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Q-switched lasing at 2 μm in a $Tm^{3+}:YAlO_3$ laser

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***Abstract*. The parameters of a *Q*-switched longitudinally-diode-pumped $Tm^{3+}:YAlO_3$ laser are presented. The pulse repetition rate is $f = 1 - 15$ Hz. The maximum average output power is 5 W (at $f = 5 - 15$ kHz), the minimum pulse duration is 130 ns ($f = 1$ kHz), the efficiency is 26 % (with the slope efficiency of 58 %). The laser wavelength under pumping in the region of 803–805 nm is 1.99 μm.**

Keywords: *two micron lasing, Q switching, diode pumping.*

1. Introduction

At present, near-IR laser sources with a wavelength of 2 μm are used both at the fundamental wavelength (in medical devices and environmental monitoring) and with wavelength conversion into the mid-IR region (3–5 μm). Efficient nonlinear conversion requires a high peak power, which can be obtained in *Q*-switched lasers. Traditionally, such lasers are based on Ho^{3+} ions, while thulium lasers serve as pump sources [1]. An efficient *Q*-switched regime in lasers based on Tm^{3+} ions is difficult to achieve due to up-conversion, which is unavoidable in crystals because of high concentrations of active ions; nevertheless, such a possibility was recently shown elsewhere [2].

2. Experimental samples and methods

As a laser material, we chose the $Tm^{3+}:YAlO_3$ crystal with the atomic dopant concentration of 5.5 %. Previously, we obtained efficient cw lasing in this crystal [3]. The samples were $3 \times 3 \times 4$ and $3 \times 3 \times 10$ mm in size; their faces were antireflection coated at $\lambda = 2$ μm. The sample was mounted on a copper holder, whose temperature was kept in the region of 15–25 °C using a Peltier element. A 30-W LIMO laser diode array with a fibre pigtail of diameter 400 μm served as an 803–805-nm pump source. The pump beam was focused by an objective into a spot 0.66 mm in diameter.

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As a *Q*-switch, we used an acousto-optical modulator. The cavity length was 85 cm, and the reflection coefficient of the plane output coupler was 94.5 %. The pump beam entered through a convex mirror with a radius of 300 nm, which completely reflected the laser radiation and was highly transparent for the pump radiation. The use of a convex mirror allowed us to compensate for the thermal lens in the active element and achieve the TEM_{00} operation mode.

3. Laser characteristics

The average output power of the laser with a 4-mm-long active element was 4.1 W both in the cw regime and in the *Q*-switched regime with a pulse repetition rate of 10 kHz. The absorbed pump power corresponding to the lasing threshold was 9 W. The dependence of the average output power on the absorbed pump power is shown in Fig. 1. The efficiency with respect to the absorbed power was 26 % with the slope efficiency of 58 %. With decreasing the *Q*-switching rate to 5, 2.5, and 2 kHz, the average output power slightly decreased to 4, 3.9, and 3.6 W, respectively (at the absorbed pump power of 15.5 W). Thus, the maximum laser pulse energy was 1.8 mJ ($f = 2$ kHz). The use of a 10-mm-long active element allowed us to obtain the maximum average output power of 5 W at the pulse repetition rate in the range from 5 to 15 kHz.

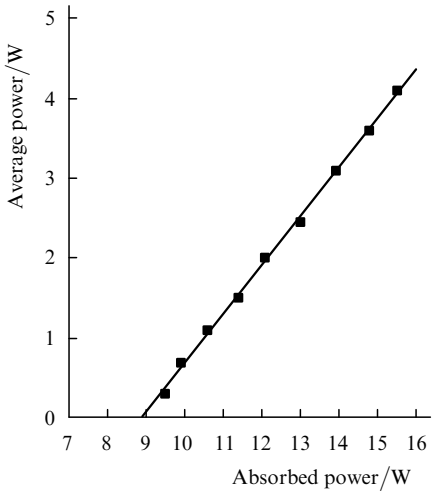

Figure 1. Dependence of the average output power on the absorbed pump power at the pulse repetition rate of 10 kHz.

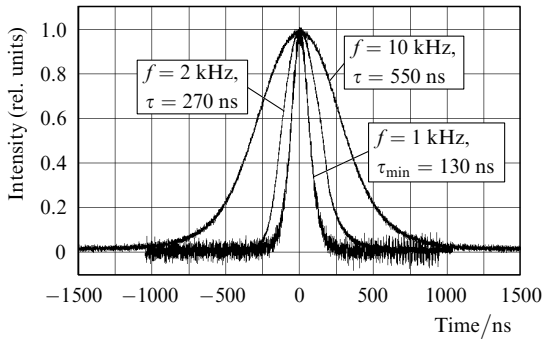

Figure 2. Laser pulse durations at different pulse repetition rates f.

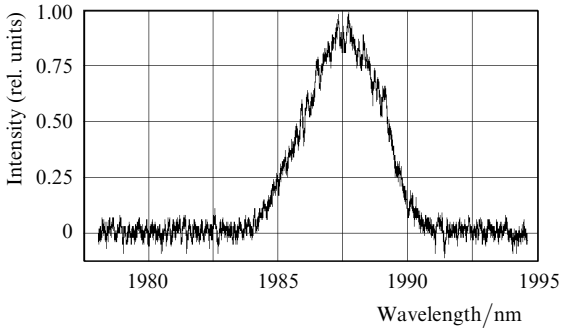

Figure 3. Emission spectrum of the $Tm^{3+}:YAlO_3$ laser.

The minimum laser pulse duration was 130 ns. It was achieved at the pulse repetition rate $f = 1$ kHz. With increasing the Q-switching rate, the laser pulse duration increased to 270 (2 kHz), 400 (5 kHz), and 550 ns (10 kHz) (Fig. 2). The laser wavelength was 1097.5 nm with the FWHM line of 3.4 nm (Fig. 3).

4. Conclusions

Our experiments show the possibility of designing rather efficient (slope efficiency 59 %) lasers operating in the wavelength region near 2 μm under diode pumping into the absorption band 803 – 805 nm. An important feature of this laser is that it operates in the Q-switched regime. The minimum laser pulse duration is 130 ns. The achieved laser output parameters indicate that, at the used pump densities, the up-conversion in this crystal causes no noticeable losses in the population of the upper laser level in the case of high pulse repetition rates (above 2 kHz).

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