

Growth and spectroscopy of new laser crystals $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$

M.B.Kosmyna, B.P.Nazarenko, V.M.Puzikov, A.N.Shekhovtsov, A.S.Yasukevich*, N.V.Kuleshov*, A.E.Gulevich*, M.P.Demesh*, N.V.Gusakova*

Institute for Single Crystals, STC "Institute for Single Crystals", National Academy of Sciences of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine
*Center for Optical Materials and Technologies, Belarusian National Technical University, 65 Nezavisimosty Ave., 220013 Minsk, Belarus

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$Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$ single crystals have been grown for the first time. Absorption and luminescence spectra, luminescence decay kinetics of $^2F_{5/2}$ level for Yb^{3+} ion are investigated.

Впервые выращены монокристаллы $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$. Изучены спектры поглощения, люминесценции и кинетика затухания люминесценции уровня $^2F_{5/2}$ иона Yb^{3+}.

Double vanadate single crystals with a "whitlokite" type structure are effective media for second harmonic generation of laser radiation [1–4]. The present study is motivated by search for new crystal hosts for non linear optics and lasers, and continues the works of the authors [5, 6] concerned with the growth of new double vanadate single crystals and investigation of their properties.

The charge for growing $Ca_{10}K(VO_4)_7$ single crystals was synthesized by the solid phase technique. Yb^{3+} — doping was carried out in correspondence with the stoichiometric composition. The compound was formed according to the reaction:

$$10CaCO_3 + 3.5V_2O_5 + 0.05KCO_3 + 0.15Yb_2O_3 \rightarrow$$

$$Ca_{10}K_{0.1}Yb_{0.3}(VO_4)_7 + 10.05CO_2\uparrow.$$

The double vanadate single crystals were grown by the Czochralski method using an inert atmosphere and iridium crucibles. For the growth process, an automatic "Crystal 3M" set up equipped with a weight control system was used. The procedures of charge synthesis and crystal growth are described in detail in [5]. The pure and Yb-doped double vanadate crystals had a diameter up to 20 mm and a length up to 50 mm, and did not contain gas bubbles and cracks in their bulk (Fig. 1).

The absorption spectra of $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$ crystal in polarized

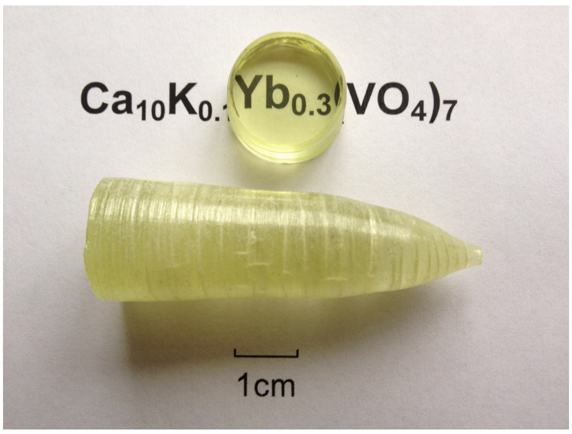

Fig. 1. Photograph of the $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$ single crystal.

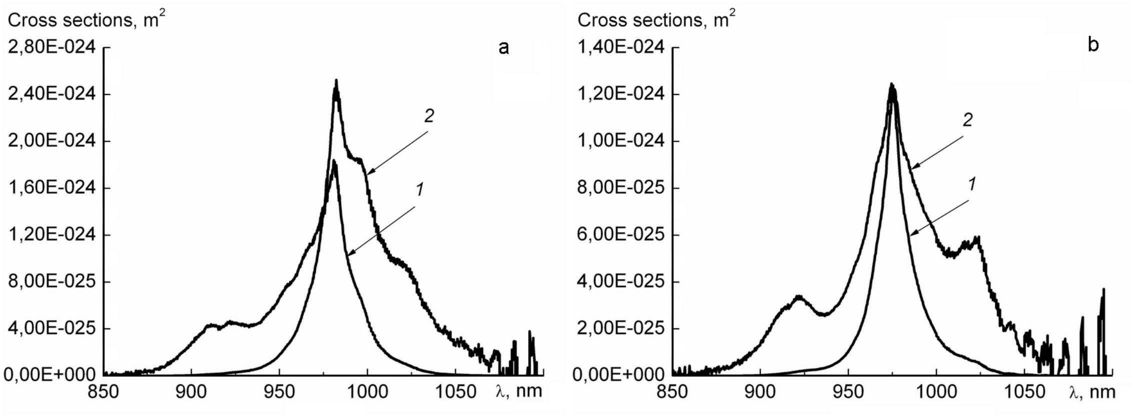

Fig. 2. Absorption cross section (*1*) and stimulated emission cross section (*2*) for σ and π polarization, (a) and (b), respectively.

light were registered by a Cary 5000 spectrophotometer and used to determine the absorption cross section (Fig. 2).

Ytterbium ions have a simple structure of levels which consists of two multiplets — $^2F_{7/2}$ and $^2F_{5/2}$ containing the Stark sublevels. Since the energy distance between individual sublevels is comparable with kT, the distribution of the particles in the sublevels is defined by the Boltzmann's ratio. This results in re-absorption of the luminescence light followed by delay of luminescence decay. To avoid such a phenomenon we used the procedure for preparation of powder suspension in glycerine [7]. The measurement results are presented in Fig. 3. If to assume that the quantum luminescence yield of ytterbium ions is close to 1, their radiation lifetime is 425 μs.

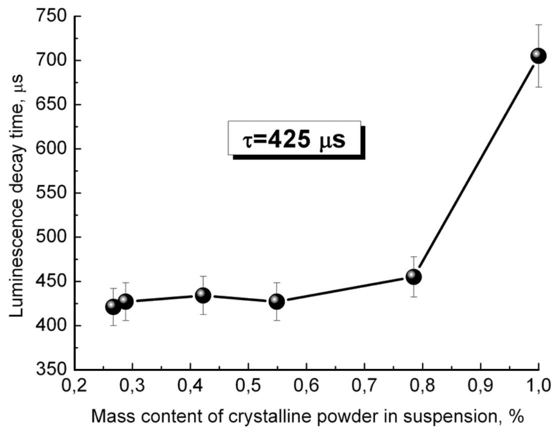

Fig. 3. Dependence of luminescence decay time on the content of crystalline powder in suspension.

Using the integrated correspondence method [8] there were calculated the spectra of stimulated emission section (Fig. 2). Based on the obtained spectroscopic characteristics we calculated the amplification-absorption curves for σ and π polarization shown in Fig. 4. The calculations were carried out for the typical conditions of occupation of the upper multiplet $\beta = N_2/N \sim 0.1-0.2$, where N_2 is the population of the multiplet $^2F_{5/2}$, N, the concentration of the ytterbium ions. The results presented in

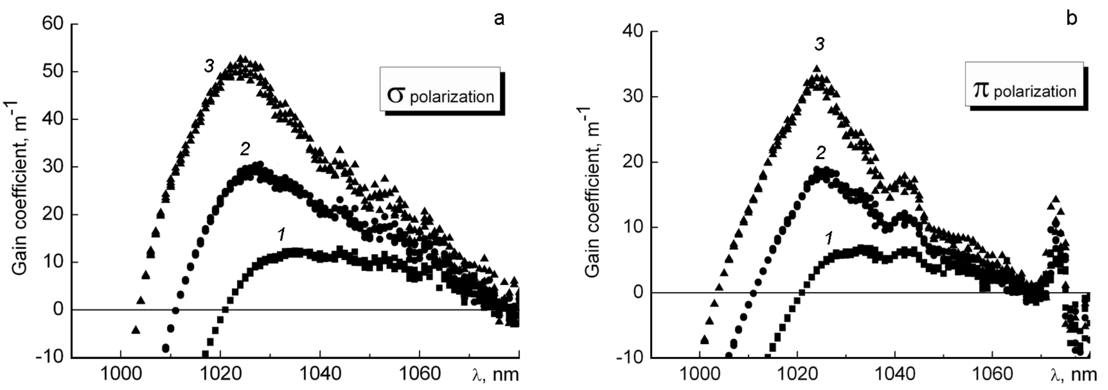

Fig. 4. Gain coefficient for different values of the population inversion rate β. *1* — β = 0.1; *2* — β = 0.15; *3* — β = 0.2 for σ (a) and π (b) polarization.

Fig. 3 make it possible to estimate the duration of spectrally limited pulses which can be obtained in lasers with mode synchronization based on $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$ crystal used in the capacity of active medium. The width of the amplification band for σ polarization is approximately 40 nm which corresponds to a pulse duration less than 100 fs.

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Вирощування та спектроскопія нових лазерних кристалів $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$

М.Б.Космина, Б.П.Назаренко, В.М.Пузіков, О.М.Шеховцов, А.С.Ясюкевич, М.В.Кулєшов, О.Є.Гулевіч, М.П.Демеш, Н.В.Гусакова

Вперше вирощено монокристали $Ca_{10}Yb_{0.3}K_{0.1}(VO_4)_7$. Вивчені спектри поглинання, люмінесценції та кінетику загасання люмінесценції рівня $^2F_{5/2}$ іону Yb^{3+}.