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CW and Q-switched Performance of a Diode End-pumped Yb: YAG Laser

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Abstract:

Using an end-pumped technology developed at LLNL we have demonstrated a Yb:YAG laser capable of delivering up to 150 W of CW power and 100 W of Q-switched power.

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Many potential applications motivate the development of efficient, compact 1 μm laser systems with operational lifetimes capable of exceeding thousands of hours. Yb-doped laser hosts offer spectroscopic and laser properties that make them promising candidates for high power 1 μm laser systems. In particular, Yb:YAG has a long storage lifetime 951 us and a very low quantum defect (8.6%) resulting in less heat generation during lasing than comparable Nd-based laser systems[1]. In addition, the broad pump line at 940 nm makes this material highly suitable for diode pumping using InGaAs diodes which are more robust than AlGaAs diodes which are used to excite Nd:YAG at approximately 808 nm. Recent results from lifetime tests on LLNL fabricated 940 nm diode packages have shown projected lifetimes of over 10,000 hours when operated at 25-30 W per cm. Another advantage of using Yb:YAG occurs because the 940 nm absorption feature is approximately 10 times broader that the 808 nm absorption feature in Nd:YAG and therefore the Yb:YAG system is less sensitive to the diode wavelength specifications.

Figure 1 is a sketch of our end-pumped Yb:YAG laser. The pump source consisted of a 43 bar stack of 1 cm long InGaAs laser diode bars packaged on microchannel coolers. The diode light is first conditioned by a uniquely shaped microlens directly mounted on each diode package. The microlens allows the diode light to emerge with a far field 1/e divergence of ~10 mrad and 150 mrad in the fast and slow axis directions respectively. The pump light is then focused or concentrated down with a fused silica lens duct to allow for end-pumping of the laser rod. The laser rod is a composite of doped and undoped YAG. The undoped YAG pieces or endcaps are diffusion bonded to both ends of the doped rod. The endcaps help reduce the thermal loading and stresses on the input and output faces of the rod and therefore help prevent damage. The Yb:YAG composite rod was coated at the pump end of the rod with a multilayed, dichroic coating for high reflectance at 1030 nm and high transmission at 940 nm, thus allowing one end of the rod to perform as a flat high reflector for the laser cavity. A conjugate coating was placed on the opposite or output end of the rod. An alternate design uses a wedge at the output end of the rod and therefore only requires a simple broad band anti-reflection coating.

We have demonstrated the Yb:YAG laser in both CW and Q-switched operation. The doping concentration was 0.5% and the rod diameter was 2 mm with and overall composite length of 60 mm. The rod was housed in a simple aluminum cooling jacket designed to flow coolant along the barrel of the rod. The rod temperature was kept close to zero degrees by using a mixture of water and propanol. With our present pump delivery design that includes the microlens and lens duct, we can deliver approximately 50% of the pump light into the end of the rod. Through internal reflections down the barrel of the rod, the pump light becomes well homogenized with approximately 80% of the pump light being absorbed on the first pass. In CW operation we produce up to 155 W CW power with an intrinsic optical to optical efficiency of 31% as shown in Figure 2. The model for the data is also shown. We believe that the roll over seen is due to a thermal issue which has been addressed. An 85% reflective output coupler with a

1 m radius of curvature was used. The cavity length was approximately 15 cm. Measurements of the beam quality and a least squares fit to the data gave a $M_x^2 = M_y^2$ value of 9.

We also Q-switched output of the laser using an acousto-optic Q-switch. The insertion loss from the Q-switch was only 2%. We were able to produce up to 100 W at a repetition rate of 6.25 kHz resulting in a pulse energy of 15 mJ in a 60 ns pulse (Figure 3). The output coupler had a reflectivity of 70% and a 10 m radius of curvature. The beam quality of the Q-switched beam was $M_x^2 = M_y^2 = 4.9$.

Measurements of the thermal lensing and of the stress induced birefringence are in close agreement with the quantum defect of 8.6%. A probe beam at 632 nm was used to measure the thermal lensing of rod as shown in Figure 4. The analysis yielded a thermal efficiency factor which is the percent of power dissipated into the rod, of 10.2 %. Measurements of the stress induced birefringence were also made and yielded an thermal efficiency factor of 8.74%.

Preliminary measurements of the frequency converted output to the second harmonic will be presented along with the details of the laser performance and modeling.

We wish to acknowledge many useful conversations with Steve Payne, Bill Krupke, rich Solarz, Isaac Bass, Chris Marshall, Eric Honea, Jay Skidmore, Mark Emanuel, and Howard Powell all of LLNL during the course of this work. We also acknowledge the expert technical assistance of Scott Mitchell, Steve Mills, Dennis Maderas, John Lang, Joel Speth, Barry Freitas, Chuck Petty, Vic Sperry, Evert Utterback, Kathy Reinhardt, Larain Dimercurio all of LLNL in carrying out various portions of the work reported.

1 H. Bruesselbach and D. Sumida, "69-W-average-power Yb:YAG laser," Opt. Lett. 21, 480 (1996)

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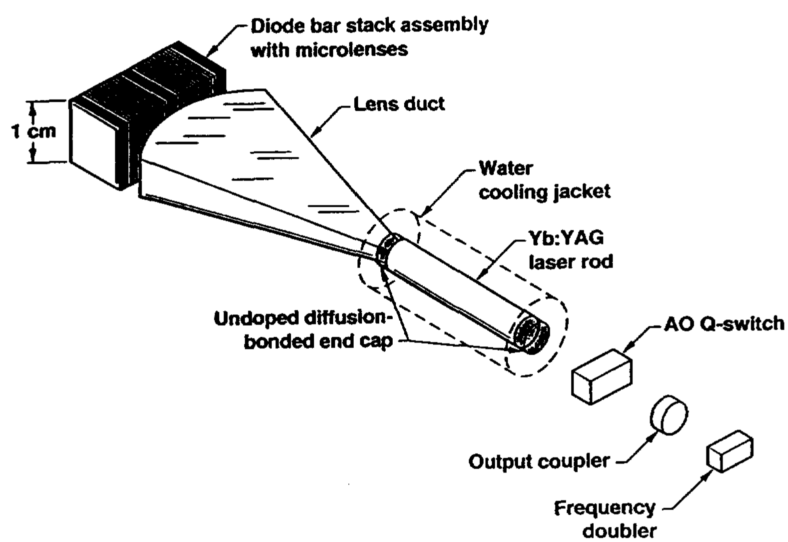

Figure 1. Schematic of the end-pumped Yb:YAG laser

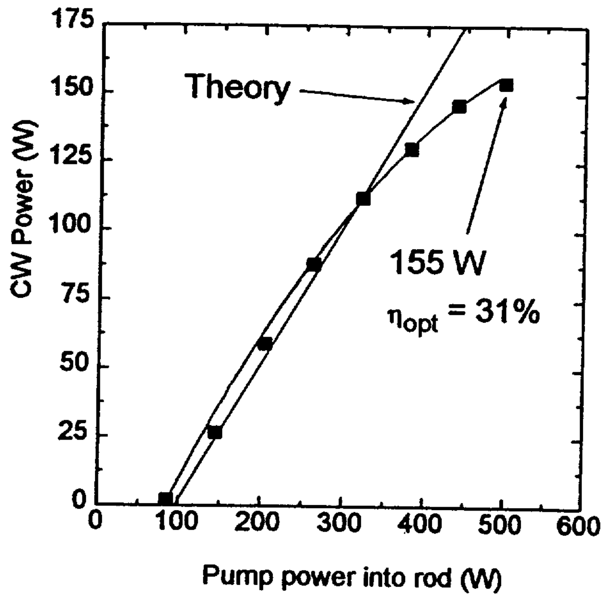

Figure 2. Data and model for the CW laser performance performance

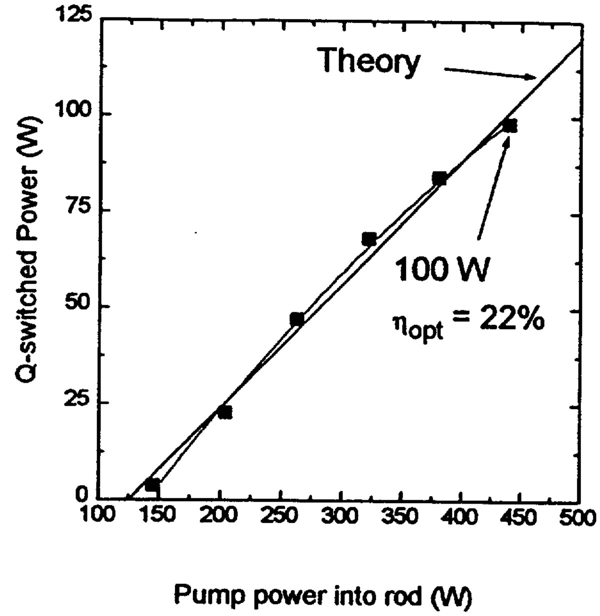

Figure 3. Data and model for the Q-switched performance

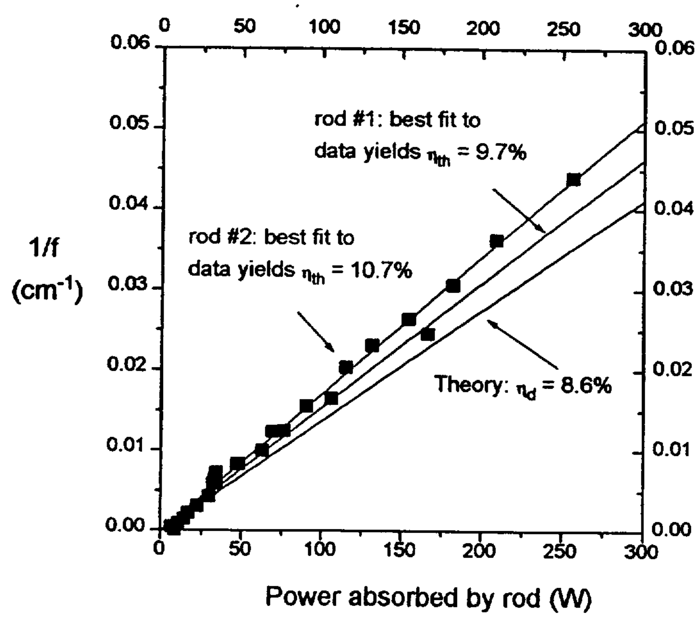

Figure 4. Thermal focusing measurements of Yb:YAG with a 632 nm probe beam

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