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Tungstate Laser Generates Raman Output

The family of ytterbium-doped potassium tungstate lasers has been frequently investigated in recent years and has spawned at least four entries in the commercial market -- the Spectra-Physics Eclipse, the Amplitude Systemes t-pulse and s-pulse, and the Light Conversion Pharos -- as well as High Q Laser oscillators and amplifiers.

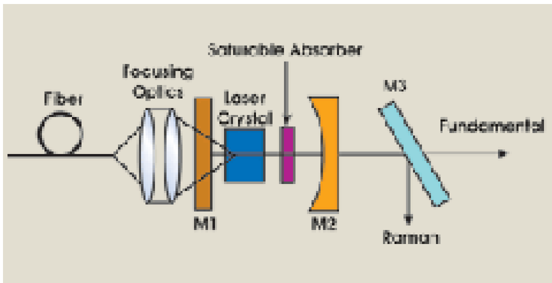

Figure 1. The scientists operated the laser both with and without the saturable-absorber Q-switch. When the Q-switch was present, the peak power was sufficient for an intracavity Raman laser, based on stimulated Raman scattering in the laser crystal, to reach threshold. In that case, a dichroic mirror separated the two output beams. Images ©OSA.

The family includes Yb:KY$(WO_4)_2$ and Yb:KGd$(WO_4)_2$, and the reason for all the interest centers on the materials' large absorption and emission cross sections, their broad absorption and emission bands, and their negligible concentration quenching. Now a new member of the family, Yb:KLu$(WO_4)_2$, has been demonstrated to have even better performance, in terms of higher pulse energy and peak power, and shorter pulse duration.

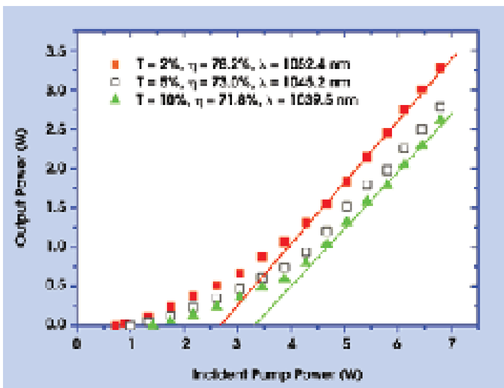

Figure 2. The output wavelength of the CW laser changed with output coupling. The laser's slope efficiency at higher output powers approached 50 percent.

The improvement stems primarily from the fact that the lutetium ion is more nearly the size of the dopant ytterbium ion that replaces it, so there is less lattice strain, especially for higher Yb-doping levels. A collaboration of scientists at Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie in Berlin and at Shandong University in Jinan, China, recently demonstrated impressive laser results with bulk Yb:KLu(WO_4)$_2$.

The scientists pumped a 3-mm-thick, uncoated Yb:KLu(WO_4)$_2$ crystal with a fiber-coupled diode laser whose maximum output was centered near 978 nm (Figure 1). The crystal was Yb-doped to 5.24 atomic percent, and its absorption peak was centered at 981 nm.

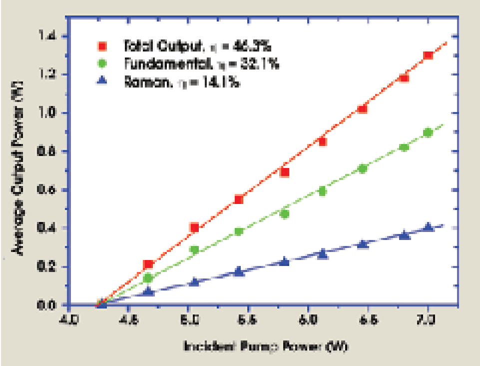

Figure 3. When the laser was Q-switched, its average power at both the fundamental and Raman wavelengths scaled linearly with pump power.

The investigators first operated the laser continuously, without the saturable absorber Q-switch shown in Figure 1. They observed that the output wavelength depended on the output coupling (Figure 2), a behavior typical of quasi-three-level lasers. (A quasi-three-level laser is one in which the lower laser level, although distinct from the ground state, is close enough to it to have a significant thermal population.) In such lasers, the wavelength dependence of both the saturated gain and the reabsorption loss -- caused by ions in the lower laser level absorbing a laser photon and jumping to the upper laser level -- varies with output coupling, and the laser seeks to oscillate at whichever wavelength maximizes its intracavity circulating power.

The best efficiency occurred with a 2 percent output coupler. With 6.8 W of pump power incident on the Yb:KLu(WO_4)$_2$ crystal, the output reached 3.28 W, for an optical efficiency of 48.2 percent. The investigators estimated that 85 to 90 percent of the incident pump power was absorbed and concluded that the slope efficiency, with respect to absorbed power, approached the 93 percent limit set by the quantum defect. They also noted that the lack of roll-off at higher power, as shown in Figure 2, indicated that further power scaling was possible.

The scientists then inserted a 1-mm-thick Cr^{4+}:YAG saturable absorber into the resonator to Q-switch the laser. The tungstates are known to be efficient Raman converters, and the peak power in the Q-switched pulse was sufficient to achieve threshold for an intracavity Raman laser. With an output coupler that transmitted 10 percent at the ytterbium wavelength of 1030 nm and about 20 percent at the Raman wavelength of 1138 nm, the ytterbium laser reached threshold at about 4.3 W of incident pump power, and the Raman laser reached threshold with only slightly more pump power.

Total output from the laser at both wavelengths reached 1.3 W for 7 W of pump power (Figure 3). The measured pulse durations were 1.41 and 0.71 ns for the fundamental and Raman outputs, respectively. These pulse durations corresponded to a peak power of 23 kW for the fundamental and of 15.2 kW for the Raman pulses. ■

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