**Double-end pumped efficient MHz self-mode-locked Pr:YLF green and red lasers**

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**Abstract:** We demonstrate an efficient tens and hundreds of MHz self-mode-locked green and red laser in a Pr3+:YLF4 crystal with V-type and Z-type cavity using a double-end-diode-pumped structure without the need of any additional components. Experimental results reveal that the laser system can be characterized in stable mode-locked operations. With an absorbed pump power of ~2.8 W, average output powers of more than 0.68 W for 522 nm green laser or more than 1.44 W for 639 nm red laser were obtained.

**Keywords:** Solid state laser, Blue diode-double-end pump, Pr:YLF crystal,visible laser source.

**1. Introduction**

The third-order nonlinear optical responses are closely related to the stimulated Raman

scattering (SRS) process and the Kerr-lensing effect [].

**2. Experimental Set-Up**

Figure 1 depicts the experimental setup for the self-mode-locked Pr:YLF red laser with a double-end pumping scheme. The cavity configuration is a Z-type resonator with a total cavity length of ~1.8 m. The active medium is an a-cut 0.2 at. % Pr3+:YLF4 crystal with a length of ~8 mm. Both end surfaces of the Pr3+:YLF4 crystal were plano and uncoated. The laser crystal was wrapped with indium foil and mounted in a water-cooled copper holder. The water temperature was maintained around 18°C to eliminate thermal effect. The laser crystal was placed close to the IM1, which was a flat mirror with high transmittance coating at ~444 nm and high-reflectance coating at 640 nm (>99.8%).

Introduction to IM2~OC

The two pump sources were ~1.8 W, 444 nm laser diodes with achromatic and collimation system. Focusing lenses with 50 mm focal length and was used to inject the pump beam into the laser crystal with an average pump size of approximately 60 μm. The optical cavity length was set to be approximately 1.8 m with the corresponding free spectral range (FSR) of 85 MHz.

After finely adjusting the cavity alignment, the laser output displayed a stable self-mode-locking operation as shown in Figure 2.

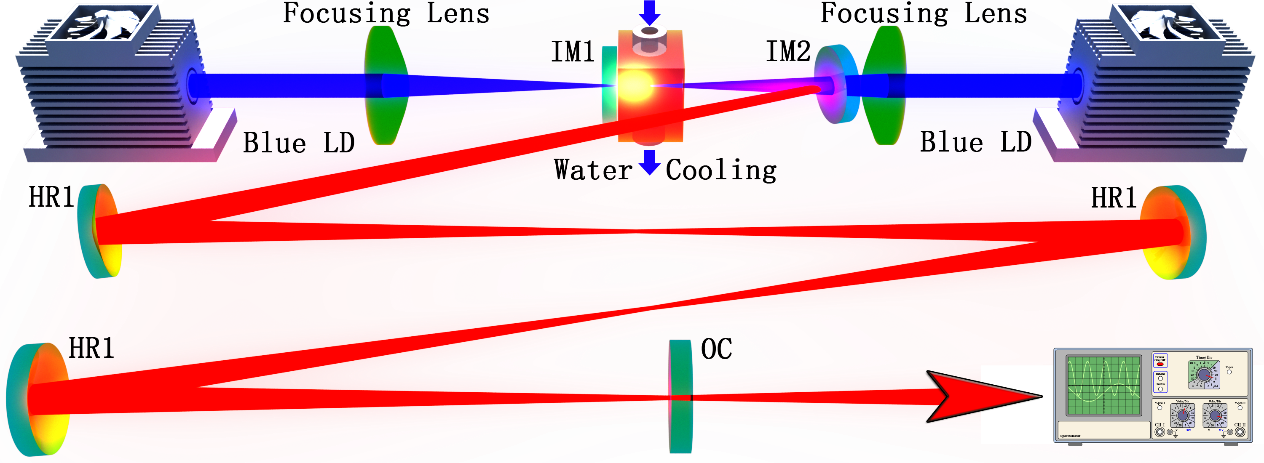


Fig. 1. Schematic of a self-mode-locked Pr:YLF red laser

Note that once the pump power reaches the lasing threshold, the laser system instantaneously steps into a stable mode-locked operation without any mechanical perturbation. The locking mechanism is presumed to be the Kerr effect. However, the laser system has high stability over day-long operation and is insensitive to mechanical vibrations and air current. As a result, some auxiliary mechanism seems to exist in the locking process. Bai et al. [Novel self-mode-locking mechanism in narrow-band lasers] proposed a novel self-mode-locking mechanism in narrowband lasers based on the analysis of the gain-line splitting induced by an intra-cavity laser field. Although the present experimental results are fairly consistent with this mechanism, further identification is still needed.

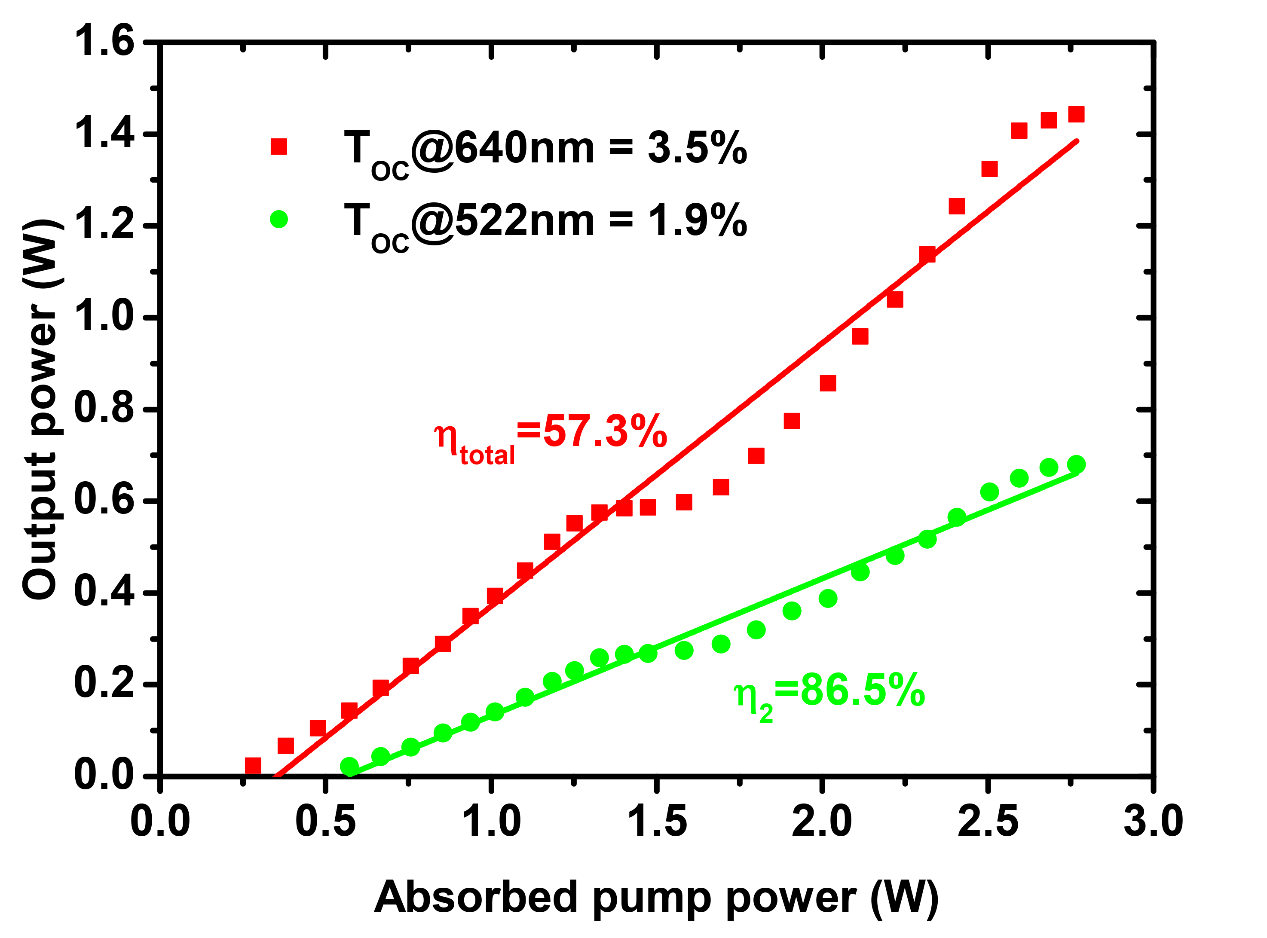


Fig. 2.

The mode-locked pulses were detected by a free space high sensitivity PIN photo detector unit (Menlo Systems, Inc. FPD310-FV with rise time 0.7 ns), whose output signal was connected to a digital mixed signal oscilloscope (Tektronix MSO 3054) with 500 MHz electrical bandwidth and a sampling interval of 0.4 ns.

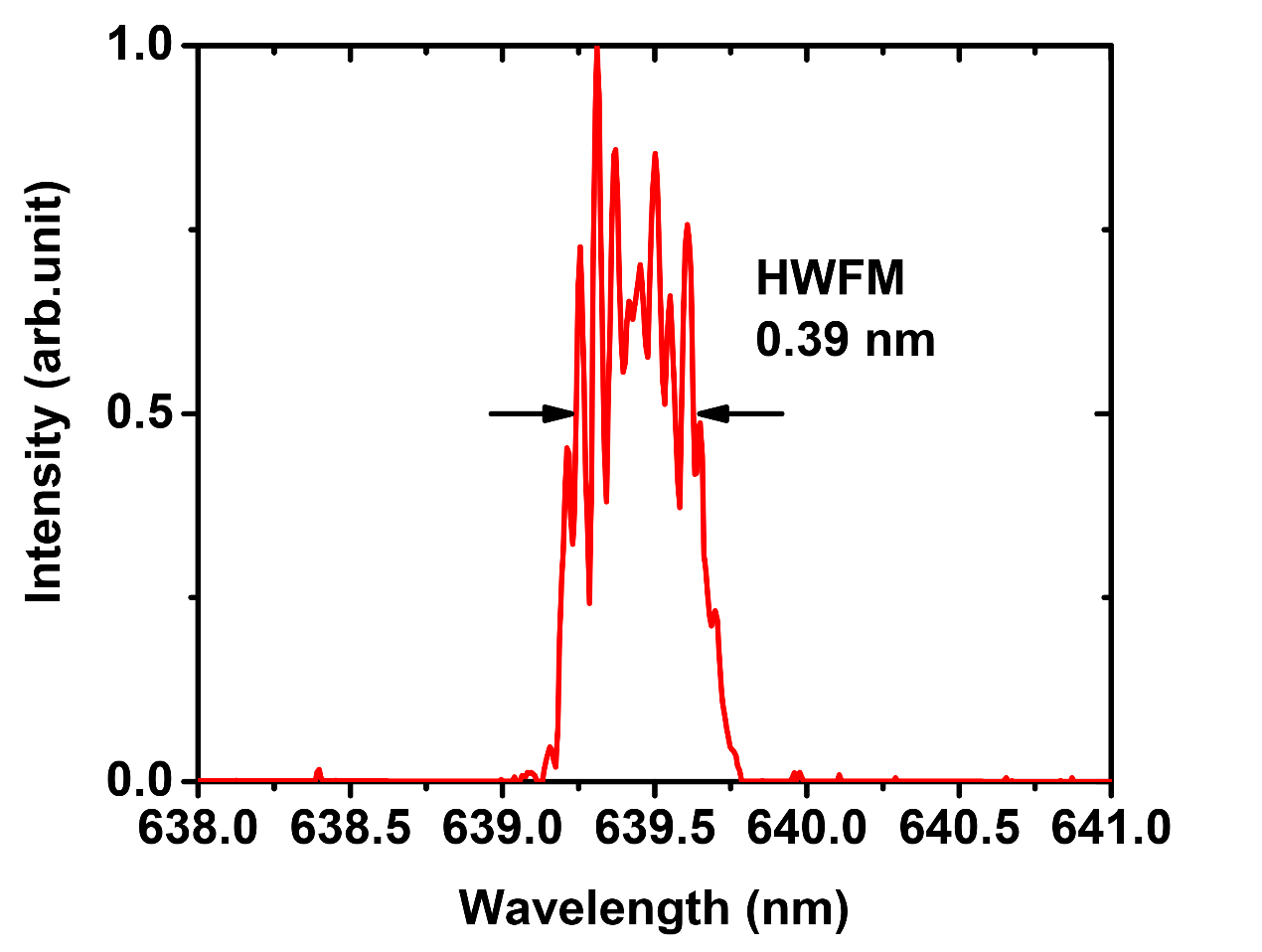


Fig. 3.

Hewlett Packard 8560E Series Optical Spectrum Analyzer with a resolution of 0.08 nm

Figures 4(c) and 4(f) show the pulse trains for the ~1.8 m-long cavity on two different time scales, one with time span of 5 ns, demonstrating mode-locked pulses, and the other with time span of 5 μs, demonstrating the amplitude stability. It can be seen that the pulse trains display full modulation, and the complete mode locking is achieved.



Fig. 4.

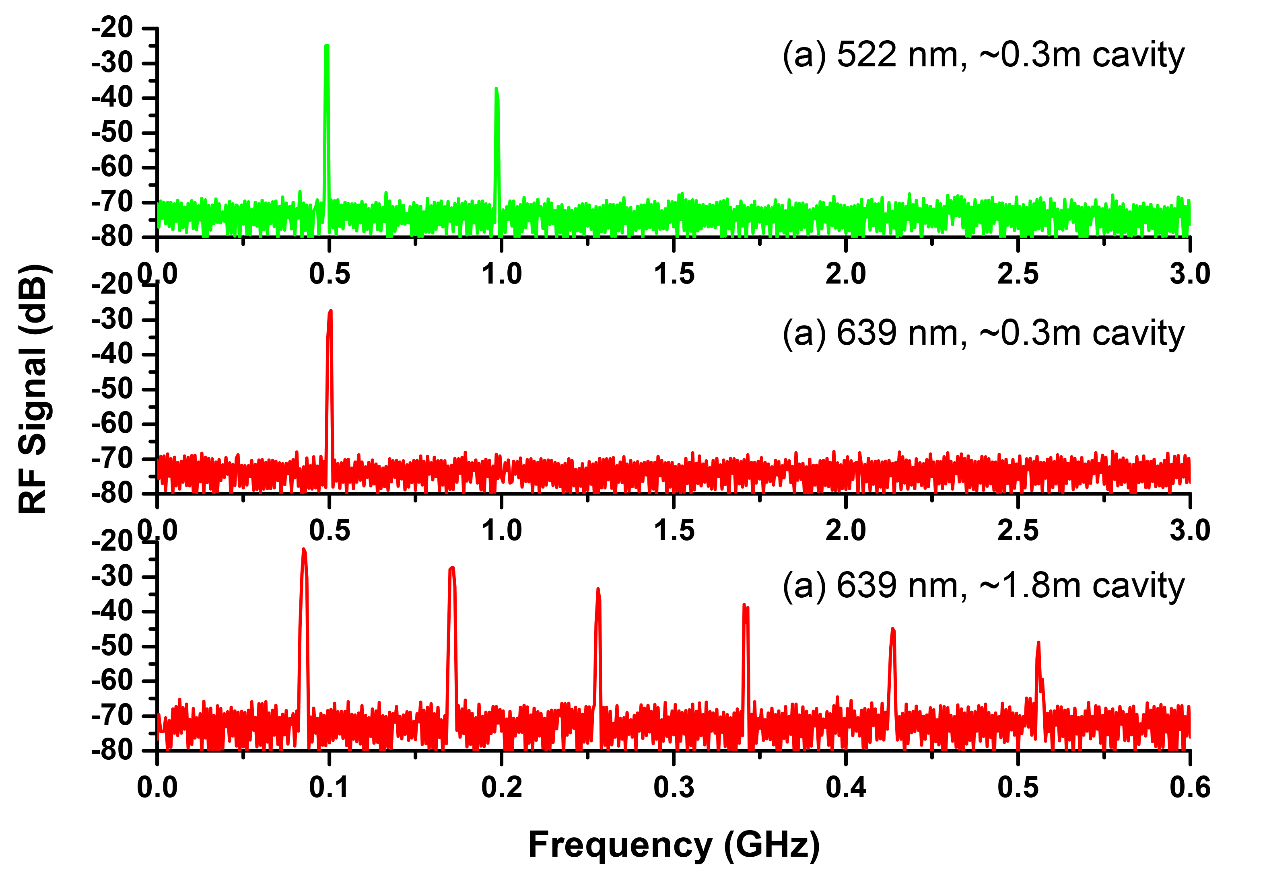


Fig. 5.

The corresponding power spectrum is measured by an rf spectrum analyzer (GωINSTEK, GSP-930) with bandwidth of 3.0 GHz.

The laser was cw mode locked at ~85 MHz with only weak noise, and the difference between the peak of mode-locked frequency and that of relaxation oscillation frequency was experimentally found to be larger than 42 dBm.

Reference

[Novel self-mode-locking mechanism in narrow-band lasers]. Y. Bai, S. Chen, Z. Wang, and G. Zhang, Appl. Phys. Lett. 63, 2597 (1993).