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Room-temperature high-energy Fe^{2+} : ZnSe laser

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Abstract. **The characteristics of a room-temperature laser based on a polycrystalline Fe^{2+} : ZnSe sample pumped by a non-chain HF laser are studied. The laser energy is $E = 175$ mJ at the efficiencies with respect to the incident and absorbed pump energy $\eta_p \approx 22\%$ and $\eta_{abs} \approx 29\%$, respectively.**

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

Since the first publication on a Fe^{2+} : ZnSe laser with optical pumping [1], these lasers attract persistent interest [2–10]. To date, the highest energy of the Fe^{2+} : ZnSe laser $E = 2.1$ J at the efficiency with respect to the absorbed pump energy (pumping by a free-running Er : YAG laser) $\eta_{abs} \approx 40\%$ is obtained at $T = 85$ K [8]. Under the same pumping, the values E and η_{abs} obtained at room temperature are 42 mJ and about 0.9%, respectively [8]. The low efficiency in this case is explained by a decrease in the lifetime of the upper laser level with increasing temperature. To achieve satisfactory efficiencies at $T > 245$ K, it is necessary to excite the crystal by short pulses [2, 3, 5–7], but the energy of Fe^{2+} : ZnSe lasers in this case is limited by the low energies of Q-switched solid-state lasers used for pumping (wavelengths $\lambda = 2.92$ and 2.8 μm) (for example, 35 mJ [6]). In the case of short pump pulses and room temperature, the maximum E and the slope efficiency with respect to the absorbed energy η_{sl} were 6 mJ and approximately 39% [9].

Non-chain electric-discharge HF lasers ($\lambda = 2.6–3.1$ μm) with a pulse duration of ~ 150 ns have almost no limitations on the laser energy and, in addition, can operate with high pulse repetition rates [11]. In [10], this laser was used in a scheme with transverse pumping of a crystal doped with Fe^{2+} ions in a thin (~100 μm) subsurface layer [4]. At room temperature, the energy E was 30.6 mJ at the efficiency with respect to the pump energy $\eta_p \approx 3.1\%$.

The aim of this work is to study the possibility of increasing the output energy and efficiency of a room-temperature Fe^{2+} : ZnSe laser pumped by a non-chain HF laser in the case of using a ZnSe active element with bulk doping by Fe^{2+} ions.

The Fe^{2+} : ZnSe sample was made from polycrystalline ZnSe grown by chemical vapour deposition (CVD) in the reaction of Zn and HSe vapours in an Ar flow. The plates cut from this material 20 mm in diameter and 4.5 mm thick were mechanically ground and polished. The method of doping ZnSe crystals with Fe did not considerably differ from the method of doping with Cr [12]. Both surfaces of the plate were coated with Fe films no thicker than 1 μm by electron-beam deposition. The plate was annealed for seven days at $T = 1000 \pm 2$ °C in a sealed quartz tube filled with hydrogen, after which it was chemically-mechanically polished.

The experimental scheme is shown in Fig. 1. The Fe^{2+} : ZnSe laser cavity 120 mm long is formed by a concave mirror M_1 (gold coating) with the curvature radius $R = 1$ m and an output mirror M_2 in the form of a plane-parallel silicon plate 4 mm thick. The Fe^{2+} : ZnSe sample was placed perpendicular to the optical axis of the cavity at a distance of 40 mm from the output mirror. The radiation of a non-chain HF laser with the pulse full width at half maximum $\tau \approx 130$ ns [9] was attenuated by optical filters F and focused on the plate surface by a spherical lens L to an elliptical spot with the axes of 6.8 and 7.5 mm. The angle of incidence of pump radiation on the active element surface was ~20°. The HF laser radiation energy E_p incident on the sample, the pump energy passed through the sample, and the Fe^{2+} : ZnSe laser output energy were measured by calorimeters C_1, C_2, and C_3 (Molectron), respectively. To control the shape of pulses of the Fe^{2+} : ZnSe and HF lasers, we replaced calorimeters C_1 and C_3 by photodetectors (Vigo-system Ltd) with a time resolution of ~ 1 ns.

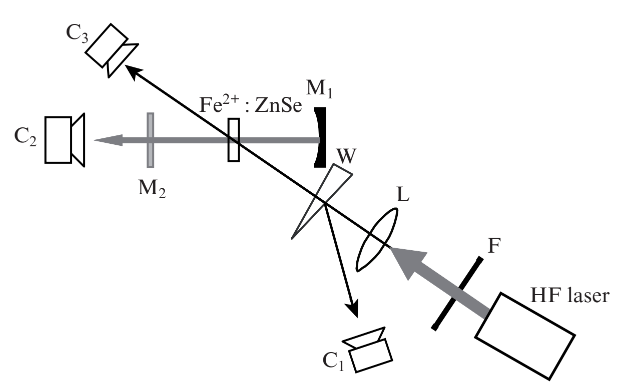

Figure 1. Experimental scheme: (W) BaF_2 wedge; (C_1, C_2, C_3) calorimeters; (F) calibrated optical filter; (L) spherical lens; (Fe^{2+} : ZnSe) active element; (M_1, M_2) mirrors of the Fe^{2+} : ZnSe laser cavity.

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The transmission of the Fe^{2+}:ZnSe plate at the HF laser wavelengths under lasing conditions varied from 4% to 7.1% as the pump energy density changed from 0.2 to 2.8 J cm^{-2}.

The dependence of the Fe^{2+}:ZnSe laser energy E on the pump energy E_p is shown in Fig. 2. The maximum obtained energy was E = 175 mJ at the efficiencies $\eta_p \approx 22\%$, $\eta_{abs} \approx 29\%$ and $\eta_{sl} \approx 32\%$. The Fe^{2+}:ZnSe laser pulse full width at half-maximum at high pump energies was ~ 90 ns. The possibility of a further increase in the laser energy is limited by two factors, namely, by the threshold of the sample surface breakdown by the pump radiation (~ 3 J cm^{-2}) and by the radiative losses in the direction perpendicular to the optical axis at large pump spots, which are typical for lasers with disk active elements. Probably, it will be possible to somewhat increase the laser energy by optimising the cavity parameters. In conclusions, note that the Fe^{2+}:ZnSe laser energies obtained by us at room temperature considerably exceed the values achieved to date.

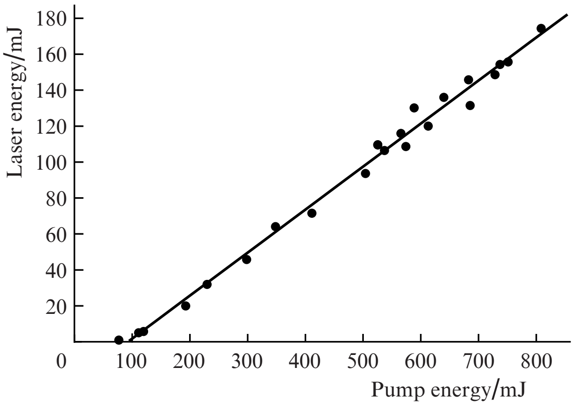

Figure 2. Dependence of the Fe^{2+}:ZnSe laser energy on the pump energy.

References

1. Adams J.J., Bibeau C., Page R.H., et al. *Opt. Lett.*, **24** (23), 1720 (1999).
2. Kernal J., Fedorov V.V., Gallian A., et al. *Opt. Express*, **13** (26), 10608 (2005).
3. Akimov V.A., Voronov A.A., Kozlovskii V.I., et al. *Kvantovaya Elektron.*, **36** (4), 299 (2006) [*Quantum Electron.*, **36** (4), 299 (2006)].
4. Il'ichev N.N., Danilov V.P., Kalinushkin V.P., et al. *Kvantovaya Elektron.*, **38** (2), 95 (2008) [*Quantum Electron.*, **38** (2), 95 (2008)].
5. Doroshenko M.E., Jelinkova H., Koranda J., et al. *Laser Phys. Lett.*, **7** (1), **39** (2010).
6. No Soung Myoung, Martyshkin D.V., Fedorov V.V., Mirov S.B. *Opt. Lett.*, **36** (1), 94 (2011).
7. Doroshenko M.E., Jelinkova H., Sulc J., et al. *Laser Phys. Lett.*, **9** (4), 301 (2012).
8. Frolov M.P., Korostelin Yu.V., Kozlovsky V.I., et al. *Laser Phys. Lett.*, **10**, 125001 (2013).
9. Kozlovsky V.I., Akimov V.A., Frolov M.P., et al. *Phys. Status Sol. B*, **247** (6), 1553 (2010).
10. Velikanov S.D., Danilov V.P., Zakharov N.G., et al. *Kvantovaya Elektron.*, **44** (2), 141 (2014) [*Quantum Electron.*, **44** (2), 141 (2014)].
11. Apollonov V.V., Belevtsev A.A., Kazantsev S.Yu., et al. *Kvantovaya Elektron.*, **32** (2), 95 (2002) [*Quantum Electron.*, **32** (2), 95 (2002)].
12. Rodin S.A., Balabanov S.S., Gavrishchuk E.M., Eremeikin O.N. *Opt. Zh.*, **80** (5), 89 (2013).