Kilowatt Yb:YAG Laser Illuminator

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ABSTRACT

We report 0.6 kW quasi-cw output power for our diode-side-pumped Yb:YAG power oscillator. This 2-mm diameter rod pump cavity is the smallest of three pump cavities slated for use in a multi-kilowatt Yb:YAG illuminator master-oscillator power-amplifier (MOPA) source. In preliminary results, we have also obtained 225 W cw average output power using alternative cw pump diode arrays. Latest performance data and on-going MOPA development will be described.

1.0 INTRODUCTION

Our high-power side-diode-pumped Yb:YAG rod laser performance attests to its superb suitability for high-pulse-rate, multi-kilowatt average power laser system applications. Yb:YAG's low thermal load, broad pump bands, and absence of negative spectroscopic effects such as excited state absorption, upconversion, or concentration quenching are key advantages. The low thermal load (11% of absorbed pump) has been measured to be three to four times lower than Nd:YAG[1] and results from the small difference between the 941-nm pump quanta and the 1029-nm laser quanta. The presence of only one excited-state manifold accounts for the lack of competing effects in Yb-doped lasers. Another extremely important advantage of Yb:YAG is the significantly longer lifetime of InGaAs laser diodes[2, 3] as compared to 808-nm AlGaAs laser diodes for pumping Nd lasers.

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[1] T.Y. Fan, IEEE J. Quantum Electron., **29**, 1457 (1993).

[2] R. G. Waters, D.P. Bour, S.L. Yellen, and N.F. Ruggieri, IEEE Photonics Tech. Lett., **2**, 531 (1990).

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2.0 EXPERIMENTAL LASER RESULTS

Being quasi-four-level at room temperature, Yb^{3+} absorbs at 1.03 µm unless pumped to inversion, and this requires different optical-pumping architectures than used in four-level Nd^{3+} systems. For this reason, we have developed a side-pumped integrating cavity geometry with impingement cooling of the laser crystal as shown in Figure 1, and as described elsewhere[4]. This side-pumped rod geometry provides maximum heat removal thorough the fine-ground barrel surface along the length of the rod. Our designed heat load per unit length is maintained at less than 100 W/cm which is safely below the YAG fracture limit of 200 W/cm [5]. Robust standard anti-reflection "V"-coatings at 941 nm are used on the rod endfaces. Other diode-pumped Yb:YAG architectures proposed for scaling to kilowatt powers include chilled face-pumped active mirror disks and lens-duct end pumped devices operating up to 80 W and 155 W of output power, respectively[6, 7] although Ref. 7 actually reported over 400 W of output power at that meeting.

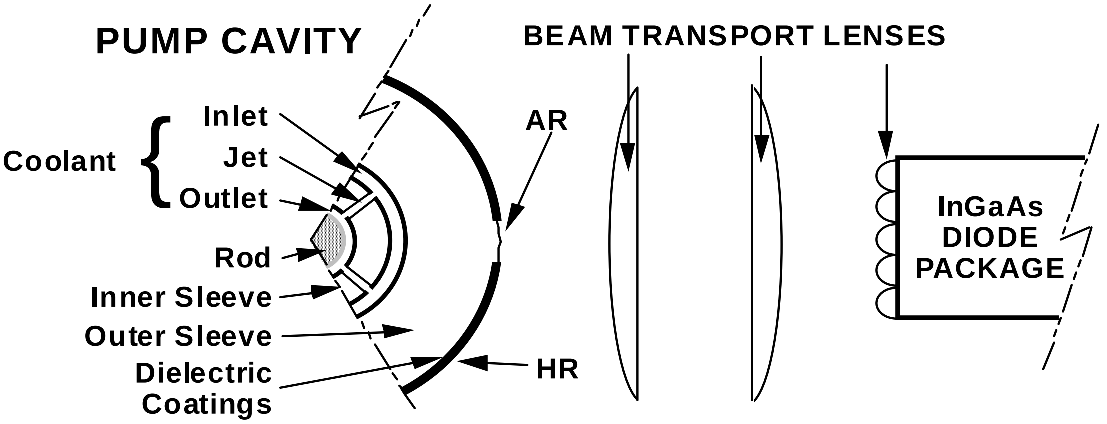

FIGURE 1. Pump cavity schematic of one-third cross-section perpendicular to rod axis; other two thirds identical.

In this paper, we report two sets of laser results. In the first case, we demonstrated 600 W quasi-cw power (Figure 2), and 460 mJ in a ~0.8 msec output pulse (figure 3) from this device, the highest pulse energy and highest power to date for Yb:YAG. This laser result was obtained using 85 quasi-cw diode bars, rated at 40 W quasi-cw output per lensed bar at ~70 A current (the lenses are 80% transmissive). The maximum duty cycle and pulse duration per the manufacturer

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[3] S.L. Yellen, R.G. Waters, Y.C. Chen, B.A. Soltz, S.E. Fischer, D. Fekete, and J.M. Ballantyne, Electron. Lett., **26**, 2083 (1990).

[4] H. Bruesselbach and D.S. Sumida, Opt. Lett. **21**, 480 (1996).

[5] W. Koechner, "Solid-State Laser Engineering," Springer-Verlag, Berlin, Germany, 3rd ed., 1992).

[6] A. Giesen, U. Brauch, I. Johannsen, M. Karszewski, C. Stewen, A. Voss, OSA Trends in Optics and Photonics on Advanced Solid-State Lasers, S.A. Payne and C.R. Pollack, eds., (Optical Society of America, Washington DC, 1996). Vol I., p. 11.

[7] C. Bibeau, R. Beach, C. Ebbers, and M. Emanuel, Advanced Solid-State Lasers, Technical Digest (Optical Society of America, Washington DC, 1997), p. 232.

(SDL) is 20% and 1 msec, respectively. This 600 W demonstration represents an upgrade in pump power from the 45 diode bars used in our previous experiment [4]. All laser diodes are directed into the 2-mm diameter, 2-cm long rod version of our pump head. The rod temperature is +18•C.

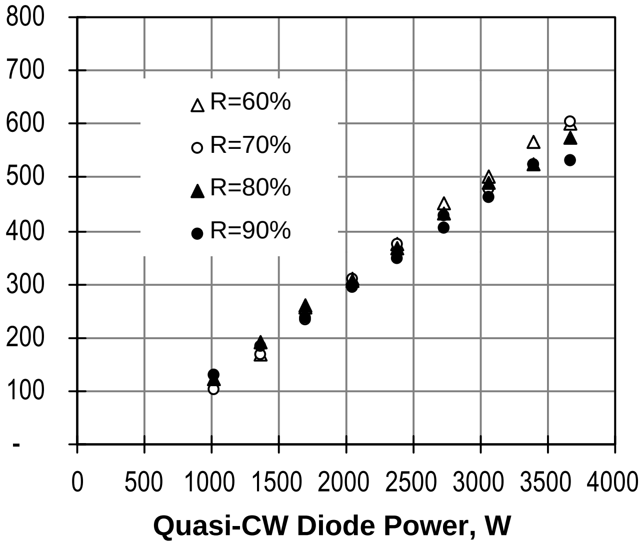

FIGURE 2. Quasi-cw output power as a function of various reflectivty output couplers. The optical-to-optical efficiency was 17% for R = 70%.

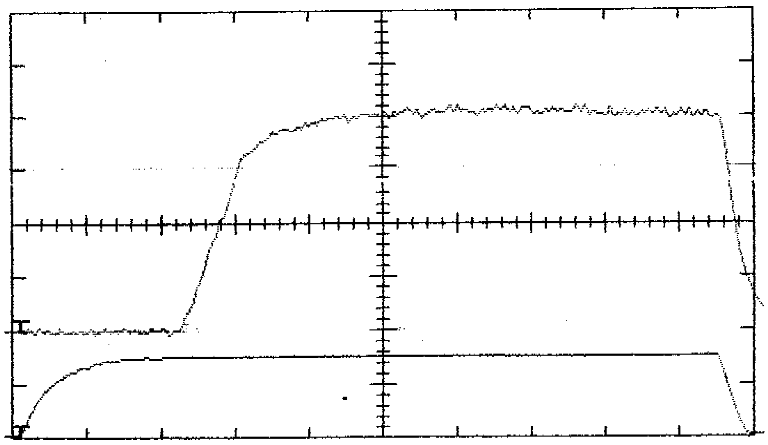

FIGURE 3. Laser output pulse and pump diode pulse. Time scale is 100 µsec/div. Upper trace is quasi-cw lasing output measured with photodiode. Lower trace is 73 A pump diode current pulse which begins ~200 µsec before lasing.

In the second demonstration, we have replaced the quasi-cw diode arrays with true cw diode devices from Siemens/DILAS. Each of the three pump modules was capable of over 600 W of pump power with a beam divergence of ~1° in the fast axis after microlens collimation. The total number of cw diode bars was 90 for a total pump power of 1800 W at 941 nm. The preliminary laser result of 225 W cw output power is shown in figure 4. The higher brightness diodes in this case did not provide better efficiency than the lower brightness quasi-cw diodes and we attribute this to a cw pump cavity coating that was not optimal. Improved coatings are in progress.

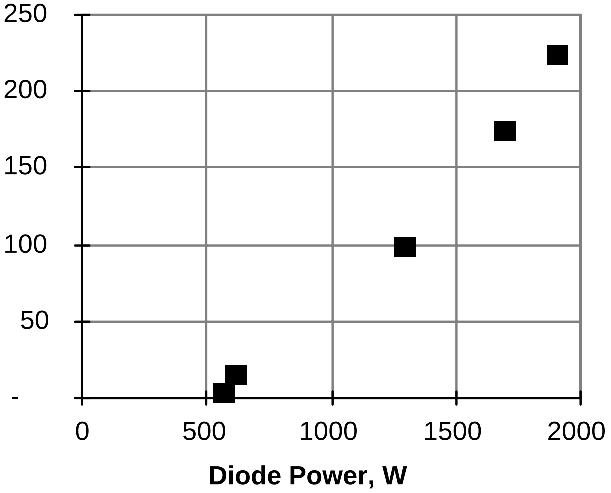

FIGURE 4. True cw laser output data using Siemens/DILAS cw pump diodes. Outcoupler reflectivity of 70% R. The optical-to-optical efficiency was 12%.

For our multi-kilowatt phase-conjugate master-oscillator power-amplifier (PC-MOPA) device, three staged amplifier pump cavities will be double-passed as shown in Figure 5. Assembly of the second-stage laser amplifier head (3-mm rod diameter) is currently progressing as well as development of the low-power high-beam-quality master oscillator.

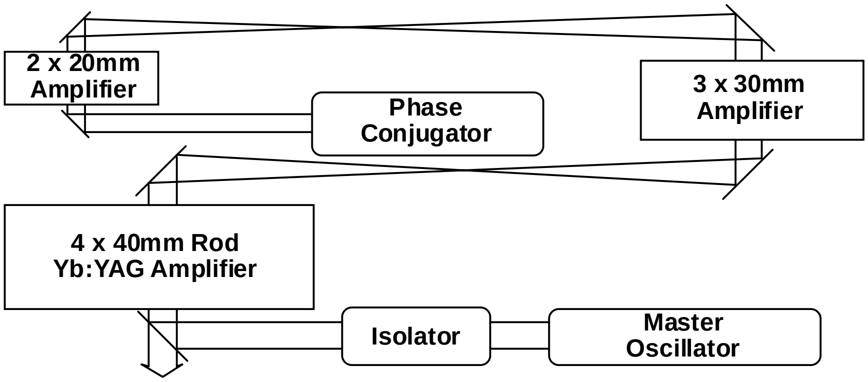

FIGURE 5. Phase-conjugate MOPA Architecture with three staged Yb:YAG rod amplifiers.

3.0 SUMMARY

In summary, we have demonstrated the highest power (600 W quasi-cw) and pulse energy to date for any diode-pumped Yb:YAG laser at room temperature. Preliminary cw output power of 225 W is reported for the 2-mm head and further improvements are forthcoming. A larger 3-mm rod amplifier is under development for a MOPA demonstration in the near future.