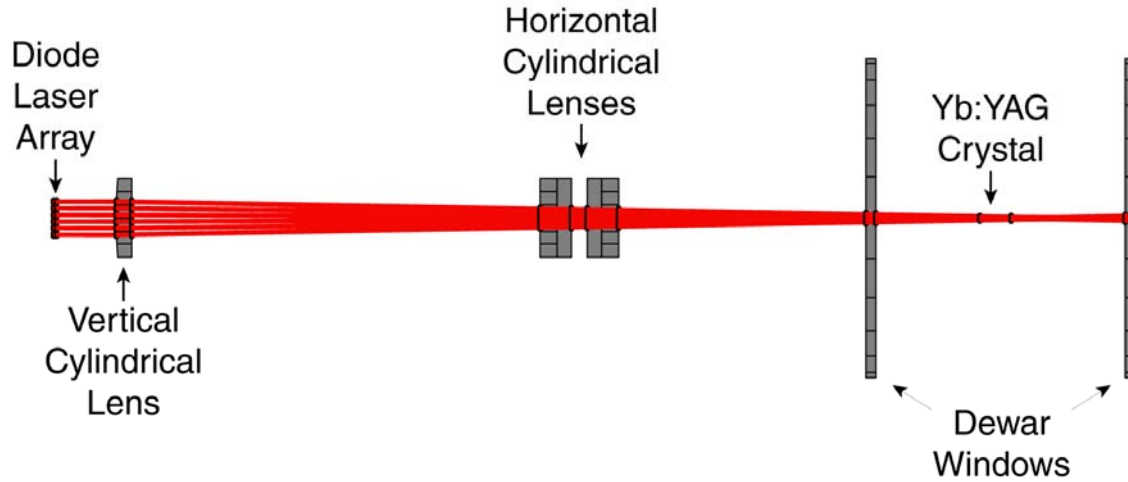
- ❑ Crystal is 2% doped and 28 x 10 x 4 mm in size.
- ❑ Two pump diode lasers are off set on the opposite sides of the slab.
- ❑ Heat is removed from the two large faces of the crystal.

Nuvonyx lensed diode laser arrays are pump sources

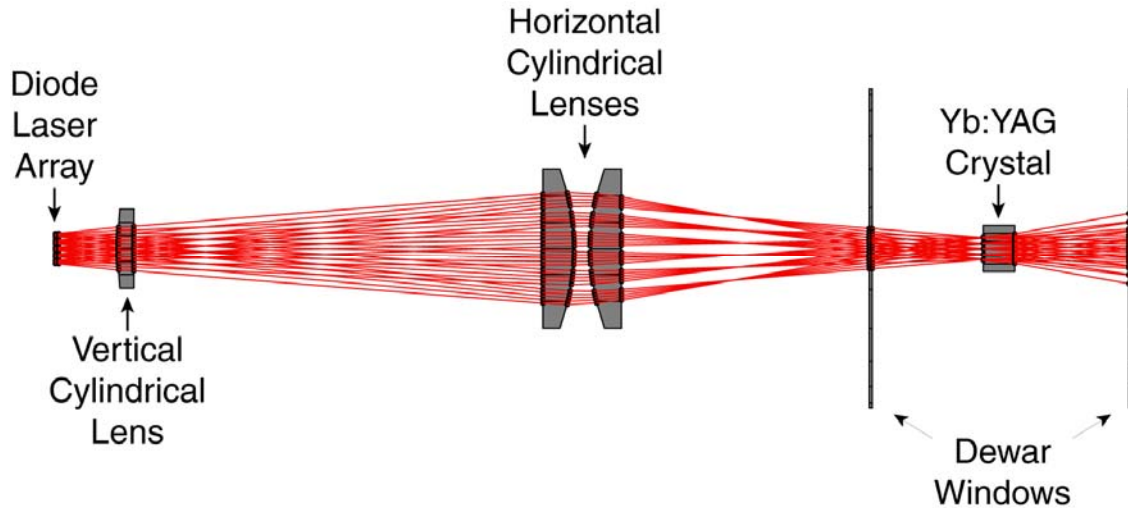


Pump Focusing Design

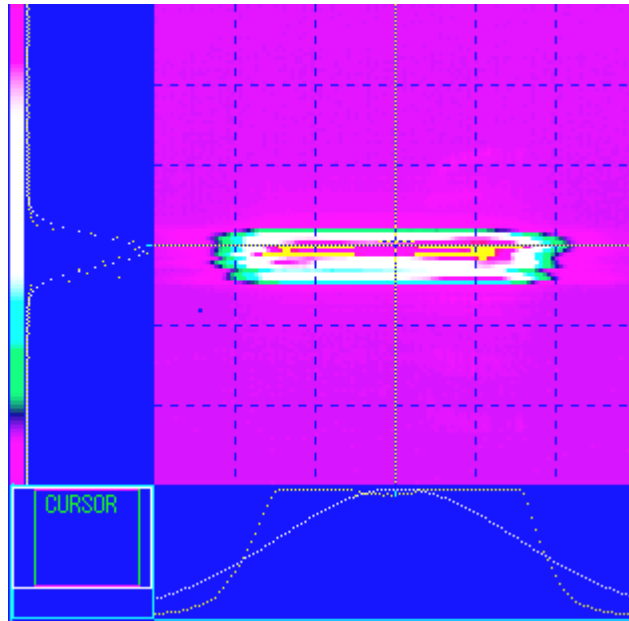
Side view



Top view



Measured pump beam at the crystal



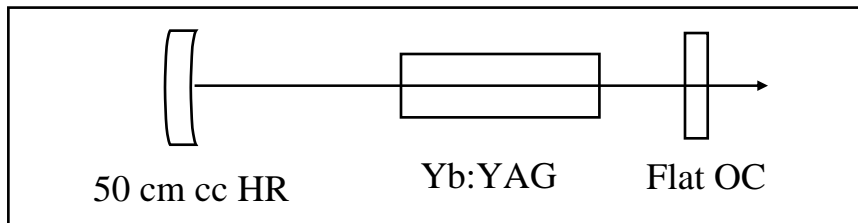
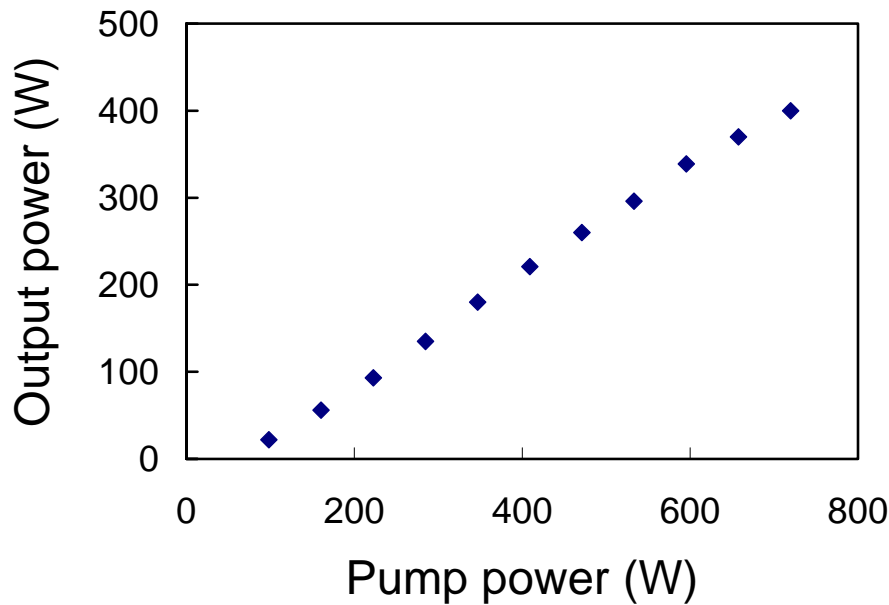
- Imaged at the plane of crystal surface
- Intensity of the beam was reduced by operating the laser in pulse mode
- Beam size 10 X 2 mm
- CCD camera and Spiricon beam analyzer.

Calculated slope efficiency is 61%

| Parameter | Symbol | Value |
|----------------------------|-------------|-------|
| Transfer efficiency | η_t | 0.98 |
| Absorption efficiency | η_a | 0.98 |
| Quantum efficiency | η_{qe} | 1.00 |
| Quantum defect | η_{qd} | 0.91 |
| Overlap efficiency | η_o | 0.80 |
| Storage efficiency | η_{st} | 0.71 |
| Output coupling efficiency | η_{oc} | 0.87 |
| Slope Efficiency | η_{sl} | 0.61 |

- **Output coupling efficiency assumes 3% round-trip losses and R = 80% OC**

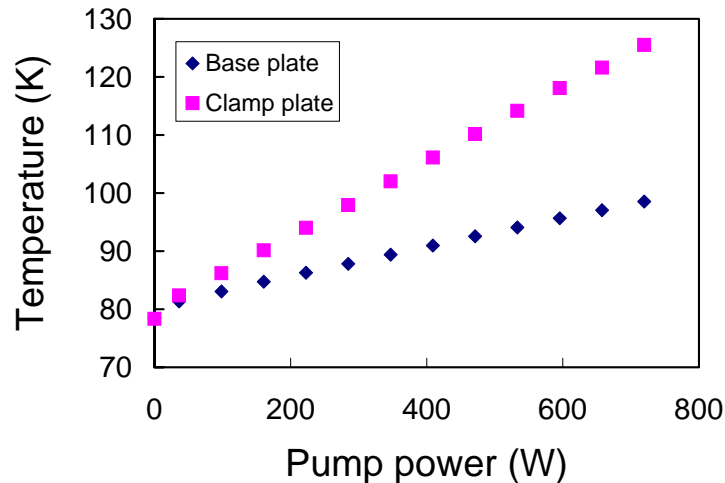
Multimode laser performance



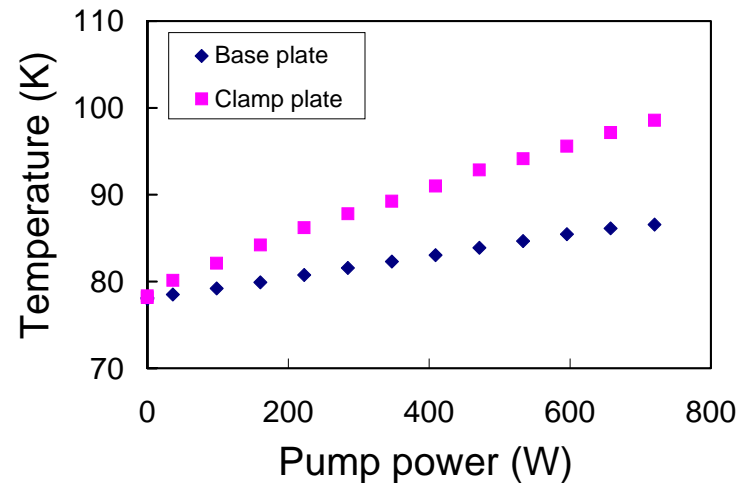
- Maximum output power was 400 W with a total pump power of 720 W.
- 98% of pump power was incident on the crystal and 98% was absorbed.
- With 80%-reflective output coupler, the slope efficiency was 62%.
- The laser was multi-mode in the horizontal plane and nearly diffraction limited in the vertical plane.

Measured temperatures - crystal base and clamp plates

Non-lasing condition



Lasing condition



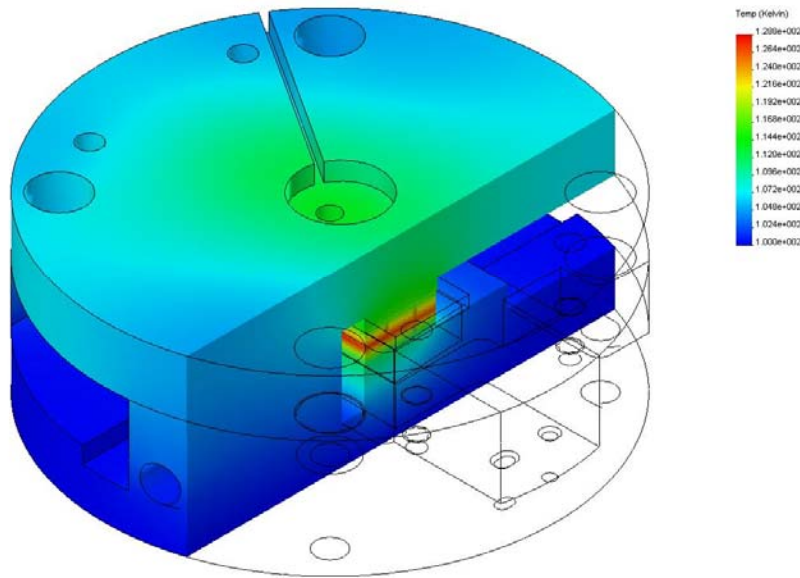
- Compared with the lasing condition, in the non-lasing condition, the temperatures of the clamp and base plates were 26 °K and 11 °K higher respectively.

Sectional view of modeled temperature distribution

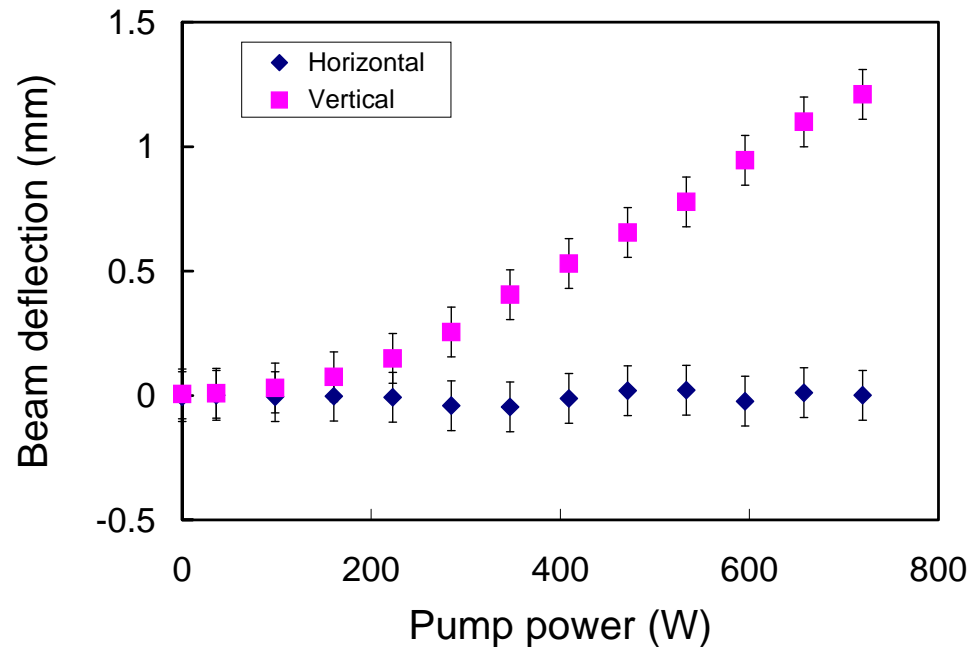
Assumptions:

- Uniform heat deposition of 360 W in the crystal.
- Perfect contact between the crystal and heat sinks. Also, perfect contact between the base and clamp plates.
- Heat removal from the crystal mount is only from the base plate.
- Temperature of the center of the crystal is ~ 129 °K .
- Crystal surface-temperatures at the interfaces of the base and clamp plates are 90 °K and 101 °K respectively.

Model name: CUBE MIRROR ASSY_3
Study name: set 2
Plot type: Thermal Plot
Time step: 1



Measured probe-beam deflection in the crystal



- Thermal wedging due to the temperature difference between the top and bottom of the crystal.
- Camera was 1 m away from the crystal.
- Beam deflection is prominent in the vertical plane

Conclusion

- We demonstrated a 400 W, cryogenically cooled Yb:YAG laser.
- We obtained a slope efficiency of 62% and optical-to-optical efficiency of 56% in a side-pumped slab geometry, in good agreement with our estimates.
- The laser is multi mode in the horizontal plane and nearly diffraction limited in the vertical plane.
- Beam quality will be improved by multi passing the laser in the crystal – experiments underway, along with Q-switching.