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Optical spectroscopy of Yb^{3+} in the Cs_2NaYF_6 single crystal

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Abstract

Results of the optical spectroscopy investigation of the cubic paramagnetic center Yb^{3+} ion in the Cs_2NaYF_6 single crystal are presented. The Stark level energies of the Yb^{3+} multiplets are established from absorption, luminescence and excitation luminescence spectra and the crystal field parameters are calculated. Information about the phonon spectra of Cs_2NaYF_6 crystals is obtained from the electron-vibrational structure of the optical absorption and luminescence spectra.

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1. Introduction

Unlike chloroelpasolites (A_2BLnCl_6) doped with impurity rare-earth (RE) ions widely studied by optical methods [1–5], fluoroelpasolites (A_2BLnF_6) are studied much less [6–10]. It is mainly due to the technical difficulties of their synthesis. Fluoroelpasolites with the cubic structure in the wide temperature interval are perfect model systems in which the isomorphous substitution of cations by trivalent RE ions provides an opportunity to study optical magnetic properties of dopants in a wide concentration range. In turn, it allows one to consider these compounds as promising materials in practice [7–10]. To the best of our knowledge, this work presents results of the first investigation of Yb^{3+} ion in cubic Cs_2NaYF_6 single crystals using optical spectroscopy. Preliminary data of this study are given in Ref. [11].

2. Experimental results and discussion

Cs_2NaYF_6 single crystals doped with 0.01, 0.1, 1.0 and 10.0 at% Yb^{3+} were synthesized by the chemical reaction

of alkali fluoride aqueous solutions with mixtures of Yb_2O_3 and Y_2O_3 at 750 K, and pressures of 100–150 MPa.

Electron paramagnetic resonance (EPR) experiments were carried out at $T = 4.2$ K. The analysis of the EPR spectra has shown that Yb^{3+} ions form one paramagnetic center of cubic symmetry (T_c) and substitute only for Y^{3+} in Cs_2NaYF_6 [12,13]. Optical spectra were registered on a homebuilt multifunctional spectrometer [14] at $T = 2$, 77 and 300 K. The luminescence of the crystal was excited by the light of a xenon lamp (power 1 kW). Luminescence excitation spectra were corrected on the spectrum of the lamp radiation. A semiconductor laser diode ATC-C1000-100-TMF-965 of 1 W was used as a source of laser selective excitation (LSE) with the laser linewidth of the order of 2 nm and the laser emission wavelength tunable from 963 nm ($10,381\text{ cm}^{-1}$) to 969 nm ($10,317\text{ cm}^{-1}$). A cooled photomultiplier was used as a detector.

The luminescence excitation (a–c) and luminescence (d–f) spectra of $\text{Cs}_2\text{NaYF}_6:\text{Yb}^{3+}$ ($c = 0.01\%$, 1% and 10%) at $T = 77$ and 2 K (d) are shown in Fig. 1. Arrows with a numbered label show the spectral lines supposedly corresponding to the Yb^{3+} ion forming T_c . These marks correspond to those of optical transitions in the energy level diagram in Fig. 1 (inset). At low concentration of Yb (0.01%), an intensive and narrow line (the width of the order of 2 cm^{-1}) is observed in the frequency range of

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