Composite Yb:YAG/Cr:YAG ceramics self-Q-switched laser

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Abstract: Composite Yb:YAG/Cr:YAG ceramics was fabricated successfully by using vacuum sintering technique and nanocrystalline technology. Self-Q-switched lasers with pulse energy of 125 μJ, and peak power of 105 kW have been demonstrated for the first time.

OCIS codes: (140.3480) Lasers, diode-pumped; (140.3540) Lasers, Q-switched; (160.3380) Laser materials.

1. Introduction

Transparent ceramic laser materials fabricated by the vacuum sintering technique and nanocrystalline technology [1] have gained more attention as potential solid-state laser materials in recent years because they have several remarkable advantages compared with similar laser single crystals, such as high concentration doping, easy fabrication of large-size ceramic samples, low cost, mass production and multilayer and multifunctional ceramics lasing components [2]. Passively Q-switched microchip solid-state lasers with high peak power have been demonstrated to be useful sources for many applications [3]. Compared to Nd:YAG gain medium, Yb:YAG has several advantages in passively Q-switched solid-state lasers such as smaller emission cross section (only one tenth of that for Nd:YAG) for obtaining high pulse energy, longer lifetime for energy storage. The shortcoming of Yb:YAG used in passively Q-switched laser with Cr:YAG as saturable absorber is that Cr:YAG has a very strong absorption at pump wavelength at 940 nm, therefore, co-doping Cr,Yb:YAG will be less efficient or even can not lase with high Cr concentration. Ceramic technology provides such a solid way to form composite ceramics for self-Q-switched laser operation. Here, we reported, for the first time to our knowledge, the optical properties and laser performance of Yb:YAG/Cr:YAG composite ceramics. The laser pulses with pulse energy of 125 μJ and peak power of over 105 kW were obtained at room temperature.

Fig. 1 Photograph of composite Yb:YAG/Cr:YAG ceramics (ϕ8 × 12 mm), the thickness of Yb:YAG and Cr:YAG are 8 mm and 4 mm, respectively.

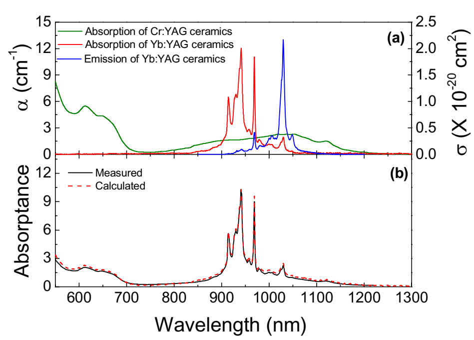

Fig. 2 Absorption and emission spectra of composite Yb:YAG/Cr:YAG ceramics at room temperature.

2. Spectral properties of composite Yb:YAG/Cr:YAG ceramics

Fig. 1 shows the photograph of composite Yb:YAG/Cr:YAG ceramics fabricated by vacuum sintering technique and nanocrystalline technology. The doping concentration of Yb and Cr in YAG is 9.8 at.% and 0.1 at.%, respectively. The absorption and emission spectra of Yb:YAG/Cr:YAG composite ceramics were measured by using Yb:YAG and Cr:YAG ceramics cut from Yb:YAG/Cr:YAG composite ceramic (as shown in Fig. 2(a)). The absorption and

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emission spectra of Yb:YAG ceramics are identical to those of Yb:YAG single crystals [4]. The absorption spectrum of Cr^{4+}:YAG ceramic is identical to those from Cr^{4+}:YAG single crystal previously reported [5]. There is a strong absorption at 940 nm of Cr^{4+}:YAG, about 70% of that at 1030 nm. The absorptance spectrum of composite Yb:YAG/Cr:YAG ceramic calculated by using the absorption spectra of Yb:YAG and Cr:YAG ceramics is in good agreement with measured absorptance spectrum (as shown in Fig. 2(b)).

3. Composite Yb:YAG/Cr:YAG self-Q-switched laser

The performance of composite Yb:YAG/Cr:YAG ceramics laser was investigated by using plane-concave cavity (Fig. 3(a)). The gain medium is a plane-parallel, 3.5-mm-thick Yb:YAG/Cr:YAG composite ceramics, the thickness of Yb:YAG and Cr:YAG ceramics are 1.5 and 2 mm. One surface of the composite ceramic with Yb doping is coated for high transmission at 940 nm and total reflection at 1030 nm. The other surface is coated for antireflection at 1030 nm. A concave mirror with 70 mm curvature and 10% transmission at 1030 nm was used as output coupler. The cavity length is about 35 mm. A fiber-coupled 940 nm laser-diode with a core diameter of 100 μm and numerical aperture of 0.22 was used as the pump source. The laser output beam profile was monitored using a CCD camera both in the near field and the far field of the output coupler. The threshold absorbed pump power was measured to be 0.9 W, the average output power increases linearly with absorbed pump power above the absorbed pump power threshold (as shown in Fig. 3(b)). The slope efficiency is 27%. The maximum average output power of 480 mW was measured when the absorbed pump power is 2.6 W, there is coating damage with further increase of the pump power. The laser pulses with pulse energy of 125 μJ, pulse width (FWHM) of 1.2 ns and peak power of over 105 kW at repetition rate of 4 kHz were obtained when the absorbed pump power of 2.6 W was launched (see Fig. 3(c)). Although the pulse energy increases slowly with absorbed pump power at high pump power, the pulse energy dose not tend to be saturated. High pulse energy can be obtained with increase of the transmission of the output coupler or improving the coating quality. The output laser transverse intensity profile was close to TEM_{00} (as shown in the inset of Fig. 3(b)) and was near-diffraction-limited with M^2 of less than 1.4.

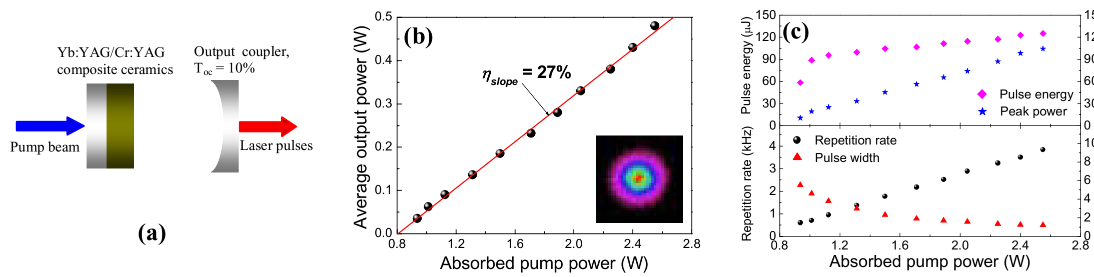

Fig. 3 Experimental setup of composite Yb:YAG/Cr:YAG self-Q-switched lasers and the performance of Yb:YAG/Cr:YAG composite ceramic laser (average output power, repetition rate, pulse energy, pulse width and peak power) as a function of absorbed pump power.

4. Conclusions

In conclusions, composite Yb:YAG/Cr:YAG ceramics has been successfully fabricated, the optical properties of Yb:YAG and Cr:YAG ceramics are measured and are identical to their counterpart sing crystals. The laser performance has been demonstrated by using composite Yb:YAG/Cr:YAG ceramics for the first time. The slope efficiency of 27% is achieved even with low initial transmission of 64% in such composite Yb:YAG/Cr:YAG ceramic. The laser pulses with pulse energy of 125 μJ and peak power of over 105 kW were obtained.

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