Fluorescence Properties of Eu$^{3+}$:Y$_2$SiO$_5$ Single Crystal

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Abstract Fluorescence properties of Eu$^{3+}$:Y$_2$SiO$_5$ have been investigated. Transitions between $^5$D and $^7$F were studied with transmission spectra, fluorescence spectra, photoluminescence excitation (or absorption) spectra and site selective fluorescence spectra. The X-ray powder diffraction pattern of Eu$^{3+}$:Y$_2$SiO$_5$ shows that the crystal belong to monoclinic, and lattice’s constants $a$, $b$, $c$ and $\beta$ are obtained by a simulation with the measured diffraction angles.

Key words Eu$^{3+}$:Y$_2$SiO$_5$ crystal, fluorescence spectra, photoluminescence excitation spectra

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1 Introduction

Eu$^{3+}$:Y$_2$SiO$_5$ crystal is used as a new luminescence material. Because the nuclear moments of the composite elements are small in this crystal, the spin-spin interaction between guest and host ions is minimized. The guest-host interaction does not cause large additional line broadening; therefore this crystal can be used as good frequency-selective optical memory both in the frequency domain (persistent spectral hole burning) and time domain (photon echo memory)$^{[1]}$. In addition, it can also be used for studying high-resolution nonlinear spectroscopy because the doped Eu$^{3+}$ ions have the longer optical dephasing time $T_2$.

The aim of this work is to study the fluorescence properties of Eu$^{3+}$: Y$_2$SiO$_5$ crystal. Eu$^{3+}$ ions-doped concentration was 0.15 % at wt in our sample. The transmission spectra of $^7$F$_{0,1,2}$--$^5$D$_0,1,2$ and $^7$F$_{0}$--$^5$L$_{6}$ transitions were detected. The fluorescence spectra of $^5$D$_{0,1,2}$--$^7$F$_{0,1,2,3,4}$ transitions were measured with 457.9 nm wavelength Ar$^+$ ion laser excitation. The photoluminescence excitation, or absorption, spectra of $^7$F$_0$--$^5$D$_0$ transition excited with a Q-switched Nd$^{3+}$:YAG laser pumped by tunable Rh6G dye laser with 0.5 cm$^{-1}$ linewidth was studied by detecting fluorescence of $^5$D$_0$--$^7$F$_2$ transition whose central wavelength is about 615 nm. The site selective fluorescence spectra of Eu$^{3+}$ ion $^5$D$_0$--$^7$F$_0$ transition were detected by exciting each site respectively. Finally, the lattice constants ($a$, $b$, $c$ and $\beta$) of this monoclinic biaxial crystal were measured with X-ray diffraction. By analyzing these spectra, we find that Eu$^{3+}$ ions occupy two optical sites whose spectral lines of $^7$F$_0$--$^5$D$_0$ transition are about 0.2 nm apart from each other at room temperature and both sites are the luminescence centers with C1 symmetry.

2 Experiment

2.1 Transmission spectra

For measuring transmission spectra, a 50 W white light lamp was used as a continuous wave source and the system of a Jobin-Yvon HR-1500 model monochromator, a SR565 phase-locking amplifier and a computer were used for receiving transmission spectra.

Fig. 1 shows the transmission spectra of $^7$F$_0$--$^5$D$_0$ transition of Eu$^{3+}$:Y$_2$SiO$_5$. Two absorption lines are observed, which indicate two different sites of Eu$^{3+}$ ions in Eu$^{3+}$:Y$_2$SiO$_5$ crystal because both $^7$F$_0$ and $^5$D$_0$...
are single-leveled.

Five absorption lines are found in the transmission spectra of $^7\text{F}_0 \rightarrow ^5\text{D}_1$ transition of Eu$^{3+}$:Y$_2$SiO$_5$ given in Fig. 2.

The transmission spectra of Eu$^{3+}$ ion $^7\text{F}_0 \rightarrow ^5\text{D}_2$ transition are shown in Fig. 3. Nine lines are found. Their wavelengths are 464.16 nm (site 1), 464.54 nm (site 2), 465.07 nm (site 2), 465.65 nm (site 1), 466.12 nm (site 2), 466.59 nm (site 2), 466.8 nm (site 1, site 2), 467.18 nm (site 1), and 467.43 nm (site 1) respectively.

Fig. 4 displays the transmission spectra of Eu$^{3+}$ ion $^7\text{F}_0 \rightarrow ^5\text{I}_6$ transition. It shows four lines located at 393.70 nm, 394.00 nm, 394.75 nm, and 395.29 nm respectively.

2.2 Fluorescence spectra

The emission spectra of the Eu$^{3+}$-doped Y$_2$SiO$_5$ crystal from 520 nm to 720 nm were measured using a Coherent Innova 10 argon ion laser (line 457.9 nm) excitation. The luminescence was dispersed with a Jobin-Yvon HR-1500 model monochromator and detected with a SR565 phase-locking amplifier.

The $^5\text{D}_0 \rightarrow ^7\text{F}_0$ fluorescence emission was induced by 457.9 nm wavelength argon-ion laser. Two $^5\text{D}_0 \rightarrow ^7\text{F}_0$ emission peaks were detected at room temperature. Each peak corresponds to a certain Eu$^{3+}$ site in the crystal. Fig. 5 shows the fluorescence spectra of $^5\text{D}_0 \rightarrow ^7\text{F}_0$ transition. Fig. 6 shows the fluorescence spectra of $^5\text{D}_1 \rightarrow ^7\text{F}_0, ^7\text{F}_1, ^7\text{F}_2$ transitions. Fig. 7 shows the fluorescence spectra of $^5\text{D}_0 \rightarrow ^7\text{F}_0, ^7\text{F}_1, ^7\text{F}_2$ transitions. Fig. 8 shows the fluorescence spectra of $^5\text{D}_0 \rightarrow ^7\text{F}_3, ^7\text{F}_4$ transitions.