Laser Performance of Nd:GGG Operating at 938 nm *

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We report an efficient diode-pumped Nd-doped Gadolinium gallium garnet (GGG) continuous-wave (CW) laser operating at 938 nm. Laser action of 1.6at.% Nd-doped GGG crystals with different lengths and temperatures are also investigated. The maximum output power of 620 mW is obtained at the incident pump power of 5.0 W with a slope efficiency of 15%.

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In recent years, applications of high power all-solid-state lasers are significantly increased in industry, medical treatment, science, military, and so on. Many kinds of crystals are used, in which Nd:YAG is used rather widely as a solid-state laser (SSL) crystal. At the same time, researchers are always looking for other laser crystals in new wavelengths, in which Nd:GGG crystal has a long history[1−4] and has a series of advantages compared with Nd:YAG.[5−9] The core of GGG can be grown up to be larger in size with superior optical quality than that of YAG single crystal. The concentration of Nd^{3+} in GGG can reach 4% or more, while in YAG it is limited within 1.5%. The segregation coefficient of Nd^{3+} in GGG crystals is 0.52 while it is 0.2 in YAG crystals. Furthermore there is weak concentration quenching of Nd^{3+} when it substitutes Gd^{3+}. Because of reabsorption loss, it is more difficult to obtain the transition at a quasi-three level system than that at a four-level system. So far we have not seen the report about the laser-diode-pumped all-solid-state laser transition of Nd:GGG on a quasi-three level ($^4F_{3/2} \rightarrow {}^4I_{9/2}$) system.[10] In this Letter, the transition of Nd:GGG on 938 nm is studied for the first time and laser action is achieved. The laser of 938 nm may be used as a high quality pump source of Yb-doped crystals.

Figure 1 shows the experimental setup of our system. A linear plane–concave resonator is employed to make the system simple and compact. The length of the resonator is 30 mm. The pump source used in our experiment is a high-brightness fibre-coupled diode laser with a core diameter of 200 μm and a numerical aperture of 0.22. The pump beam is coupled into the gain medium by a coupling system. Nd^{3+} concentration of the Nd:GGG crystal is 1.6 at.% and the dimensions of the crystal is $3 \times 3 \times 2\,mm^3$. The laser crystal is mounted in a water-cooled heat sink. For simplicity and reduction of cavity loss, both facets of the Nd:GGG crystal were coated for high transmission (HT) at 940 nm and 808 nm. The output coupler is a curvature mirror with a radius of 80 mm and has a transmission of 3.6% at 946 nm.

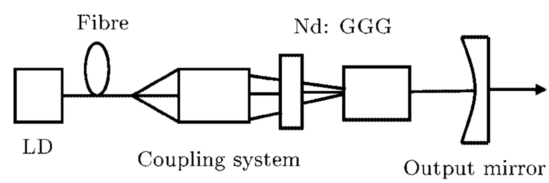

Fig. 1. Schematic of the diode-pumped Nd:GGG laser.

We measured the fluorescence spectrum and laser spectrum from 900 nm to 1100 nm. The results are shown in Fig. 2. There are two peaks at 934 nm and 938 nm in the fluorescence spectrum, but from the laser spectrum we can find the only 938 nm laser all the time, and we cannot observe the 1.06 μm laser.

Figure 3 shows the cw output power of Nd:GGG crystals with different lengths, and a 2-mm-long Nd:GGG crystal is the best one in our experiment. The threshold pump power of 938 nm laser is about 1.8 W. The maximum of output power is 620 mW at the incident pump power of 5.9 W with a slope efficiency of 15%. With the increasing length of crystal, the output power reduces apparently. The better Nd^{3+} concentrations of other crystals such as YAG, $GdVO_4$ and YVO_4 operating at quasi-three levels are lower than 1.6%. It is believed that the Nd^{3+}concentration of 1.6at.% is probably slightly higher for transition on quasi-three levels, thus the reabsorption loss may be serious due to thermal effect. We compare the output power at different cooled temperatures, as shown in Fig. 4. The output powers were measured at four temperatures (6°C, 10°C, 14°C and 18°C), the maximal output powers are 506, 450, 420, and 356 mW, respectively. What is more, the length of thermal lensing was measured to be 14 mm at the incident pump power of 5.0 W with a plane-

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plane cavity, which agrees with the critical point from a stable cavity to an unstable one calculated by using the ABCD matrix. As a result, thermal effect and reabsorption loss have serious effect on transition in the quasi-three-level system.

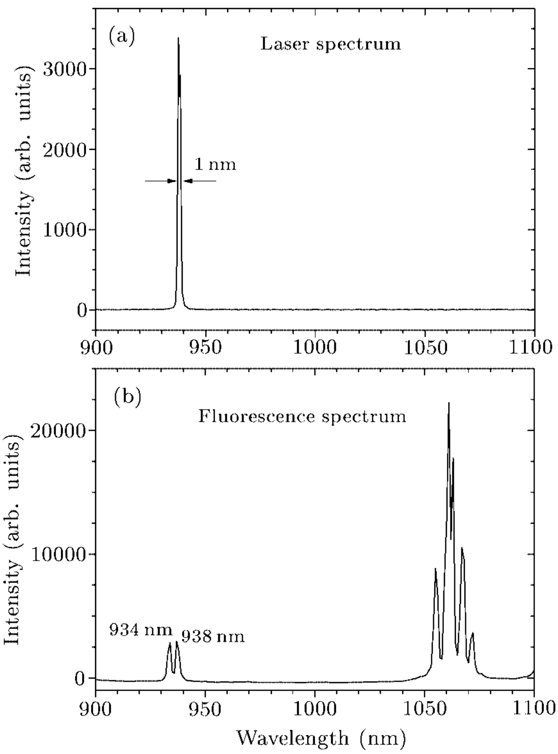

Fig. 2. Fluorescence and laser spectra of Nd:GGG.

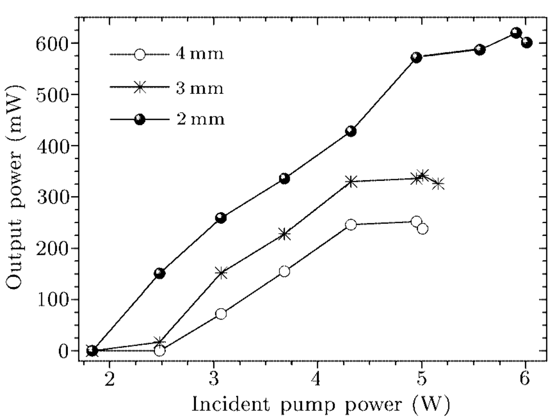

Fig. 3. Output powers of different-length crystals versus incident pump power.

The far-field beam spatial profile of the 938 nm laser at the output power of 400 mW was measured. The result is shown in Fig. 5. The Gaussian fitting curve indicates that the laser is nearly oscillated in the fundamental transverse mode. We can observe the stability of the laser by monitoring the output power with a power meter. The rms value of noise is 0.2% in 30 min at the output power level of 400 mW.

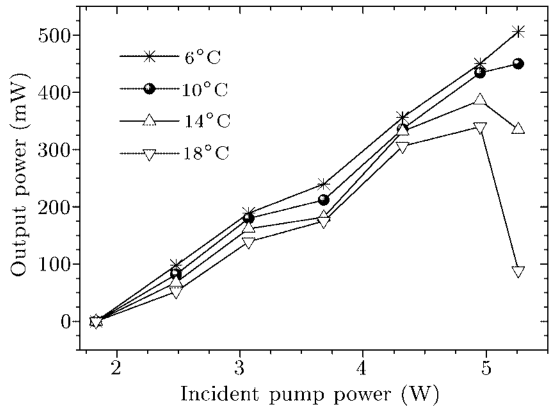

Fig. 4. Output power of different temperatures.

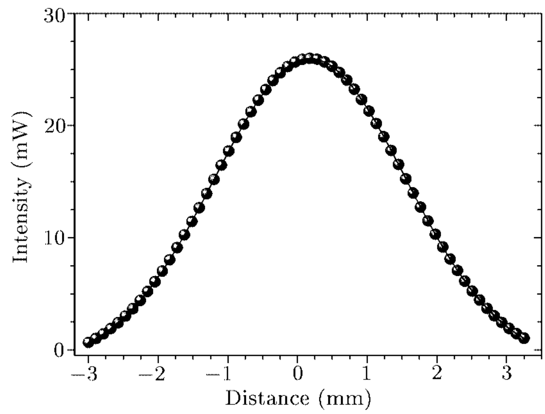

Fig. 5. Far-field beam spatial profile of 938 nm laser.

In conclusion, to the best of our knowledge it is the first time to obtain a 938-nm laser-diode-pumped all-solid-state laser in Nd:GGG on a quasi-three-level system. The maximum of output power is 620 mW at the incident pump power of 5.9 W with a slope efficiency of 15%. Higher output power of 938 nm should be achieved if we use the Nd:GGG crystal with optimal Nd^{3+} concentration, length and cooled temperature. In the near future, we will demonstrate a blue laser from the frequency doubling of 938 nm.

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