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Spectroscopic study of KY_3F_{10} crystals doped with praseodymium

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We report on the high-resolution Fourier spectroscopy study of $KY_3F_{10}:Pr^{3+}$ crystals. The analysis of the transmission and luminescence spectra allowed us to refine and supplement the information on the crystal-field levels of the Pr^{3+} ion. The value of the hyperfine splitting of the ground state of Pr^{3+} in the KY_3F_{10} cubic host is estimated. The observed shape of the spectral lines indicates the presence of defects in the sample under study.

Keywords: $KY_3F_{10}:Pr^{3+}$ crystal, Fourier spectroscopy, transmission and luminescence spectra.

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Introduction

Crystals of complex fluorides KY_3F_{10} are transparent in a wide range of the spectrum, thermally and chemically stable and isotropic. Doping with rare-earth (RE) ions provides the possibility of their application as laser media and white light emitters. In particular, cw laser radiation was obtained in green (554 nm) [1], orange (610 nm) [2], red (644.5 nm, 720 nm) [3,4] regions of the spectrum. In addition, on Pr:KY_3F_{10} crystals a quasi-continuous laser with frequency tuning in several intervals between 521 nm and 737 nm with a total tuning range exceeding 100 nm was developed [1].

The paper [5] reported about the study of the optical and scintillation properties of KY_3F_{10} single crystals doped with Pr^{3+} ions. When excited by radiation with a wavelength of 210 nm, an intense photoluminescence was observed at wavelength of 300 nm, corresponding to $5d-4f$ transition in the Pr^{3+} ion. The decay time of scintillations in the KY_3F_{10}:Pr^{3+} crystal for activator concentrations of 1 and 5 at% was 4.5 and 2.5 ns, and the scintillation light output is 700 and 300 photons / 5.5 MeV-α, respectively. The results obtained allow us to consider KY_3F_{10}:Pr^{3+} single crystals as promising for application in γ-radiation detectors.

The use of KY_3F_{10} crystals doped with ions of rare-earth (RE) elements as laser media presupposes both the availability of proven technologies for growing large crystals of the required optical quality and knowledge of the energy scheme of Stark levels of the RE ion. There are certain difficulties in growing KY_3F_{10} crystals of high optical quality, even using well proven melt methods of crystallization. As compared to other fluoride compounds, crystals KR_3F_{10} ($R =$ Y, RE element) are more susceptible to pyrohydrolysis and often grow cloudy and opalescent due to high content of oxygen impurities [6]. The quality control of the grown crystals is possible using the high-resolution spectroscopy method. In particular, the study of the shape features of spectral lines related to $f-f$-transitions in the R^{3+} ion can answer the question of the defects presence in the crystal.

The only spectroscopic study of KY_3F_{10}:Pr^{3+} crystals in the region of $f-f$-transitions in the Pr^{3+} ion was carried out in the paper [7], where based on analysis of the transmission and luminescence spectra, registered with resolution 0.25 cm^{-1}, 39 Stark levels of the Pr^{3+} ion were determined, and calculation was made according to the theory of the crystal field (CF). However, out of seven levels of the ground multiplet $^3H_4$ of the Pr^{3+} ion only five levels were determined, and there is no information about the levels of $^1G_4$ multiplet. In this paper, the results of a spectroscopic study with high spectral resolution of crystals KY_3F_{10}:Pr^{3+} (0.01 at%) were presented, they ensure significant clarification and supplement of data in paper [7].

Information about structure

Under normal conditions the KY_3F_{10} crystal has a cubic structure with the space group of symmetry $Fm-3m$ [8]. This structure is shown schematically in Fig. 1. It can be represented as ionic groups $[KY_3F_8]^{2+}$ and $[KY_3F_{12}]^{2-}$ alternating along three crystallographic directions. Trivalent RE ions replace Y^{3+} ions and occupy position with tetragonal symmetry (point group of symmetry C_{4v}). The closest environment of the RE ion in KY_3F_{10} is 8 F^- ions forming a square antiprism with different base sizes. Thus, equivalent RE optical centers are formed in this crystal, they are oriented along three different axes C_4 of the face-centered cubic lattice.

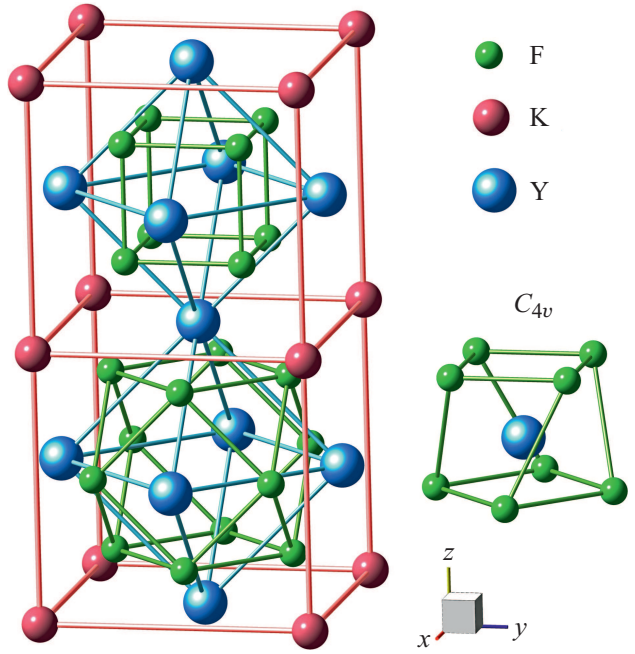

Figure 1. Crystal structure of KY_3F_{10}.

Experiment

KY_3F_{10}:Pr^{3+} (0.01 at%) single crystals were grown by the Bridgman–Stockbarger method in CF_4 atmosphere in graphite crucibles from a melt of stoichiometric composition. Anhydrous powders YF_3 and PrF_3 (99.99, LANHIT Ltd.), and KHF_2 hydrofluoride were used as initial reagents, the later was obtained by the reaction of carbonate K_2CO_3 (99.995, Sigma-Aldrich) with concentrated HF solution, were used. The growth was carried out at a temperature of 1350 K with a pulling rate of 3 mm/h. Details of the growth experiment are given in [8]. Transparent crystals with perfect cleavage along planes (111) were obtained (Fig. 2). According to data of X-ray phase analysis (Rigaku MiniFlex 600 X-ray diffractometer, CuK_α radiation), KY_3F_{10}:Pr crystals were single-phase and had cubic symmetry (space group $Fm{-}3m$) with lattice parameter $a = 1.1547$ nm. The sample 11.2 mm thick was prepared for measurements.

The transmission and luminescence spectra of crystals KY_3F_{10}:Pr^{3+} (0.01 at%) were recorded with a resolution of up to 0.01 cm^{-1} in a wide spectral range from 2000 to 22000 cm^{-1} and temperature range from 5 to 300 K on a Bruker IFS 125HR high-resolution Fourier spectrometer. The sample was placed in a Cryomech ST403 closed cycle optical cryostat. The luminescence of the sample was excited by cw semiconductor laser with a radiation wavelength of $\lambda = 462$ nm. The laser radiation power density was 50 mW/mm^2.

Results and discussion

Pr^{3+} ion has two electrons in the $4f$ shell. The electronic configuration $4f^2$ in a centrally symmetric field gives 7 terms, which are split into 13 SLJ multiplets due to the spin-orbit interaction: four singlet and nine triplet multiplets. The ground level is $^3H_4$. Bands of absorption by Pr^{3+} ions due to $^3H_4 \rightarrow {}^3H_{5,6}$, $^3F_{2,3,4}$ transitions are in the mid-infrared region; transitions to levels $^1G_4$ and $^1D_2$ are spin-forbidden (in the spectra they appear due to admixture of other states); transitions to the level $^3P_0$ occur due to the absorption of radiation quanta in the visible range. In a crystal field KY_3F_{10} the energy levels of free ion Pr^{3+} are split into Stark sublevels, whose wave functions are transformed according to non-degenerate irreducible representations Γ_1, Γ_2, Γ_3, Γ_4 and the doubly degenerate Γ_5 of point group of symmetry C_{4v}. The number and symmetry of Stark levels for multiplets with a total moment J from 0 to 6 for the ion with an even number of electrons (as in the case of Pr^{3+}) in positions with the point group of symmetry C_{4v} are given in Table 1. Table 2 lists the selection rules for electric dipole (ED) and magnetic dipole (MD) transitions in the case of the point group of symmetry C_{4v}. Since there are equivalent RE centers oriented along three different axes C_4 of the cubic lattice, there is no polarization dependence in the spectra. Note, however, that $\Gamma_{3,4} \leftrightarrow \Gamma_{1,2}$ optical transitions are strictly forbidden; transitions involving Γ_5 levels are allowed as both ED and MD; transitions $\Gamma_k \rightarrow \Gamma_k$ ($k = 1, 2, 3, 4$) are carried out as ED, only, and transitions $\Gamma_1 \leftrightarrow \Gamma_2$ and $\Gamma_3 \leftrightarrow \Gamma_4$ are allowed as MD, only.

Figure 3 shows the low-temperature transmission and luminescence spectra of the crystal KY_3F_{10}:Pr^{3+} (0.01 at%). The observed transitions are indicated in the diagram on the right. Figure 4, a–d shows the transmission spectra at temperature close to that of liquid helium in the region of transitions $^3H_4 \rightarrow {}^3H_5$, $^3H_6$, $^3F_4$, $^1G_4$. These spectra reflect the structure of excited multiplets, due to the fact that the first excited state of the ground multiplet, according to [7],

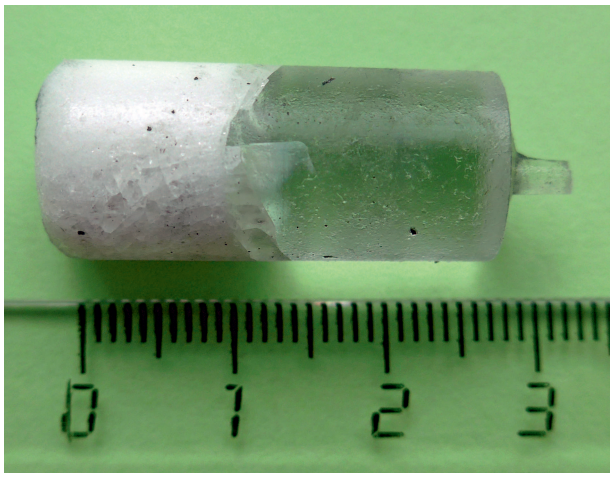

Figure 2. Grown single crystal KY_3F_{10}:Pr^{3+} (0.01 at%).

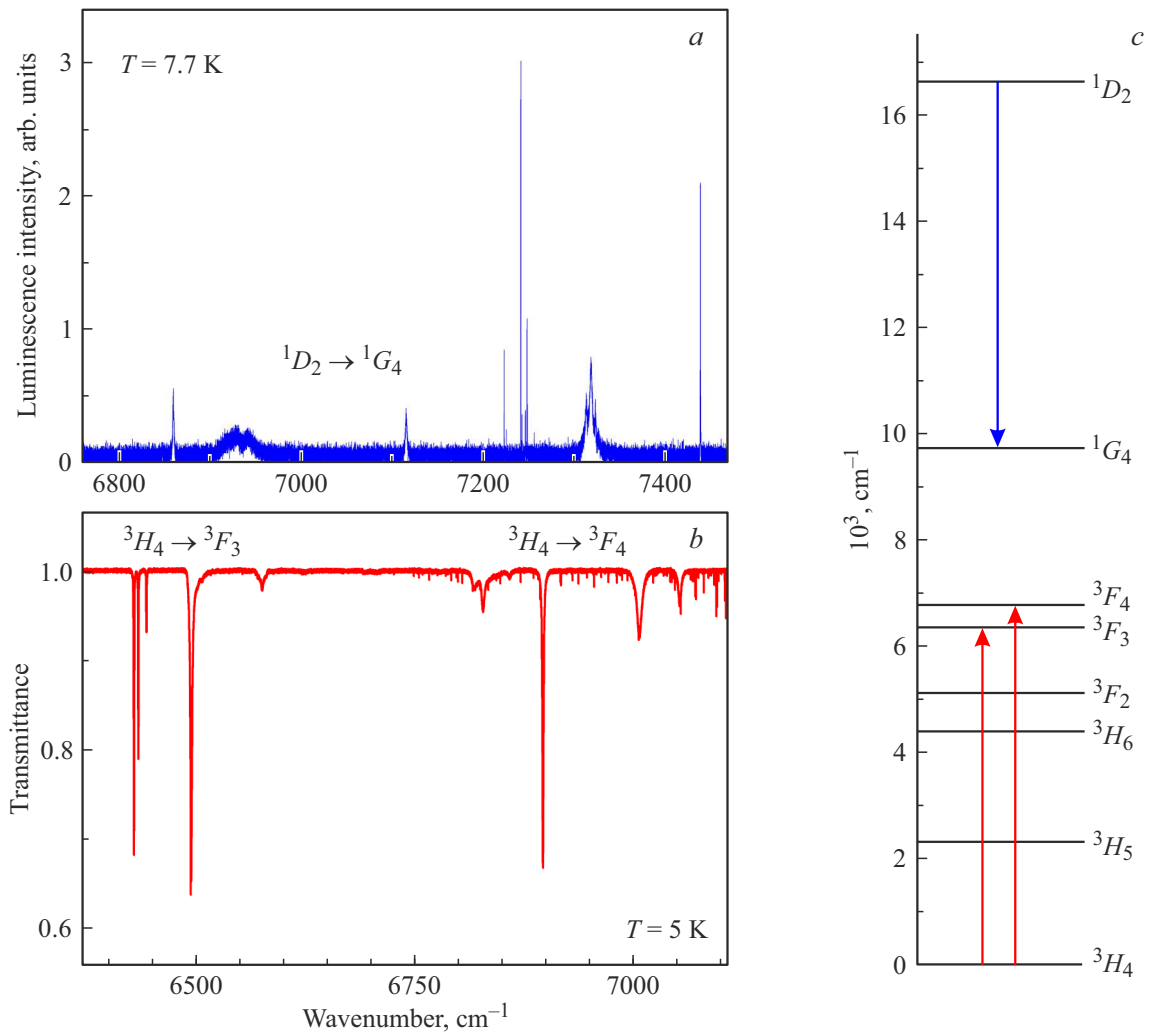

Figure 3. Luminescence (*a*) and transmission (*b*) spectra of the crystal $KY_3F_{10}:Pr^{3+}$ (0.01 at%). The observed transitions are indicated in the diagram on the right (*c*).

Table 1. The number of Stark levels and their symmetry for a multiplet with a common momentum J of a non-Kramers rare-earth ion in a crystal field of symmetry C_{4v}

J	Number of levels	Irreducible representations
0	1	Γ_1
1	2	$\Gamma_2 + \Gamma_5$
2	4	$\Gamma_1 + \Gamma_3 + \Gamma_4 + \Gamma_5$
3	5	$\Gamma_2 + \Gamma_3 + \Gamma_4 + 2\Gamma_5$
4	7	$2\Gamma_1 + \Gamma_2 + \Gamma_3 + \Gamma_4 + 2\Gamma_5$
5	8	$\Gamma_1 + 2\Gamma_2 + \Gamma_3 + \Gamma_4 + 3\Gamma_5$
6	10	$2\Gamma_1 + \Gamma_2 + 2\Gamma_3 + 2\Gamma_4 + 3\Gamma_5$

has an energy exceeding 100 cm^{-1} and is not populated. The designations of the lines are given in accordance with the diagram in Fig. 5: Arabic numerals enumerate the Stark levels of the ground multiplet, and capital Latin letters are for the levels of excited multiplets. Recall that the article [7] has no data on the Stark structure of $^1G_4$ multiplet levels. From the analysis of our absorption and luminescence spectra, we determined the energies of five of the seven Stark levels of $^1G_4$ multiplet.

As the temperature increases, spectral lines appear in the transmission spectra, these lines correspond to transitions from the excited levels of the ground multiplet $^3H_4$. Figure 6 shows the temperature dependence of the spectra in the region of transitions $^3H_4 \to {}^3F_2$, $^3F_3$. Figure 6, *a, b* shows the marked transitions from the excited levels of the ground multiplet $^3H_4$: 2A, 2B, 2C, 4A, 4C and 5A. Frequency differences of lines 2A, 4A, and 5A and line 1A in the region of transition $^3H_4 \to {}^3F_2$ (Fig. 6, *a*) correspond to the energies of the Stark levels 2, 4, and 5 of the ground multiplet $^3H_4$ of the Pr^{3+} ion, respectively. The energy of level 2 is confirmed by the position of the line 2A in the region of transition $^3H_4 \to {}^3F_3$ (Fig. 6, *b*). Note that the

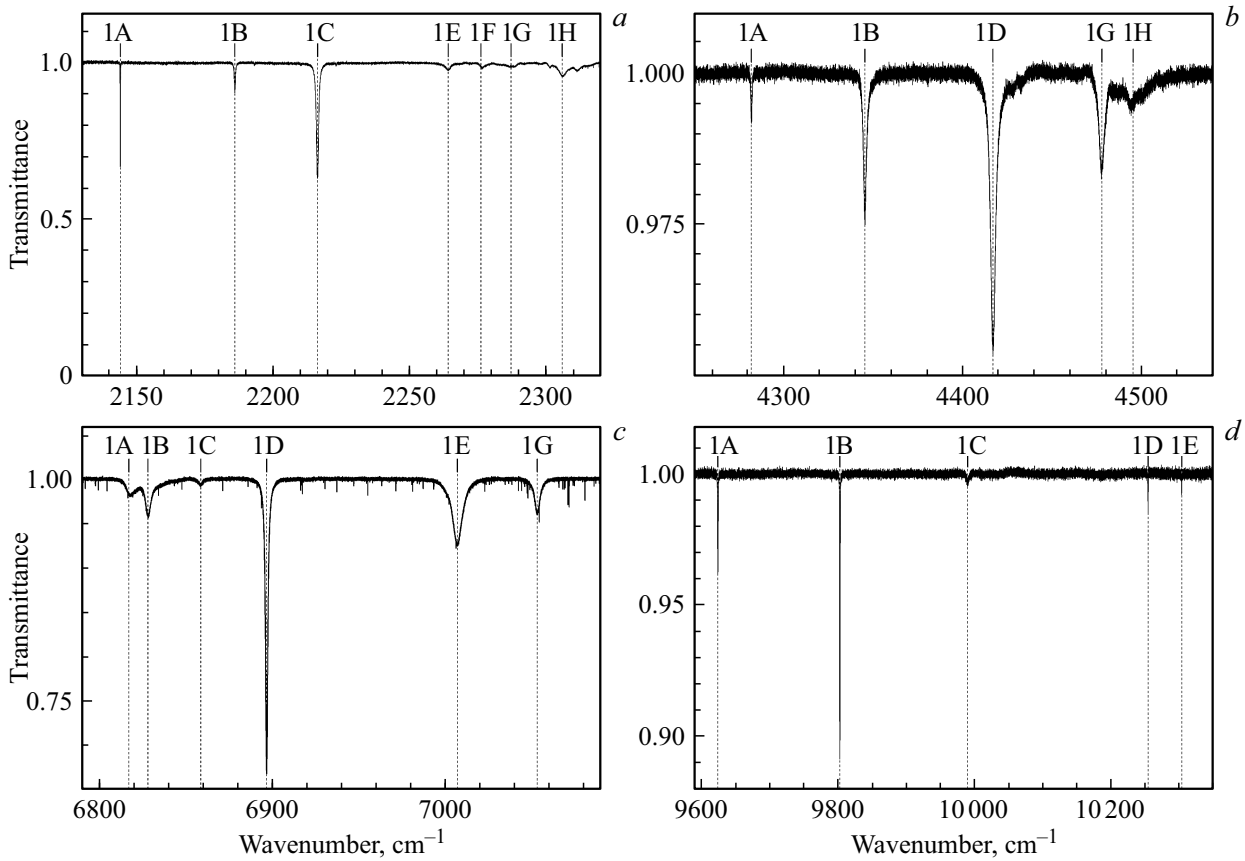

Figure 4. Transmission spectrum in the region of transitions: $^3H_4 \to {}^3H_5$ (a), $^3H_4 \to {}^3H_6$, (b), $^3H_4 \to {}^3F_4$ (c), $^3H_4 \to {}^1G_4$ (d) in the Pr^{3+} ion in the crystal KY_3F_{10}:Pr^{3+} (0.01 at%) at temperature 5 K. The designations of the spectral lines are given in accordance with the diagram in Fig. 5.

Table 2. Selection rules for electric dipole ($d_{x,y,z}$) and magnetic dipole ($\mu_{x,y,z}$) transitions in the case of the point group of symmetry C_{4v}. Here, x, y, z are the local axes of the center of symmetry C_{4v}. In a cubic crystal KY_3F_{10} the local axis z is oriented along one of the three equivalent axes C_4 of the cube

Γ_i	Γ_1	Γ_2	Γ_3	Γ_4	Γ_5
Γ_1	d_z	μ_z	—	—	$\mu_{x,y}$, $d_{x,y}$
Γ_2	μ_z	d_z	—	—	$\mu_{x,y}$, $d_{x,y}$
Γ_3	—	—	d_z	μ_z	$\mu_{x,y}$, $d_{x,y}$
Γ_4	—	—	μ_z	d_z	$\mu_{x,y}$, $d_{x,y}$
Γ_5	$\mu_{x,y}$, $d_{x,y}$	$\mu_{x,y}$, $d_{x,y}$	$\mu_{x,y}$, $d_{x,y}$	$\mu_{x,y}$, $d_{x,y}$	d_z, μ_z

level 2 energy of $^3H_4$ multiplet is determined in our paper for the first time. Also, the energies of levels 4 and 5 of $^3H_4$ multiplet were refined in comparison with the data of [7].

Thus, the analysis of the temperature dependence of the transmission spectra in the studied spectral region made it possible to determine the exact energies of the Stark levels of the excited multiplets $^3H_{5,6}$, $^3F_{2,3,4}$, $^1D_2$, $^1G_4$ and $^3P_0$, and some levels of the ground multiplet $^3H_4$ of the Pr^{3+} ion in KY_3F_{10}:Pr^{3+}. The spectroscopic data are summarized in Table 3 in comparison with the data of the paper [7]. According to the selection rules (Table 2), if the ground state is a singlet, the lines corresponding to strictly forbidden transitions will not be visible in the low-temperature absorption spectra for all multiplets. But if the ground state is a Γ_5 doublet, then transitions to all Stark levels of the given excited multiplet are allowed. Transmission spectra at $T = 5$ K show transitions to all levels of multiplets $^3F_2$ (Fig. 6, a) and $^3F_3$ (Fig. 6, b). This speaks in favor of the fact that the ground state is Γ_5 doublet, which agrees with the calculation by the CF theory presented in the paper [7]. In the transmission spectra at $T = 5$ K in each of the regions of transitions $^3H_4 \to {}^3H_5$, $^3H_6$, $^3F_4$, $^1G_4$ shown in Figs. 4, a, 4, b, 4, c, 4, d, respectively, not all possible lines are visible, which can be explained by the low probability of some transitions.

The luminescence spectra show no transitions to the excited levels of the ground $^3H_4$ multiplet. This conclusion was made from the comparison of the absorption and luminescence spectra at different temperatures. From the luminescence spectra, it was possible to refine the position

Table 3. Energies E of the Stark levels of the Pr^{3+} ion in the KY_3F_{10}-Pr^{3+} crystal at $T = 5$ K and designations of levels adopted in this paper. The experimental values of the energies E at $T = 10$ K and the theoretically calculated irreducible representations Γ_i from the paper [7] are also provided

$^{2S+1}L_J$	E, cm^{-1} at $T = 5$ K	Levels	E, cm^{-1} [7] at $T = 10$ K	Γ_i [7]	$^{2S+1}L_J$	E, cm^{-1} at $T = 5$K	Levels	E, cm^{-1} [7] at $T = 10$ K	Γ_i [7]
$^3H_4$	0	1	0	Γ_5	$^3F_2$	5041.1	A	5042	Γ_3
	88	2	—	Γ_3		5073.6	B	5075	Γ_4
	—	3	136	Γ_1		5098.8	C	5100	Γ_5
	163	4	170	Γ_5		5229.6	D	5230	Γ_1
	211	5	214	Γ_4	$^3F_3$	6429	A	6430.3	Γ_3
	—	6	—	Γ_2		6434.1	B	6435	Γ_5
	—	7	508	Γ_1		6443.5	C	6444.6	Γ_4
$^3H_5$	2144	A				6494.5	D	6497	Γ_5
	2185.9	B	2186	Γ_5		6575.6	E	6576.6	Γ_2
	2216.2	C	2216	Γ_4	$^3F_4$	6817	A		
	—	D	—	Γ_2		6828.1	B	6831	Γ_5
	2264	E	2263	Γ_1		6858	C	6859.4	Γ_3
	2276	F	2277	Γ_5		6896.7	D	6901	Γ_4
	2287	G	2287	Γ_3		7006.9	E	7006	Γ_1
	2305.7	H	2306.6	Γ_2		—	F	—	Γ_2
	—	I	2636	Γ_5		7053.1	G	7056	Γ_5
$^3H_6$	4282	A	4285	Γ_1		—	H	7126	Γ_1
	4345.3	B	4347	Γ_5	$^1G_4$	9625	A	—	
	—	C	—	Γ_2		9803.2	B	—	
	4416.7	D	4417.6	Γ_3		9900	C	—	
	—	E	4429	Γ_5		10253.5	D	—	
	—	F	4433.4	Γ_1		10302.6	E	—	
	4477.4	G	4478	Γ_5	$^1D_2$	16651.8	A	16557	Γ_4
	4494.8	H	4495	Γ_4		16706.4	B	16712	Γ_3
	—	I	—	Γ_3		16878	C	16886	Γ_1
	—	J	—	Γ_4		—	D	17236	Γ_5
					$^3P_0$	20725.3	A	20733	Γ_1

of the only Stark level of $^3P_0$ multiplet (Table 3). Figure 7 shows the luminescence spectra in the region of transitions from the $^3P_0$ level to the Stark levels of multiplets $^3F_4$, $^3F_3$ (Fig. 7, *a*) and $^3H_6$ (Fig. 7, *b*).

Let us consider in detail the spectral region 6320–6380 cm^{-1} shown in Fig. 8. Attention is drawn to the complex shape of absorption lines 2A, 2B and 2C in the region of transition $^3H_4 \rightarrow {}^3F_3$: each of these lines has two components. The distances between the components of the lines 2A, 2B, and 2C are practically the same and equal to 2.5 ± 0.1 cm^{-1}. It should be noted that no other spectral lines with a pronounced doublet structure were found. What could be the reason for the observed splitting of lines 2A, 2B, and 2C? It is natural to assume the existence of two Stark levels close in energy with energies ~ 87 and 89 cm^{-1}. According to the theoretical calculation in the paper [7], level 2 has energy from 105 to 113 cm^{-1} depending on the calculation method. The energy

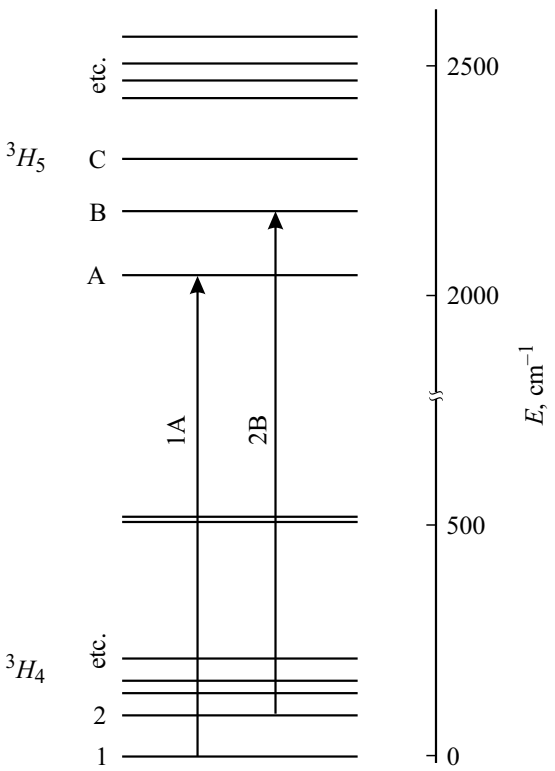

Figure 5. Scheme of designations for Stark levels and the corresponding transitions adopted in this work.

of the level 3 was determined experimentally in [7] and is equal to 136 cm^{-1}, and according to the calculation — from 121 to 133 cm^{-1}. In the spectra of the Pr^{3+} ion measured by us in the crystal KY_3F_{10}:Pr^{3+} (0.01 at%) the spectral lines corresponding to transitions from level 3 of the ground multiplet $^3H_4$ are not observed. The energies of levels 4 and 5 were determined (Table 3), and their values ??are close to the experimental data of the work [7]. Comparison of the spectroscopic data obtained in this paper with the results from the article [7] shows the validity of the theoretical calculation [7], as a result of which the obtained parameters of the crystal field describe mainly the energy structure of the levels of the Pr^{3+} ion in the KY_3F_{10}:Pr^{3+} crystal. However, note that in the case of two excited multiplets $^3H_5$ and $^3F_4$ the energies of the first Stark levels significantly do not agree with the experimental data of the paper [7], used as the basis of made theoretical calculation (Table 3). The narrow, 0.07 cm^{-1}, low-frequency line 2144 cm^{-1} could not be registered in [7] due to the low resolution use. All the above refinements and additions to the energy scheme of the Stark levels of the Pr^{3+} ion in the KY_3F_{10}:Pr^{3+} crystal can lead to correction of the CF parameters obtained earlier in the paper [7].

What other reason exists for this kind of splitting of the considered spectral lines? Random deformations of the crystal lattice caused by various kinds of defects formed during crystal growth can lead to inhomogeneous widening and splitting of spectral lines. The value of the deformation splitting of the absorption lines varies from a few hundredths to units of a wave number. Splittings similar to those shown in Fig. 8 were observed earlier in the optical spectra of cubic centers of Yb^{3+} doping ions in elpasolite crystals [9]. In the paper [9] an explicit expression for the generalized deformations distribution function was obtained, and the splitting of the lines corresponding to optical transitions involving degenerate electronic states was successfully simulated. In our case, the same splitting of three lines 2A, 2B, and 2C indicates the supposed deformation splitting of the Stark level 2 of the ground multiplet $^3H_4$ of the Pr^{3+} ion. If refer to calculation from paper [7], then the assumption of deformation splitting contradicts the information obtained from calculation of symmetry Γ_3 of the first excited state of the ground multiplet $^3H_4$ of the Pr^{3+} ion in KY_3F_{10}:Pr^{3+}.

The unresolved hyperfine structure of the spectral lines confirms the assumption about the deformation splittings presence. Figure 9 shows the line 9625 cm^{-1} in the region of transition $^3H_4 \rightarrow {}^1G_4$ in absorption and luminescence spectra. The shape of this line is not described unambiguously by a single contour. Let us estimate the hyperfine splitting of the Stark levels of the Pr^{3+} ion in KY_3F_{10}:Pr^{3+}. The hyperfine structure (HFS) is due to the interaction of the electric and magnetic moments of the nucleus with electrons. Usually, the main contribution to HFS is made by the magnetic dipole hyperfine interaction, which is determined by the magnetic field $\mathbf{H}(0)$ created on the nucleus by electrons, and by the magnetic moment of the nucleus $\boldsymbol{\mu}_n$ with spin $\mathbf{I}$:

$$V_m = -\boldsymbol{\mu}_n \mathbf{H}(0). \tag{1}$$

In the case of multiplet with given $\mathbf{J}$, the Hamiltonian (1) takes the form

$$V_m = A_J(\mathbf{JI}), \tag{2}$$

where A_J is the magnetic hyperfine constant. Electron doublets Γ_5 split into $(2I+1) = 6$ equidistant ultrafine sublevels by magnetic dipole hyperfine interaction. Spin of the praseodymium nucleus is $^{141}Pr^{3+}$: $I = 5/2$. In the first approximation, the singlet states do not have HFS. The ground state is doublet Γ_5. This means that all spectral lines in low-temperature absorption spectra must have HFS. The estimate of the g-factor of the ground state from the parameters of the crystal field calculated in the paper [7] is $g_z = 4.28$ [10]. Knowing this value, we can calculate the hyperfine splitting ΔE_{HF} of the ground level Γ_5 using the formula [11]:

$$\Delta E_{\mathrm{HF}} = A_J \cdot |g_z|/2g_0, \tag{3}$$

where A_J is magnetic hyperfine constant, g_0 is Lande factor. The magnetic hyperfine constant for the ground multiplet $^3H_4$ of the Pr^{3+} ion is $A_J =$ 1093 MHz $=$ 0.0364 cm^{-1} [12]. Thus, we obtain an equidistant HFS of levels with an interval between components equal to 0.0974 cm^{-1}. The calculation according to the crystal field theory using the parameters from the paper [7] made it possible to determine the irreducible

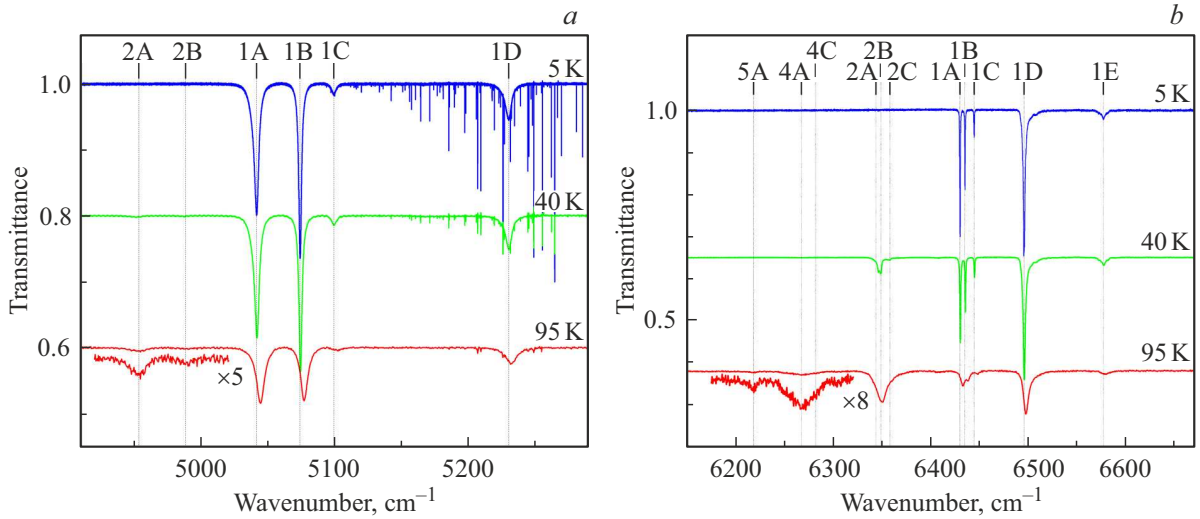

Figure 6. Transmission spectrum in the regions of transitions $^3H_4 \rightarrow {}^3F_2$ (*a*) and $^3H_4 \rightarrow {}^3F_3$ (*b*) in the Pr^{3+} ion in the crystal $KY_3F_{10}:Pr^{3+}$ (0.01 at%) at temperatures 5, 40, 95 K. The designations of the spectral lines are given in accordance with the diagram in Fig. 5. The vertical scale refers to the transmission spectrum at $T = 5$ K. Narrow lines in the high-frequency region of the spectrum refer to absorption by residual vapors H_2O in the device.

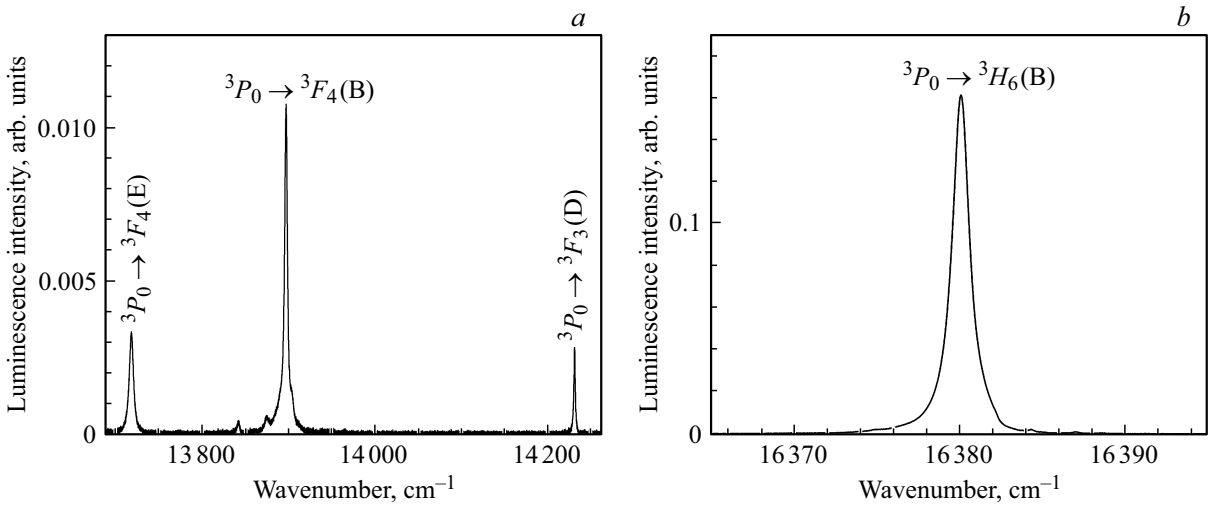

Figure 7. Luminescence spectra of the crystal $KY_3F_{10}:Pr^{3+}$ (0.01 at%) at $T = 6.6$ K in the region of transitions in the Pr^{3+} ion from the level $^3P_0$ to Stark levels of multiplets $^3F_4$, $^3F_3$ (*a*) and $^3H_6$ (*b*). The final level of the transition is indicated in parentheses in the designations given in the diagram in Fig. 5.

representations of the Stark levels of the multiplet $^1G_4$ [10]. According to this calculation, the first level of the excited multiplet $^1G_4$ is a singlet. The half-width of the line 9625 cm^{-1} is 0.7 cm^{-1}. Thus, the inhomogeneous widening, probably caused by local changes in the crystal environment of RE ions due to thermal post-growth stresses, did not allow to detect the allowed HFS in the optical spectra of the crystal $KY_3F_{10}:Pr^{3+}$ (0.01 at%). The observed shape of the line 9625 cm^{-1} may be due to the combined action of the unresolved HFS and deformation splitting.

As for the doublet structure of the absorption lines 2A, 2B, and 2C in the region of the transition $^3H_4 \rightarrow {}^3F_3$, then it can be explained by both the presence of two close levels in the ground multiplet $^3H_4$ and the presence of deformation splitting. Both of these suppositions contradict the calculation according to the theory of the crystal field carried out in the paper [7]. Based on the foregoing, we believe that it is necessary to carry out a new calculation based on the spectroscopic data obtained in this paper.

Conclusion

The use of high-resolution Fourier spectroscopy made it possible, on the basis of comparative analysis of the temperature dependence of the transmission and luminescence spectra of the $KY_3F_{10}:Pr^{3+}$ crystal, to significantly

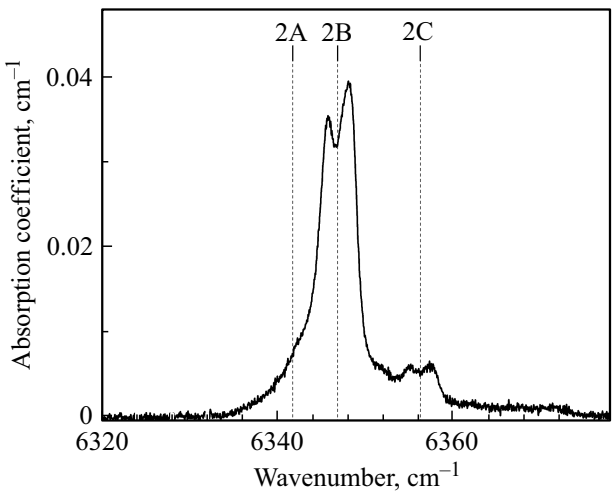

Figure 8. Absorption lines 2A, 2B and 2C in the region of transitions $^3H_4 \rightarrow {}^3F_3$ at $T = 40$ K.

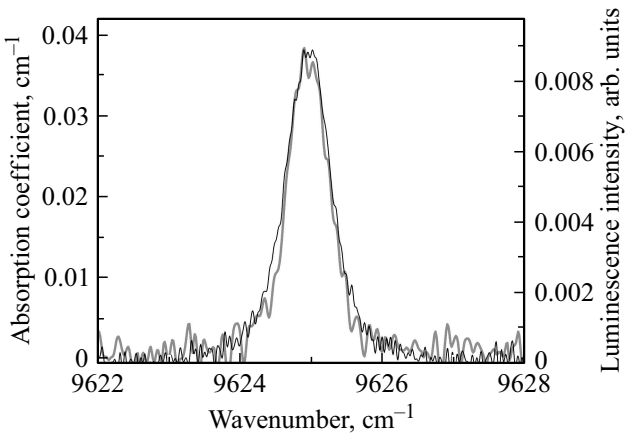

Figure 9. The line 9625 cm^{-1} in the absorption (thin black line) and luminescence (thick gray line) spectra of the crystal KY_3F_{10}:Pr^{3+} (0.01 at%) at $T = 5$ K.

refine and supplement the energy diagram of the Stark levels of the Pr^{3+} ion. Data on the levels of the excited multiplet $^1G_4$ and the first excited level of the multiplet $^3H_4$ were obtained for the first time. The complex shape of the spectral lines is explained by the combined action of hyperfine and deformation splittings. The splitting of the lines corresponding to the transition from the first excited level of the ground multiplet $^3H_4$ can be explained both by the presence of two close Stark levels and by deformation splitting. The justified decision in favor of one of these two assumptions requires a new calculation according to the crystal field theory based on more complete spectroscopic data obtained in this paper. Besides, to obtain KY_3F_{10} crystals doped with rare-earth ions of the required optical quality, further optimization of the process conditions for their growth from the melt is required.

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Conflict of interest

The authors declare that they have no conflict of interest.

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