

LETTERS

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Passive Fe^{2+} : ZnSe single-crystal *Q* switch for 3-μm lasers

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***Abstract*. Passive *Q*-switching of 3-μm lasers with the help of a Fe^{2+} : ZnSe single crystal is demonstrated. The 6-mJ, 50-ns giant pulses are obtained from a 2.9364-μm Er : YAG laser by using this passive *Q* switch.**

Keywords: *IR lasers, passive Q-switching, Fe^{2+} : ZnSe crystal.*

Mid-IR lasers are widely used in spectroscopy, remote atmosphere probing, medicine, etc. This stimulates the development and improvement of the methods for controlling their operation regimes, in particular, the search for new *Q* switches for generation of giant pulses. *Q*-switched lasers are required, for example, for some medical applications [1].

A 2.9364-μm Er : YAG laser was earlier *Q* switched by using a rotating mirror [2], an electrooptical *Q* switch [3], and a passive water/ethanol *Q* switch [4]. Passive *Q* switches have obvious advantages of compactness and simplicity, the use of solid-state *Q* switches being the most convenient from the technical point of view; and at present an active search for solid-state saturable absorbers for mid-IR lasers is continued.

Chalcogenide crystals doped with transition-metal ions are promising for this purpose. For example, Cr^{2+} : ZnSe and Co^{2+} : ZnSe crystals were successfully used for *Q*-switching of a 1.54-μm erbium glass laser [5] and Cr^{2+} : $Cd_{0.55}Mn_{0.45}Te$ crystals for *Q*-switching of a 2.09-μm Tm, Cr : YAG laser [6]. In our paper, we use for the first time a passive Fe^{2+} : ZnSe crystal *Q* switch in a 2.9364-μm Er : YAG laser.

The *Q* switch was made of a Fe^{2+} : ZnSe single crystal grown from a vapour phase by the free growth method using a single-crystal seed and chemical transport in hydrogen. The crystal was doped with Fe^{2+} ions directly during its growth. Active elements were fabricated from this crystal earlier [7, 8].

Figure 1 shows the absorption spectrum of the crystal at room temperature. The concentration of Fe^{2+} ions measured from this spectrum by using the absorption cross section presented in [9] was $\sim 5 \times 10^{17}$ cm^{-3}. The absorption band in Fig. 1 corresponds to the $^5E \rightarrow {}^5T_2$ vibronic transition in the Fe^{2+} ion. The absorption cross section at 2.9364 μm is 9.5×10^{-19} cm^2, which is approximately 35 times higher than the cross section for the laser transition of the Er^{3+} ion in an yttrium – aluminium garnet. It is known that the lifetime of the $^5T_2$ level decreases with increasing temperature from 105 μs at 120 K to 5 μs at 220 K [9] due to the increase in the rate of multiphonon nonradiative relaxation. Therefore, this lifetime does not exceed 5 μs at room temperature.

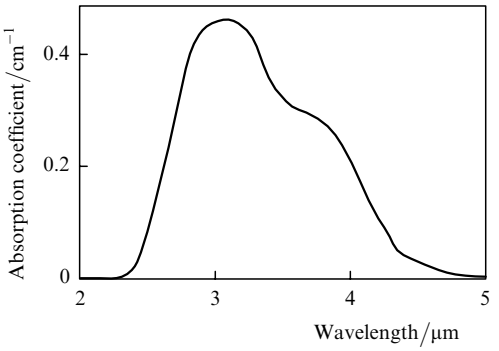

Figure 1. Absorption spectrum of the Fe^{2+} : ZnSe single crystal.

We used a flashlamp-pumped Er : YAG laser for studying the Fe^{2+} : ZnSe passive *Q* switch. The pump-pulse FWHM was 100 μs. The laser resonator had a length of 23 cm and was formed by a plane output mirror with the reflectance of 82 % and a spherical highly reflection mirror ($R = 100$ cm). The active element of size $\varnothing 4 \times 90$ mm with the concentration of erbium ions equal to 50 % was used. The laser emitted the fundamental transverse mode, which was provided by placing a $\varnothing 2.4$-mm aperture between the spherical mirror and active element. The passive *Q* switch in the form of a plane – parallel plate with the initial transmission 85 % was placed at the Brewster angle between the spherical mirror and aperture.

The threshold pump energy in the presence of the passive *Q* switch in the resonator was 19 J. For the pump energy $E_p = 19 - 21$ J, the laser generated single 6-mJ, 50-ns giant

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pulses. For $E_p = 21 - 24$ J, the laser emitted a pair of giant pulses of close energies with a total energy of 13 – 14 mJ, which followed each other after 30 μs. As the pump energy was further increased, the laser began to generate three giant pulses following with an interval of ~ 25 μs. The total output energy in this case was 22 – 23 mJ. The output energy of the free-running laser (without the passive Q switch in the resonator) was 30 mJ for $E_p = 20$ J.

Therefore, we have performed for the first time the passive Q-switching of the Er : YAG laser by means of the saturable Fe^{2+} : ZnSe crystal filter. The conversion efficiency (the ratio of the giant-pulse energy to the output energy of the free-running laser) is 20 %. The broad absorption band of the Fe^{2+} : ZnSe crystal (2.5 – 4.2 μm) makes it a promising material for passive Q switches for mid-IR lasers.

Note in conclusion that Q switches with a higher optical density can be fabricated either by increasing the doping degree (for example, the concentration of Fe^{2+} ions in active elements in [7, 8] was $\sim 10^{18}$ cm^{-3}) or by increasing the filter thickness (we used a 3-mm thick filter, while single crystal of thickness more than 10 mm can be grown).

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