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Room-temperature 1.2-J Fe^{2+} : ZnSe laser

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Abstract. **The characteristics of a laser based on a Fe^{2+} : ZnSe single crystal pumped by an electric-discharge HF laser at room temperature are studied. The HF laser beam diameter on the crystal surface was 17 mm. The achieved laser energy was 1.2 J with an efficiency of ~ 25 % with respect to the pump energy.**

Keywords: *Fe^{2+} : ZnSe laser, electric-discharge HF laser, optical pumping.*

Optically pumped Fe^{2+} : ZnSe lasers (λ = 4 – 5 μm) have attracted interest for many years [1 – 15]. To date, the maximum laser energy (4.9 J) was achieved in [14] upon pumping the crystal cooled to liquid nitrogen temperature by a free-running Er : YAG laser. At room temperature, the lifetime of the upper $^5T_2$ state of Fe^{2+} ions in the ZnSe matrix is approximately 360 ns [8], and, for efficient pumping, one must use short-pulse sources. Ideal sources for this purpose are electric-discharge HF lasers, which have a pulse duration of 100 – 200 ns and almost unlimited energy [16 – 18]. The use of these lasers allowed one to considerably increase the energy of room-temperature Fe^{2+} : ZnSe lasers [10 – 14] compared to the energies achieved upon pumping by solid-state lasers [6, 8, 14, 15]. An energy of 192 mJ was achieved in [12] using a polycristalline Fe^{2+} : ZnSe sample diffusion-doped from two sides (in [19], the energy was increased to 253 mJ as a result of optimisation of the cavity). However, the possibilities of a further improvement of laser characteristics of these crystals [which have a high (~ 10^{19} cm^{-3}) concentration of Fe^{2+} ions in the surface layer at a relatively short length of the active medium] are limited by spurious oscillations typical for disk lasers at large pump beam spots. An obvious solution of this problem is to increase the length of the active medium with a simultaneous decrease in the Fe^{2+} concentration [11, 12, 19]. These properties are characteristic of Fe^{2+} : ZnSe single crystals grown by chemical vapour transport in hydrogen on a single crystal seed with simultaneous doping during the growth [Fe^{2+} concentration (1.5 – 2.5) × 10^{18} cm^{-3}] [3, 8, 14]. The aim of the present work was to study the possibility of a further increase (compared to [12, 19]) in the energy of Fe^{2+} : ZnSe lasers based on such crystals by increasing the pump spot size.

The scheme of the experimental setup is shown in Fig. 1. A crystal 27 mm in diameter and 15 mm in thickness was placed in a cavity 60 mm long, which was formed by plane mirrors M1 and M2. The transmission coefficient of M1 at the pump wavelengths was 84.2 %, while the reflection coefficient in the spectral range 4 – 5 μm exceeded 99 %. The reflection coefficient of M2 at the laser and pump wavelengths was 80 % and 95.8 %, respectively. The HF laser [10 – 12] radiation attenuated by filter F1 was focused by lens L on the crystal surface into a spot 17 mm in diameter (~ 90 % of the energy). Filter F2 was used to cut off the pump radiation passed through the cavity. The energies of the HF and Fe^{2+} : ZnSe lasers were measure by C1 (Molectron) and C2 (Gentec-EO) calorimeters, respectively. The crystal transmission at the pump wavelengths in the presence of lasing was measured in a separate experiment. We used an optical scheme with inclined incidence of the pump beam on the crystal surface similar to the scheme used in [12]. The transmission increases with increasing pump energy density W and reaches saturation at $W \approx 1$ J cm^{-2}. At $W > 1$ J cm^{-2}, the transmission under our experimental conditions was ~ 21 % (Fe^{2+} concentration 1.5 × 10^{18} cm^{-3}).

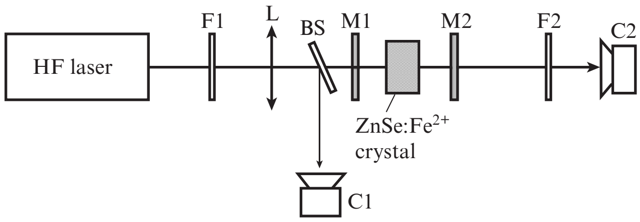

Figure 1. Experimental scheme: (M1, M2) cavity mirrors; (F1, F2) optical filters; (L) BaF_2 lens; (BS) MgF_2 beam-splitting plate; (C1, C2) calorimeters.

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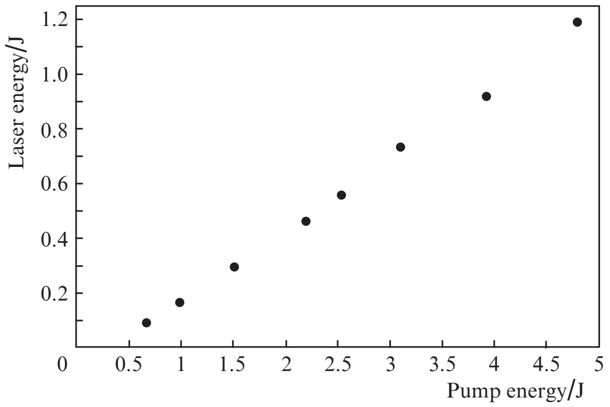

Figure 2. Dependence of the Fe^{2+}:ZnSe laser energy on the HF laser energy incident on the crystal surface.

Figure 2 shows the dependence of the laser energy on the HF laser energy incident on the sample. The maximum laser energy in the reported experiment was 1.2 J at an efficiency of ~25% with respect to the incident energy.

Thus, a decrease in the dopant concentration with a simultaneous increase in the length of the active medium compared to diffusion-doped polycrystals, which was implemented in the crystal studied in the present work, did allow us to considerably increase the Fe^{2+}:ZnSe laser energy by increasing the pump spot size and, hence, the pump energy.

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