$ZnMgSe:Cr^{2+}$ — a new active medium for lasers of middle IR

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For the first time, laser generation is obtained in $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ single crystal. It is established that wavelength tuning in this laser can be realized in 2.2–2.6 μm region. The optical, luminescent and generation characteristics of the new active laser medium are studied and compared with the corresponding characteristics of $ZnSe:Cr^{2+}$ single crystal.

Впервые получена лазерная генерация в монокристалле $Zn_{0,75}Mg_{0,25}Se:Cr^{2+}$. Перестройка длины волны генерации может осуществляться в диапазоне 2,2–2,6 мкм. Изучены оптические, люминесцентные и генерационные характеристики новой активной лазерной среды и проведено их сравнение с характеристиками монокристаллов $ZnSe:Cr^{2+}$.

As reported in [1], $Zn_{1-x}Mg_xSe:Cr^{2+}$ single crystals can be used as a new thermostable material for active elements of tunable lasers for middle IR region, with a generation band shifted towards longer wavelengths with respect to that of $ZnSe:Cr^{2+}$ lasers being under active investigation and development [2–5]. Firstly $ZnMgSe:Cr^{2+}$ samples were obtained by diffusion doping of 10×10×1 mm^3 $Zn_{0.79}Mg_{0.21}Se$ single crystal samples with chromium diffusing from vapor phase in evacuated and sealed quartz ampoules at 1250 K during 120 hours [1].

In this work, the optical, luminescence and generation properties of $Zn_{0.75}Mg_{0.25}Se$ crystals activated with chromium ions immediately in the growing process (the chromium concentration is $4\cdot10^8$ cm^{-3}) are studied for the first time. $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ single crystal boules of 20 mm in diameter and 80 mm length were grown by the vertical Bridgman method in graphite crucibles under inert gas pressure. The determined characteristics of these crystals were compared with those of $ZnSe:Cr^{2+}$ crystals grown by the Bridgman method.

The optical transmission spectra of $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ and $ZnSe:Cr^{2+}$ single crystals measured by a PerkinElmer Spectrum One FT-IR Fourier spectrometer and a Shimadzu spectrophotometer show that the maximum in the Cr^{2+} ion absorption spectra of the $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ crystal (1.855 μm) is shifted towards longer wavelengths as compared to that of the other crystal (1.770 μm). This fact suggests that $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ is a material of promise for pumping by lasers with the generation

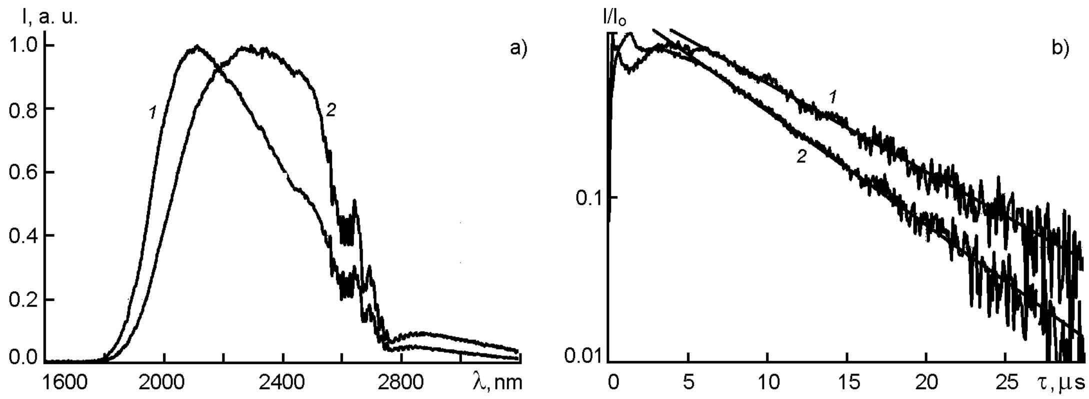

Fig. 1. Luminescence spectra of Cr^{2+} ions (a) and luminescence decay kinetics of Cr^{2+} ions (b) in ZnSe:Cr^{2+} (*1*) and $Zn_{0.75}Mg_{0.25}Se$:Cr^{2+} (*2*) crystals.

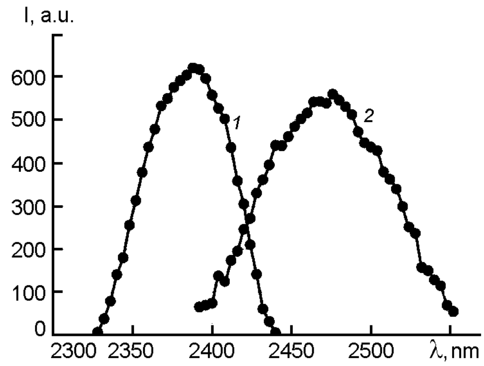

Fig. 2. Spectra of Cr^{2+} generation in ZnSe:Cr^{2+} (*1*) and ZnMgSe:Cr^{2+} (*2*) crystals in non-selective resonator.

wavelength of 1.9–2.1 μm (e.g. by those based on Tm^{3+} ions with diode pumping).

The luminescence spectrum of Cr^{2+} ions in ZnMgSe crystal is also shifted towards longer wavelengths as compared to that of ZnSe (Fig. 1a). Such a shift in the luminescence and absorption spectra may be caused by the fact that the crystal field in ZnMgSe is weaker than in ZnSe. The presented spectra measured under the same conditions were excited by YAG:Nd^{3+} laser with the generation wavelength of 1.32 μm. As a receiver, InSb was used cooled down to liquid nitrogen temperature. Both spectra were not corrected for the spectral sensitivity of the measuring system. The luminescence decay kinetics was also measured under YAG:Nd^{3+} laser excitation at the same generation wavelength (Fig. 1b), but in this case the laser worked in the modulated Q-factor mode, the generation pulse duration being approximately 100 ns.

The measured data on the luminescence decay kinetics of Cr^{2+} in ZnMgSe and ZnSe (Fig. 1b) testify that the lifetime of Cr^{2+} ions in the ZnMgSe crystal is shorter than in ZnSe one (6.3 μs and 8.1 μs, respectively).

The generation properties were studied under pumping by a pulsed YAP:Er^{3+} laser (the generation wavelength 1.66 μm) working in the free generation mode. The output characteristics of the Cr^{2+} lasers were examined both in non-selective and selective resonator. The non-selective resonator was formed by two plane mirrors with the rear one having 100 % reflection at the generation wavelength and about 80 % transmission at the pumping wavelength, while the output mirrors had various transmission at the pumping wavelength. The selective resonator was obtained by placing a 60° dispersing CaF_2 prism inside the non-selective resonator.

The output characteristics of the $Zn_{0.75}Mg_{0.25}Se$:Cr^{2+} laser were measured depending on the absorbed pumping energy. For that crystal, the differential generation efficiency did not exceed 15 %, obviously due to insufficiently good treatment of the sample.

In Fig. 2, shown are the spectra of Cr^{2+} ion generation in the ZnSe:Cr^{2+} and ZnMgSe:Cr^{2+} crystals. According to the presented data obtained under the same conditions (pumping, optical resonator configuration, mirrors), the generation spectrum for ZnMgSe:Cr^{2+} crystal (the generation band maximum at $\lambda = 2.475$ μm) is shifted towards longer wavelengths as compared to that of ZnSe:Cr^{2+} (the generation band maximum at $\lambda = 2.390$ μm).

With the dispersion prism placed inside the optical resonator, there was attained the tuning of the output generation wavelength

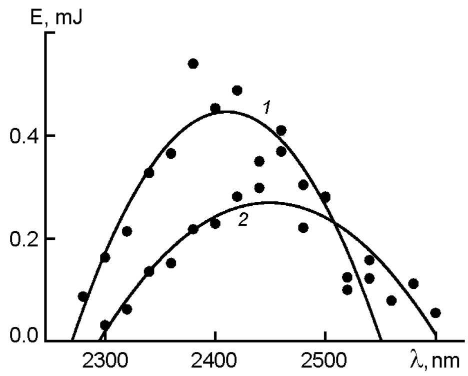

Fig. 3. Tuning curves of laser generation in $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ crystal at different output windows of the optical resonator: *1* – R=60 %, *2* – R= 75%.

for $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ laser in 2.2–2.6 μm range (Fig. 3).

It should be noted that, in comparison with all the known $A^{II}B^{VI}$ type compounds (ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, $Cd_{0.9}Zn_{0.1}Te$, $Cd_{0.65}Mg_{0.35}Te$, $Cd_{0.85}Mn_{0.15}Te$, $Cd_{0.55}Mn_{0.45}Te$) doped with Cr^{2+} ions and being used as active media for tunable lasers of middle infrared region [6], the new active material $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$ has the longest wavelength of the generation band maximum.

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ZnMgSe:Cr^{2+} – нове активне середовище для лазерів середнього ІЧ діапазону

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Вперше отримано лазерну генерацію у монокристалі $Zn_{0.75}Mg_{0.25}Se:Cr^{2+}$. Перестроювання довжини хвилі генерації такого лазера можна здійснювати у діапазоні 2,2–2,6 мкм. Досліджено оптичні, люмінесцентні та генераційні характеристики нового активного лазерного середовища та проведено їх порівняння з характеристиками монокристалів ZnSe:Cr^{2+}.