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Rapid communication

CW and quasi-CW diode-laser-pumped Nd:SSGM

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Abstract. Fiber-coupled laser diodes were used to pump a Nd-doped SGGM slab (Nd: 4at.%) in the Continous Wave (CW) and Quasi-CW (Q-CW) modes of operation. The optical-to-optical and slope efficiencies were determined in both cases.

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The Nd:YAG (Neodium-doped Yttrium Aluminum Garnet) has been used extensively for the fabrication of diode-pumped compact laser systems at 1.064 μm in the CW or Q-CW mode of operation. Two schemes have been utilized for pumping the Nd:YAG rods. These are the end-pumping [1-7] and side-pumping [8-12] schemes. The end-pumping scheme has shown the highest conversion efficiency, whereas side pumping is the most convenient means of pumping the gain medium in the form of rods or slabs. By employing the end-pumping scheme, a slope conversion efficiency of 60% and an optical-to-optical efficiency of 46% have been observed at 1.064 μm from a Nd:YAG rod pumped by a laser diode at 808 nm [1]. In a combination of the side-pumping and end-pumping schemes, i.e., a multiplexing geometry, *Tidwell* et al. [5-7] have produced 60 W of CW laser power at 1.064 μm with an optical-to-optical conversion efficiency of 26% and a slope efficiency of 60%. The same scheme has been used to pump a Nd:YAG rod in Q-CW mode, and 3 W of average power has been reported at a repetition rate of 200 Hz [13]. For several applications such as LIDAR (LIght Detection And Ranging), an infrared laser must operate at a very high repetition rate to scan large areas quickly, and the pulses must be shorter than 20 ns to provide good resolution for range-gated LIDAR systems. The Q-CW laser at 1.064 μm from Nd:YAG pumped by a diode laser may meet these requirements for LIDAR. However, the absorption linewidth at 808 nm due to the Nd^{3+} transition ($^4I_{9/2} \rightarrow {}^4I_{3/2}$) is very narrow ($\simeq$nm at 1.1 at.% Nd:YAG). The diode-laser wavelength is temperature dependent and changes at the rate of $\simeq$0.3 nm/°C. A long-term operation of the laser diode may shift the wavelength away from the absorption peak of the Nd:YAG absorption line at 808 nm, which will substantially reduce the performance of the laser system at 1.064 μm. The absorption linewidth may be increased by using a higher concentration of Nd atoms in the YAG host. However, concentration quenching of the excited state responsible for laser action at 1.064 μm becomes very severe leading to a cessation of the laser action. Attempts have been made by many investigators in the past [14-17] to dope different host crystals with Nd atoms at a high concentration, thereby increasing the absorption linewidth without sacrificing the energy-storage capability of the excited state. One of such crystals is the Nd:SGGM (Nd:$SrGdGa_3O_7$) which has an absorption linewidth of about 8 nm at a Nd concentration of 4 at.%. At this concentration, the lifetime of the excited state $^4I_{3/2}$ is about 245 μs at room temperature, comparable to the Nd:YAG [16,17]. For a quick review, we display the absorption spectra of Nd:YAG and Nd:SGGM crystals at different Nd concentrations in Fig.1. Recently, we have studied the flashlamp-pumped laser performance of Nd:SGGM [18]. In this communication we report on the laser parametric studies on the Nd:SGGM (Nd: 4at.%) pumped by CW and Q-CW diode lasers tuned to 808 nm.

The experiments were performed by using a fiber-coupled diode laser (Spectral Diode Lab., model SDL-3450-P_5) to pump a small Nd:SGGM slab (3×5×3mm^3) with a Nd concentration of 4 at.%. The diode-laser power was controlled by a current driver (Spectra Diode Lab., model 920) and was capable of delivering a maximum CW power of 10 W at 20 A. The diode laser was mounted on a water-cooled heat sink. The wavelength of the diode laser was scanned by changing its temperature at a rate of $\simeq$0.3 nm/°C. The Nd:SGGM chip was polished and antifeflection coated at 1.065 μm. Two mirrors separated by a distance of 3 cm formed the laser cavity. The input mirror was high-reflection coated at 1.065 μm and high-transmission coated at 808 nm and had a radius of curvature of 10 cm. Flat output couplers of various reflectivites were used throughout the experiments. The CW and Q-CW laser-performance studies were performed with the above-described Nd:SGGM chip. The experimental results for each of these operations will be described below.

In Fig.2, we display the results obtained in the CW mode of operation. The highest output power obtained was 90 mW at a pump power of 2 W with 1.4% transmission of the output coupler. The optical-to-optical conversion efficiency observed was 4.5%, whereas the optical slope efficiency was about 7%. At input powers of more than 2 W, the lasing action completely ceased. In Fig.3, we display the results obtained during Q-CW operation of the Nd:SGGM slab. The highest laser-output energy observed was with the 1.4% transmission output coupler at a threshold energy of 0.2 mJ. The laser was operated at a 50 Hz repetition rate and a pulse duration of 500 μs. The optical-to-optical conversion efficiency observed was 17%, whereas the optical slope efficiency was about 19%. The effect of repetition rate on the laser performance is shown in Fig.4 for a pulse duration of 500 μm and an output-coupler transmission of 5%. The highest output energy was obtained at the repetition rate of 50 Hz closely followed by 20 Hz and 100 Hz in the input energy range of 1÷5 mJ. At higher repetition rates the output energy drops significantly beyond 2 mJ input energy. It may be worth mentioning here that *Hanson* et al. [15] have reported pulsed diode-pumped laser performance of the Nd:SGGM (Nd: 4at.%) at 1.065 μm. The slab thickness in their experiment

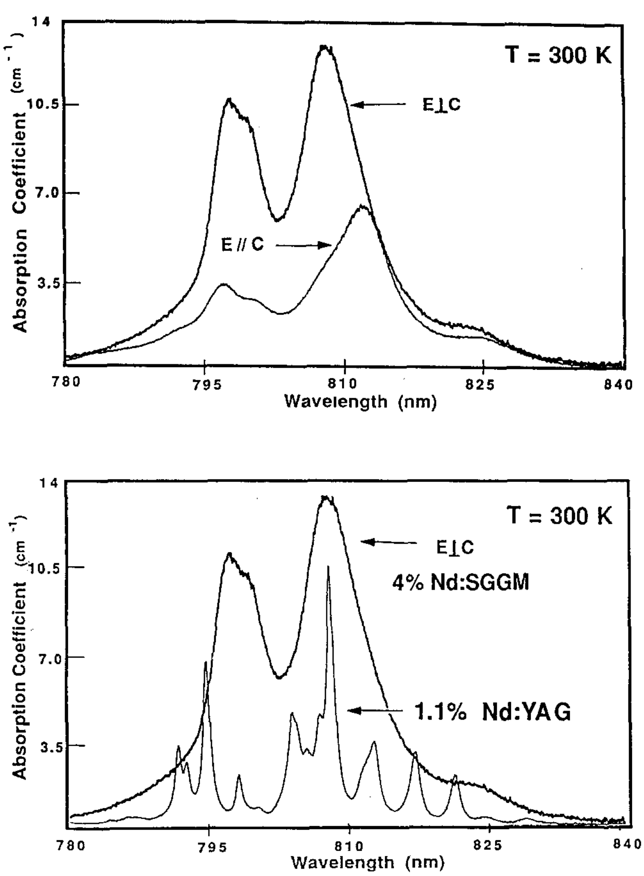

Fig.1. Absorption spectra of Nd:YAG and Nd:SGGM crystals [14]

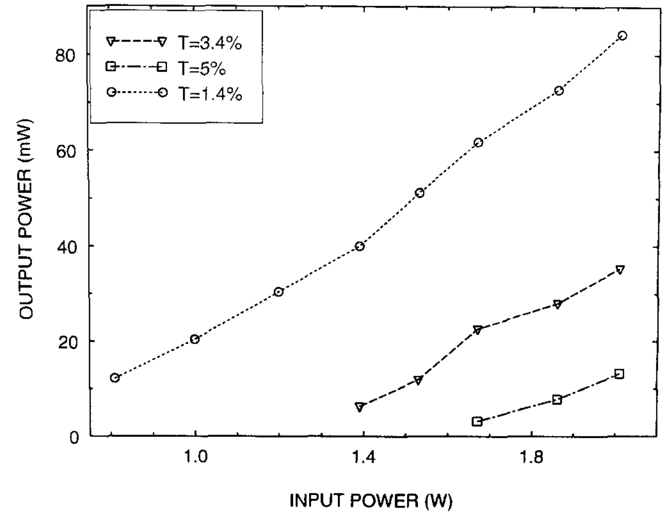

Fig.2. Output power from Nd:SGGM pumped at 808 nm in CW mode of operation

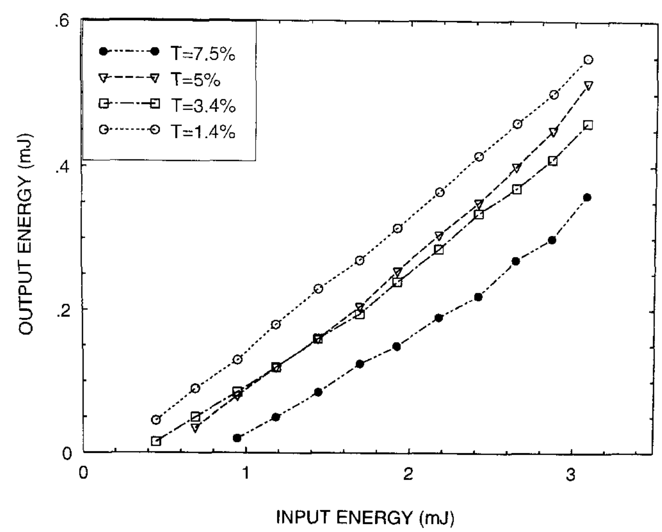

Fig.3. Output energy from Nd:SGGM pumped at 808 nm in Q-CW mode of operation

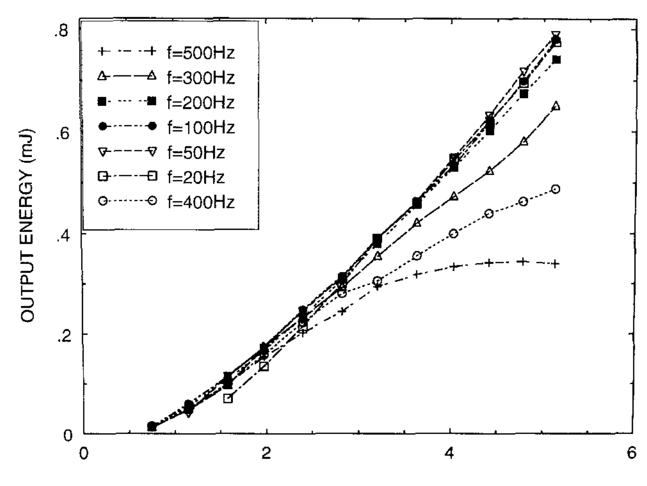

Fig.4. Output energy vs repetition rates of the Q-CW diode laser

was 1 mm and the laser-cavity length was 7.5 cm. The highest energy observed was about 2.5 mJ with 17.6% transmission of the output coupler and 200 μs pulse duration. They observed an optical-to-optical conversion efficiency of about 5%, whereas the slope efficiency was about 9%. These efficiencies are much lower than those observed in the present study. Our observation of substantial loss in the laser slab is consistent with the observation of *Hanson* et al. [15]. The thermal conductivity of Nd:SGGM seems to be very low and this may be the main reason for low energy output at higher repetition rates (Fig.4).

In conclusion, we have studied the laser performance of a Nd:SGGM (Nd: 4at.%) slab pumped by CW and Q-CW laser diodes at 808 nm. The optical-to-optical and slope conversion efficiencies at the laser wavelength of 1.065 μm was determined to be 4.5% and 7% in the case of CW, whereas it was 17% and 19%, respectively, in the case of Q-CW mode of operation.

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