Novel material for active elements of lasers tunable in 4–5 μm range: Fe^{2+}:$Zn_{1-x}Mg_xSe$ single crystals

Yu.A.Zagoruiko, N.O.Kovalenko, O.A.Fedorenko, A.S.Gerasimenko

Institute for Single Crystals, STC "Institute for Single Crystals", National Academy of Sciences of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine

Received August 19, 2010

As a new laser material for active elements of tunable lasers for mid IR region (4–5 μm), $Zn_{1-x}Mg_xSe$ ($0.11<x<0.42$) single crystals doped with Fe^{2+} ions are proposed. The optical absorption spectra of Fe^{2+}:$Zn_{0.89}Mg_{0.11}Se$ and Fe^{2+}:$Zn_{0.69}Mg_{0.31}Se$ samples contain intense absorption bands peaked at 3.212 and 3.374 μm, respectively. The absorption band maximum of the wideband semiconductor laser material Fe^{2+}:$Zn_{1-x}Mg_xSe$ shifts towards longer wavelengths as the magnesium concentration in the crystal matrix increases.

В качестве нового лазерного материала для активных элементов перестраиваемых лазеров среднего ИК диапазона (4–5 мкм) предложены монокристаллы $Zn_{1-x}Mg_xSe$ ($0,11<x<0,42$), легированные ионами Fe^{2+}. Спектры оптического поглощения образцов Fe^{2+}:$Zn_{0.89}Mg_{0.11}Se$ и Fe^{2+}:$Zn_{0.69}Mg_{0.31}Se$ характеризуются полосами сильного поглощения с максимумами соответственно 3,212 и 3,374 мкм. Положение максимума полосы поглощения широкозонного полупроводникового лазерного материала Fe^{2+}:$Zn_{1-x}Mg_xSe$ смещается в длинноволновую область с увеличением концентрации магния в кристаллической матрице.

In modern material science, a great deal of attention is given to new class of laser crystals intended for active elements of tunable lasers for mid IR range (2–5 μm). Such materials are obtained by doping the crystals of $A^{II}B^{VI}$ binary compounds and the solid solutions thereof with transition metal ions (Cr^{2+}, Fe^{2+}, Co^{2+}, etc.) [1, 2]. The Cr^{2+}:ZnSe and Fe^{2+}:ZnSe crystals are studied most comprehensively [1–3]. For the 4–5 μm wavelength range, a laser medium of promise is the Fe^{2+}:ZnSe crystal with Fe^{2+} ion concentration of about 10^{18} cm^{-3}. The continuous tuning of Fe^{2+}:ZnSe lasers within the 3.77–4.40 μm spectral range in a prismatic dispersion resonator has been realized in [2].

In [4], we have first reported the application possibility of Cr-doped $Zn_{1-x}Mg_xSe$ single crystals (being more thermostable and wider band as compared to ZnSe) for active elements of the mid-IR tunable lasers. The generation characteristics and parameters of such lasers have been studied in [5] taking Cr^{2+}:$Zn_{0.76}Mg_{0.24}Se$ as an example. It has been found that the generation band maximum in the new thermostable wideband semiconductor hexagonal material Cr^{2+}:$Zn_{1-x}Mg_xSe$ is at 2.47 μm wavelength, thus exceeding the corresponding parameter of all the known active media based on $A^{II}B^{VI}$ binary compounds and the solid solutions thereof doped with Cr^{2+}:ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, $Cd_{0.9}Zn_{0.1}Te$, $Cd_{0.65}Mg_{0.35}Te$, $Cd_{0.85}Mn_{0.15}Te$, $Cd_{0.55}Mn_{0.45}Te$. In continuation of studies [4, 5], $Zn_{1-x}Mg_xSe$ ($0.11<x<0.42$) single crystals are proposed in this work as a new active laser meduim.

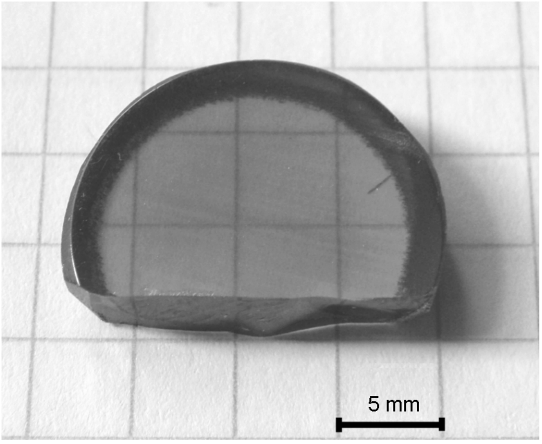

Fig. 1. The appearance of a Fe^{2+}:$Zn_{1-x}Mg_xSe$ single crystal sample.

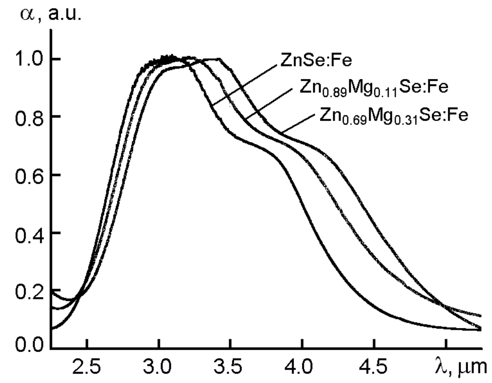

Fig. 2. Optical absorption spectra of crystals: Fe^{2+}:ZnSe (*1*), Fe^{2+}:$Zn_{0.89}Mg_{0.11}Se$ (*2*) and Fe^{2+}:$Zn_{0.69}Mg_{0.31}Se$ (*3*).

The raw blend for the crystal growth consisted of polycrystalline ZnSe, MgSe, and FeSe compounds. The Fe^{2+}:$Zn_{1-x}Mg_xSe$ single crystals with iron concentration of $2 \cdot 10^{-2}$ wt. % having 23 mm in diameter and 50 mm height were grown using the vertical Bridgman technique in graphite crucibles under excess argon pressure (Fig. 1). In Fig. 2, presented are the optical absorption spectra of Fe^{2+}:ZnSe and Fe^{2+}:$Zn_{1-x}Mg_xSe$ samples calculated from their optical transmission spectra taking into account the corresponding refractive indices. The transmission spectra were measured using a Perkin Elmer Spectrum One FT-IR. The data for the Fe^{2+}:ZnSe sample are presented for comparison.

As is seen in Fig. 2, the optical absorption spectra of Fe^{2+}:$Zn_{0.89}Mg_{0.11}Se$ and Fe^{2+}:$Zn_{0.69}Mg_{0.31}Se$ crystals are characterized by intense absorption bands with maxima at at 3.21 and 3.37 μm, respectively, due to the Fe^{2+} ions present in the crystal matrix. As to Fe^{2+}:ZnSe, the absorption band maximum is at 3.106 μm. The presence of those absorption bands evidences a possibility to use the Fe^{2+}:$Zn_{1-x}Mg_xSe$ crystals as a new thermostable material for active elements for the mid-IR tunable lasers with the generation band shifted towards longer wavelengths as compared to that of Fe^{2+}:ZnSe. The position of the absorption band maximum of the wideband semiconductor laser material Fe^{2+}:$Zn_{1-x}Mg_xSe$ depends on the magnesium concentration in the matrix, being shifted towards longer wavelengths at increasing Mg concentration.

The results obtained are of a practical interest, because those show a possibility to shift the generation band of tunable Fe^{2+}:$Zn_{1-x}Mg_xSe$ lasers towards longer wavelengths (by approx. 0.27 μm) and to extend the tuning spectral range thereof, similarly to the facts observed for the Cr^{2+}:$Zn_{0.76}Mg_{0.24}Se$ crystal [4–6].

References

1. I.T.Sorokina, *Opt. Mater.*, **26**, 395 (2004).
2. V.A.Akimov, A.A.Voronov, V.I.Kozlovsky et al., *Kvantovaya Elektronika*, **34**, 879 (2004).
3. M.E.Doroshenko, P.Koranda, H.Jelinkova et al., *Laser Phys. Lett.*, **4**, 503 (2007).
4. Yu.A.Zagoruiko, N.O.Kovalenko, O.A.Fedorenko, et al., *Functional Materials*, **15**, 247 (2008).
5. Yu.A.Zagoruiko, N.O.Kovalenko, V.M.Puzikov et al., *Functional Materials*, **16**, 329 (2009).
6. E.Sorokin, V.K.Komar, V.M.Puzikov et al., in: Abstr. 14th Int. Conf. "Laser Optics 2010", St.Petersburg, Russia (2010).

Монокристали $Fe^{2+}:Zn_{1-x}Mg_xSe$ — новий матеріал для активних елементів лазерів з перестроюванням у діапазоні 4–5 мкм

Ю.А.Загоруйко, Н.О.Коваленко,
О.А.Федоренко, А.С.Герасименко

Як новий лазерний матеріал для активних елементів лазерів з перестроюванням довжини хвилі випромінювання у середньому ІЧ діапазоні (4–5 мкм) запроновано монокристали $Zn_{1-x}Mg_xSe$ ($0,11<x<0,42$), леговані іонами Fe^{2+}. Спектри оптичного поглинання зразків $Fe^{2+}:Zn_{0.89}Mg_{0.11}Se$ та $Fe^{2+}:Zn_{0.69}Mg_{0.31}Se$ характеризуються смугами сильного поглинання з максимумами відповідно 3,212 та 3,374 мкм. Положення максимуму смуги поглинання широкозонного напівпровідникового лазерного матеріалу $Fe^{2+}:Zn_{1-x}Mg_xSe$ зсувається у довгохвильову область з підвищенням концентрації магнію у кристалічній матриці.