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SPECTROSCOPY OF Tm:KY(WO_4)$_2$ CRYSTAL GROWN BY THE MODIFIED CZOCHRALSKI METHOD

Gusakova N.[1], Gorbachenya K.[1], Kisel V.[1], Yasukevich A.[1], Guretskii S.[2], Trukhanova E.[2], Kravtsov A.[2], Karpinsky V.[2], Ozen Y.[3], Ozcelik S.[3, 4], Kuleshov N.[1]

[1]Center for Optical Materials and Technologies of Belarusian National Technical University
[2]Scientific and Practical Materials Research Center NAS Belarus
Minsk, Belarus
[3]Photonics Application & Research Center, Gazi University
[4]Photonics Department of Applied Science Faculty, Gazi University
Ankara, Turkey

Abstract. Tm^{3+}:KY(WO_4)$_2$ (KYW) single crystals were grown by the modified Czochralski method. Laser-related spectroscopic properties of Tm^{3+}:KYW crystal: absorption and luminescence spectra as well as kinetics of luminescence decay were studied.

Key words: tungstate crystals, thulium, laser-related spectroscopy.

СПЕКТРОСКОПИЧЕСКИЕ СВОЙСТВА КРИСТАЛЛОВ Tm:KY(WO_4)$_2$, ВЫРАЩЕННЫХ МОДИФИЦИРОВАННЫМ МЕТОДОМ ЧОХРАЛЬСКОГО

Н.В. Гусакова[1], К.Н. Горбаченя[1], В.Э. Кисель[1], А.С. Ясюкевич[1], С.А. Гурецкий[2], Е.Л. Труханова[2], А.В. Кравцов[2], Д.В. Карпинский[2], И. Ожен[3], С. Ожелик[3,4], Н.В. Кулешов[1]

[1]Центр оптических материалов и технологий БНТУ
[2]Научно-практический центр материаловедения НАН Беларуси
Минск, Беларусь
[3]Научно-практический центр фотоники, Университет Гази
[4]Отделение фотоники факультета прикладных наук Университета Гази
Анкара, Турция

Аннотация. Кристаллы Tm^{3+}:KY(WO_4)$_2$ (KYW) были выращены модифицированным методом Чохральского. Проведено исследование спектрально-люминесцентных свойств кристаллов Tm:KYW. Зарегистрированы спектры поглощения и люминесценции, исследована кинетика затухания люминесценции.

Ключевые слова: кристаллы вольфраматов, тулий, спектрально-люминесцентные свойства.

Laser sources emitting in the 1.9–2 μm spectral range are of high interest for a variety of practical applications in medicine, remote sensing, micro structuring of semiconductor materials, and pumping of optical parametrical oscillators. Interest in thulium-doped crystals is particularly caused by the availability of powerful AlGaAs diode pump sources and cross-relaxation process $^3H_6 + ^3H_4 \rightarrow ^3F_4 + ^3F_4$ leading to efficient excitation of $^3F_4$ laser level thus increase the quantum efficiency of the systems. Monoclinic potassium double tungstate crystals activated with thulium ions attract attention due to relatively high absorption and emission cross-section, broad emission bands, and the possibility to grow highly activated crystals [1].

The growth of KYW crystals has been carried out at temperatures below the point of the phase transition (900–985 ºC) using the oriented crystal seed which gradually pull up upon slow cooling of the solution- melt. The details of KYW single crystals growth were presented in [2]. The photograpgh of the Tm:KYW single crystal grown by the modified Czochralski method is demonstrated in Fig. 1.

The polarized absorption spectra obtained for the Tm^{3+} – doped KYW crystal at room temperature were registered by a Varian CARY-5000 spectrophotometer in the spectral ranges 750–850 nm and 1500–2100 nm with the spectral bandwidth of 0.3 nm and 1 nm, respectively. Two polished plates with dimensions of 5×7×2 mm^3 oriented along three principal optical indicatrix axes *N*g, *N*m, and *N*p were used. The concentration of doping ions in the crystal was determined to be $1.9\cdot10^{26}$ m^3 (~3 at.%).

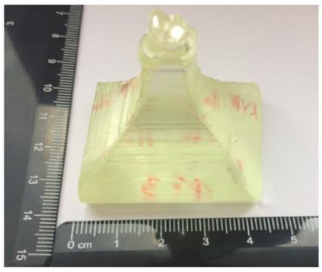

Figure 1 – Photograph of the 3% Tm doped KYW single crystal

The room-temperature polarized absorption cross-section spectra of the Tm:KYW crystal in the spectral range of 750–850 nm ($^3H_6 \rightarrow ^3H_4$ transition) are shown in Fig. 2. The Tm:KYW crystal belongs to monoclinic crystallographic system and consequently it is bi-axial optical system. The polarized $^3H_6 \rightarrow ^3H_4$ absorption spectra were measured parallelly to adequate indicatrix axes. The maximum absorption cross-section of $6.4\cdot10^{20}$ cm^2 was determined at 794 nm with a bandwidth (FWHM) of 2.2 nm for light polarization E//*N*p axis. The slightly lower value of $5.4 \cdot 10^{20}$ cm^2 at 802 nm was found for E//*N*m polarization.

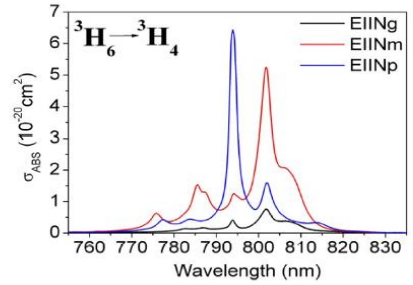

Figure 2 – Polarized absorption cross-section spectra of Tm:KYW crystal at near 800 nm

Absorption cross-section spectra of Tm^{3+} ions in KYW at near 1.75 μm at room temperature are presented in Fig. 3.

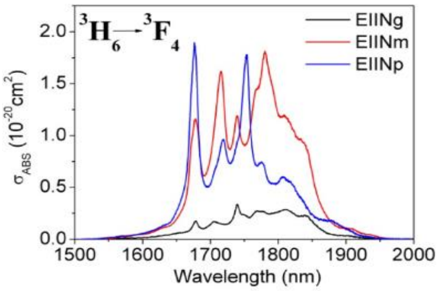

Figure 3 – Polarized absorption cross-section spectra of Tm:KYW crystal at near 1750 nm

Two prominent components located at 1676 nm and 1752 nm as well as three intense components located at 1678, 1715, and 1780 nm can be recognized for the E*IINp* and E*IINm* spectra, respectively. In contrast to these both polarizations, the E*IINg* spectrum is characterized by significantly lower value of the absorption cross-section $0.33 \cdot 10^{20}$ cm^2 at 1740 nm.

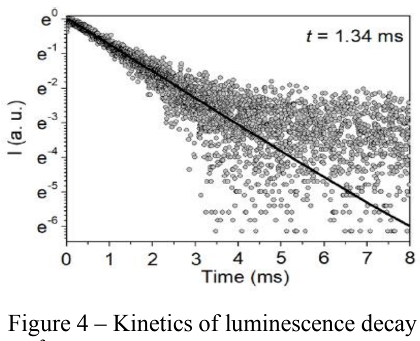

Figure 4 – Kinetics of luminescence decay of the $^3F_4$ level of Tm:KYW crystal in the region of about 1.75 μm

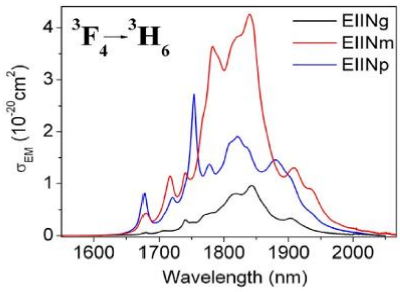

Figure 5 – Polarized emission cross-section spectra of the Tm:KYW crystal in the spectral range of 1500–2100 nm

The luminescence decay time of the $^3F_4$ level was estimated to be 1.34±0.05 ms. The luminescence decay of the $^3F_4$ level of Tm:KYW crystal in the region of about 1.75 μm is presented in the Fig. 4. Emission cross-section spectra of Tm:KYW corresponding to the $^3F_4 \to {}^3H_6$ transition calculated using modified reciprocity method [3] are presented in Fig. 5. The stimulated emission cross-section is most efficient for E*IINm* polarization and maximal value of $\sigma_{em} = 4.2 \cdot 10^{20}$ cm^2 was found at 1840 nm. The substantially lower peak values of emission cross-sections were estimated at 1753 nm ($2.7 \cdot 10^{20}$ cm^2) and at 1843 nm ($0.9 \cdot 10^{20}$ cm^2) for E*IINp* and E*IINg* polarizations, respectively.

In conclusion, high quality Tm^{3+}:KYW single crystals were grown by the modified Czochralski method. The optical characterization of the crystal and determined absorption and emission cross-section spectra indicated high structural and optical quality of the single crystal.

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References

1. Gaponenko, M. Efficient diode-pumped Tm:KYW 1.9- μm microchip laser with 1 W cw output power / M. Gaponenko, N. Kuleshov, T. Sudmeyer // Opt. Express, 2014. – Vol. 22. – P. 11578–11582.

2. Guretskii, S.A. Tm^{3+}:$KY(WO_4)_2$ single crystals: controlled growth and spectroscopic assessment / S. A. Guretskii [et al.] // Opt. Mat. – 2021. – Vol. 120. – P. 111451.

3. Yasyukevich, A. S. Integral method of reciprocity in the spectroscopy of laser crystals with impurity centers / A. S. Yasyukevich // Journal of Applied Spectroscopy. – 2004. – Vol. 71, № 2. – P. 202–208.