Efficient mode-locked picosecond Yb:YAG ceramic laser

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A diode-pumped picosecond mode-locked Yb:YAG ceramic laser is realized with a slope efficiency of 44%. Output power up to 1.04 W is obtained with pulse duration of 10.4 ps at central wavelength of 1 049.5 nm. The standard deviation of maximum output power instability is 0.00453.

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Ultrafast laser is a powerful tool in many applications because of its high peak power and ultrashort interaction time with matter. Compared to convertional Ti:sapphire lasers, diode pumped picosecond laser performs importance specifically and interestingly in high precision micromachining for high efficiency and superior stability, as well as lower cost. In general, the relaxation time of electrons is at the range of 1–20 ps[1]. The ytterbium(Yb^{3+}) doped YAG ceramics is an attractive gain medium for the research of diode-pumped solid-state laser[2]. Compared with the Yb:YAG crystals, highly transparent Yb:YAG ceramics have advantages of 10% higher hardness, high doping concentration, easy fabrication of large-size samples. Recently, researchers have been progressively investigated this kind of gain medium. First mode-locked operation of Yb:YAG ceramic was demonstrated by Yoshioka *et al.*[3]. Pulse duration shorter as 233 fs was obtained with a 9.8 at.-% Yb:YAG ceramic as the gain medium. The output power was only 20 mW. In 2009, Zhou *et al.*[4] demonstrated an efficient femtosecond Yb:YAG ceramic laser at the wavelength of 1 048 nm, which output power up to 1.9 W was obtained with pulse duration of 418 fs. In this letter, we report new results on an efficiency picosecond continue wave (CW) mode-locked Yb:YAG ceramic laser. Stable output power to 1.04 W was successfully obtained by using a 969-nm laser diode as pump, correspoding to an average slope efficiency as high as 44%.

Figure 1 shows the schematic of our picosecond Yb:YAG ceramic laser. A high-brightness fiber-coupled diode lase emitting at 969 nm (Jenoptik, JOLD-7.5-BAFC-105) is used to end-pump the crystal. In order to realize a compact all solid-state laser, the total length is set to correspond a repetition of 109.7 MHz. M1 is a plane dichroic mirror with high transmission at 969 nm and high reflection at 1 020–1 100 nm; M2, M3, M4 are concave mirrors with curvature radius of 200, 200, 300 mm, respectively. A highly transparent Yb:YAG ceramic with 2-mm long and 10% doping concentration is wrapped with indium foil and mounted in a water-cooled copper heat sink block set at temperature of 11 °C. A Gires-Tournois interferometer (G-TI) mirror and a chirped mirror(Layertec GmbH) are set into cavity and provided 1 420 fs^2 per rebound in the spectral range from 1 000 to 1 100 nm. With a 2%-output coupler, we observe that the laser running in a steady mode-locking regime.

We measured the average maximum output power which is about 1.04 W, corresponding to the absorbed pump power of 3.25 W. Figure 2 shows the output power versus the absorbed pump power with an average slope efficiency of 44%. According to the measurement results, the spectrum width (FWHM) of the pulses is 0.3 nm at the central wavelength of 1 049.5 nm (insert figure of Fig. 3). Using a commercial noncolinear autocorrelator (FR-103MN, Femtochrome Research, Inc.),

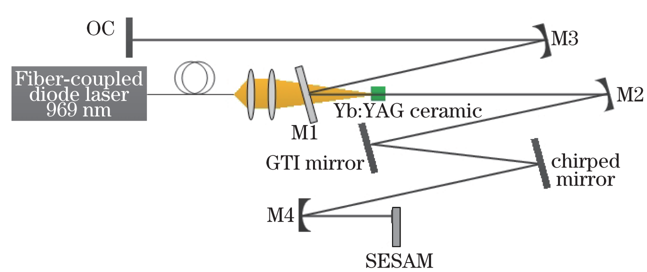

Fig. 1. Schematic of the mode-locked Yb:YAG ceramic laser.

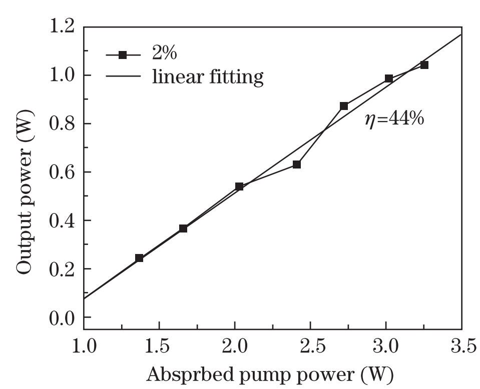

Fig. 2. Output power versus absorbed pump power with ouput coupler 2.

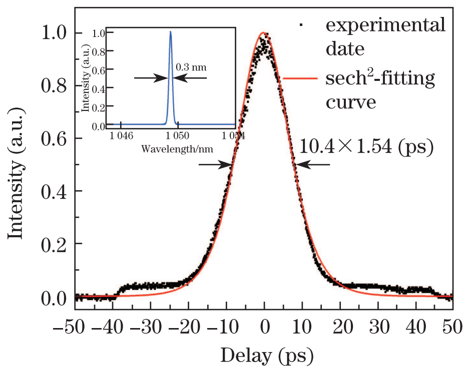

Fig. 3. Measured autocorrelation trace and $sech^2$ fitting. Insert: the correponding spectrum.

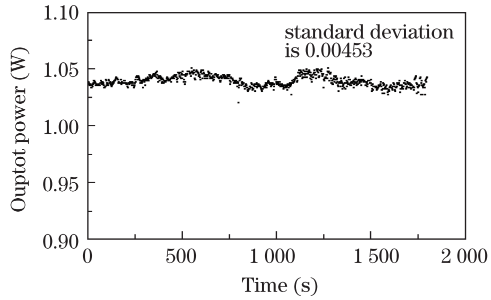

Fig. 4. Instability under the maximum output power.

we measured the autocorrelation trace of mode-locked pulses at maximum output power. The FWHM width of the autocorrelation trace is about 16 ps. If a $sech^2$-pulse shape is assumed, the mode-locked pulse duration will be 10.4 ps (Fig. 3). We measured the stability at maximum output power for 30 min at a speed of 2 s/data dot (Fig. 4). The standard deviation of instability is 0.00453.

In conclusion, we demonstrates a diode-pumped efficient picosecond Yb:YAG ceramic laser. At 1 049.5 nm with a bandwidth of 0.3 nm, the mode-locked laser with a 2% OC generated 10.4-ps pulese with average maximum output power of 1.04 W. The standard deviation of instability is 0.00453.

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