Diode Pumped Laser Action and Self-Frequency Doubling in Nd^{3+}:YCOB

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Development of the oxyborate materials has brought about the realization of single crystal elements under diode pumped operation for compact, simple, solid state lasers producing visible laser emission. $YCa_4B_3O_{10}$ (YCOB) doped with Nd^{3+} has the distinct advantage of combining both an active laser medium with a modest nonlinear coefficient [1] without associated photorefractive damage and self-absorption as with other self-frequency doubling (SFD) lasers.[2,3] By beam shaping high brightness diodes and proper mode matching of the cavity mode with the laser mode, SFD output powers as high as those achieved by Ti:Sapphire pumping [4] can be obtained in a simple compact air cooled laser system ready for the market.[5] We report efficient laser action and SFD generation in Nd^{3+}:YCOB under diode pumping.

The spectroscopic properties of Nd^{3+} in YCOB were measured for prospective laser operation. Since YCOB has a monoclinic crystalline structure with crystalographic axes that are non-orthogonal, we measured the absorption and emission spectra according to our defined X,Y, and Z optical indicatrix axes relative to the crystalographic axes and planes by adopting the traditional refractive index convention $n_x<n_y<n_z$.[4]The strongest absorption and emission points were found with light polarized parallel to the Z-axis at 812 nm and 1060 nm, respectively.[4] The upper state lifetime has been measured to be approximatley 100 μs.

The hemispherical laser resonator used for these diode pumped laser experiments, consisted of a flat highly reflective rear mirror and a 10-cm radius of curvature output coupler or high reflector. The 3 x 3 x 5 mm long 5% Nd:YCOB crystal was cut with the polished faces aligned at an angle of 33.95° with respect to the X-axis. Both surfaces were coated with a triple band anti-reflection coating which had less than 1% reflectivity at 1060, 530, and 812 nm. A 125 μm diameter fiber lens was utilized to collect the strongly diverging light from the high brightness AlGaAs laser diode's (Polaroid POL-5100BW) fast axis which helps to equalize the divergence of the fast and slow axes. An additional 50 mm focal length achromatic doublet lens was used to collimate the diverging pump beam. Refocusing of the pump beam with a 60 mm focal length Gradium™ plano/convex lens produces spot sizes ~ 50 x 70 μm (FWHM) which have good mode overlap with the cavity mode.

Fig. 1 shows the fundamental (1060 nm) output power versus the absorbed pump power for both 1% and 2% transmission output couplers. The laser output was polarized with the emission parallel to the Z-axis. Output powers exceeding 340 mW for 900 mW of absorbed

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pump power were obtained for 2% output coupling. Slope efficiencies of 37% and 51% were measured for 1% and 2% output coupling, respectively. Efficient SFD was achieved by optimizing the angle of the crystal and the length of the cavity. The SFD output power as a function of absorbed pump power is shown in Fig. 2. A maximum output of 62 mW at 530 nm was obtained with 900 mW of pump power absorbed in the crystal. The laser threshold for SFD output was only 100 mW of diode power absorbed in the crystal. The spectrum of the SFD output consisted of a single, narrow (<0.6 nm) line at 530.5 nm. No observation of thermal rollover has been observed. Scalability to higher powers is currently being investigated.

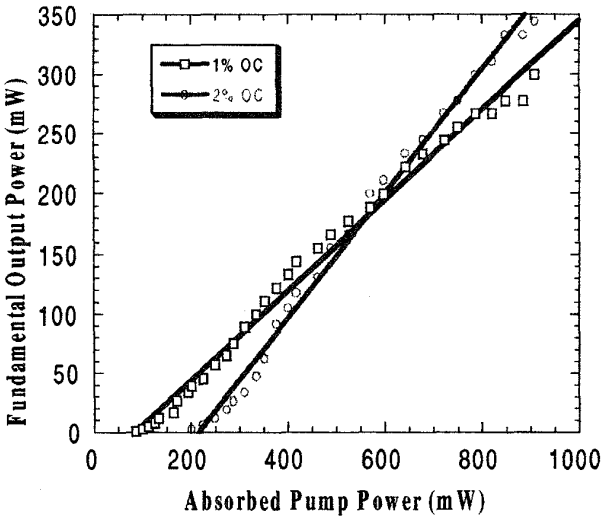

Figure 1. Fundamental output power at 1060 nm versus absorbed diode pump power at 812 nm with 1% and 2% 10-cm ROC output coupling. Slope efficiency for 1% and 2% OC are 37% and 51%, respectively.

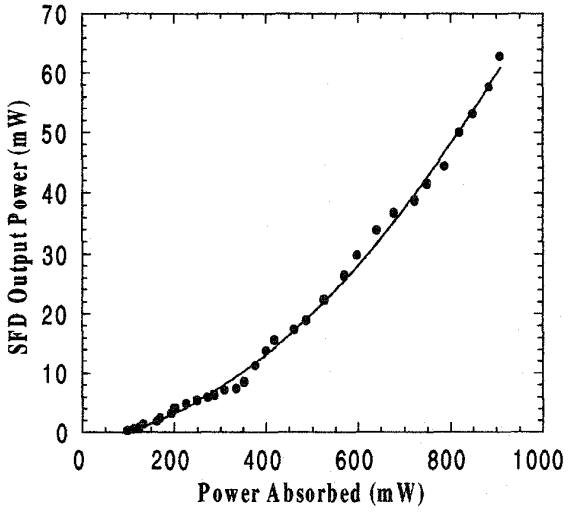

Figure 2. Self-frequency doubled output power at 530 nm versus absorbed diode pump power at 812 nm with HR 10-cm ROC reflector at 1060 nm and HT at 530 nm

In conclusion, we have demonstrated laser action with slope efficiencies as high as 51% and have generated 62 mW of green light by self-frequency doubling of the fundamental light. We have yet to observe any thermally induced limitations which would limit the scaling of the SFD output to higher powers (>1W).

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