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Growth and Optical Studies of Erbium Doped KY_3F_{10} Solid State Laser Material

[1]S. Khiari, [2]M. Diaf and [2]K. Labbaci
[1]University Centre of El-Tarf, El-Tarf 36000, Algeria
[2]Department of Physics, University of Annaba, POB 12, 23000 Annaba, Algeria

Abstract: In this study, we examine the optical properties of Er^{3+} ions doped KY_3F_{10} single crystals. After crystal growth and X-ray diffraction analysis, the optical properties of Erbium ions in KY_3F_{10}.The measured absorption line strength at room temperature were used to fit the three phenomenological Jud-Ofelt (JO) parameters Ω_t(t = 2,4,6).The emission transition probabilities branching ratios and radiative lifetimes are then deduced. The possibility to use such material for laser emissions is discussed.

Key words: Solid state laser, laser spectroscopy, laser materials, fluoride, rare earth, judd-ofelt theory

INTRODUCTION

The fluoride single crystals were intensively studied during the last decade[1-8] in order to develop efficient and reliable all solid state lasers emitting in both visible and near infrared domain. The crystals studied are doped with rare earth ions which constitute the optically active centres by considering the 4f-4f transitions. Among all solid-state laser materials, the fluorides have the advantageous to be transparent in a large electromagnetic domain and they have low-maximum phonon frequency leading to a large number of potential emitting levels.

In this study, we present the optical absorption properties of KY_3F_{10} laser material doped with trivalent Erbium ions. The Jud-Ofelt (JO) analysis was applied to this crystal in order to determine the optical transition probabilities, the branching ratio and the radiation lifetimes of the Erbium main emitting levels. The study seems to have not been done previously.

Experimental procedure: Crystals of KY3F10 doped with different concentrations of Erbium ions were grown by Czochralski technique. X-ray diffraction spectra confirm that KY_3F_{10} single crystals have a cubic structure with a lattice parameter a = 11.55 A° in good agreement of literature data[4,9]. The Erbium ions which substitutes Yttrium ions occupy C_{4v} symmetry sites. The pulled crystals are of good optical quality.

For spectroscopic measurements, the crystals were cleaved and polished in order to obtain parallel face samples with 3 mm thickness. The room temperature optical spectra were recorded with a Perkin-Elmer Lambda 9 spectrophotometer.

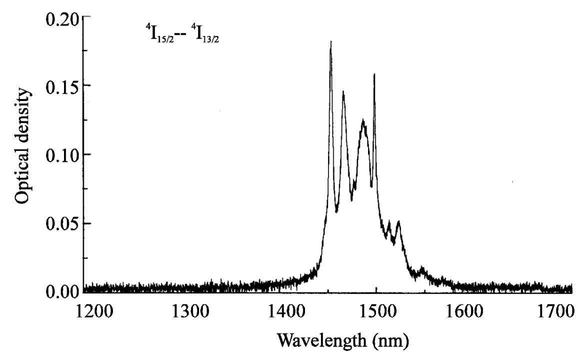

Fig. 1: Room temperature absorption spectrum of $^4I_{13/2}$ level of Er^{3+} doped KY_3F_{10}

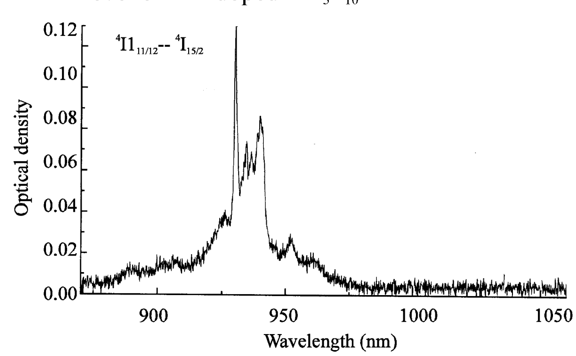

Fig. 2: Room temperature absorption spectrum of $^4I_{11/2}$ level of Er^{3+} doped KY_3F10

Corresponding Author: Khiari, S., University Centre of El-Tarf, El-Tarf 36000, Algeria

Table 1: Calculated electric and magnetic dipole emission probabilities, life times and branching ratios in KY_3F_{10} doped with Erbium ions

Transition	Average wavelength (nm)	Average energy (cm^{-1})	A^{rad} (s^{-1})	τ_{rad} (ms)	β(%)
$^4I_{13/2} \rightarrow {}^4I_{15/2}$	1481.3	6751	175.61	5.694	100
$^4I_{11/2} \rightarrow {}^3H_6$	932.5	10724	176.76	4.678	82.7
$^4I_{13/2}$	2517.3	3973	36.98		17.3
$^4I_{9/2} \rightarrow {}^4I_{15/2}$	883.2	11322	112.57	7.148	80.5
$^4I_{13/2}$	2187.4	4572	27.31		19.5
$^4I_{11/2}$	16695.0	599	0.02		0.0
$^4F_{9/2} \rightarrow {}^4I_{15/2}$	656.4	15235	1701.87	0.539	91.8
$^4I_{13/2}$	1141.5	8760	76.76		4.1
$^4I_{11/2}$	2020.7	4949	62.76		3.4
$^4I_{9/2}$	3609.6	2770	12.71		0.7
$^4S_{3/2} \rightarrow {}^4I_{15/2}$	545.0	18349	1517.24	1.23	66.3
$^4I_{13/2}$	848.6	11784	595.67		26.0
$^4I_{11/2}$	1240.3	8063	39.71		1.7
$^4I_{9/2}$	1699.4	5884	137.27		6.0
$^4F_{9/2}$	3211.3	3114	0.72		0.0
$^2H_{11/2} \rightarrow {}^4I_{15/2}$	521.3	19183	3556.05	0.257	91.2
$^4I_{13/2}$	792.5	12618	160.58		4.1
$^4I_{11/2}$	1124.0	8897	61.15		1.6
$^4I_{9/2}$	1488.4	6719	108.51		2.8
$^4F_{9/2}$	2532.8	3948	10.53		0.3
$^4S_{3/2}$	11987.5	834	0.04		0.0
$^4F_{7/2} \rightarrow {}^4I_{15/2}$	487.6	20509	4610.82	0.161	74.4
$^4I_{13/2}$	717.1	13945	767.97		12.4
$^4I_{11/2}$	978.2	10223	377.52		6.1
$^4I_{9/2}$	1243.1	8044	402.63		6.5
$^4F_{9/2}$	1896.1	5274	34.17		0.5
$^4S_{3/2}$	4629.6	2160	0.15		0.0
$^2H_{11/2}$	7542.6	1326	5.67		0.1

Optical spectroscopy: Room temperature optical spectra were recorded between 200 and 1600 nm. The observed spectra were .The observed spectra were independent of doping concentration in the range 0.1-1% molar concentration.

The Judd-Ofelt theory, widely used to analyse the forced electric dipole transitions within the 4fn configuration of the rare earth ions and extensively introduced in the literature[10-16] is performed on Er^{3+} doped KY_3F_{10}. We have identified seven absorption bands around 488, 521, 545, 656, 883, 932 and 1980 nm (Fig. 1 and 2).

The observed bands are attributed, respectively, to the multiplets $^4F_{7/2}$, $^2H_{11/2}$, $^4S_{3/2}$, $^4F_{9/2}$, $^4I_{9/2}$, $^4I_{11/2}$ and $^4I_{13/2}$. They are used in the fitting procedure. The three phenomenological parameters are $\Omega_2 = 2.207$, $\Omega_4 = 2.284$ and $\Omega_6 = 1.908$ in 10^{-20} cm^2 unit.

The computed transition probabilities and corresponding radiative lifetimes were then deduced and are given in Table 1.

CONCLUSION

We have synthesized Er^{3+} single crystals by Czochralski technique. The measured absorption line strengths at room temperature were used for a standard Judd-Ofelt analysis. The JO parameters were determined and they are in accordance with those calculated for other hosts. The radiative transition probabilities, radiative lifetimes and branching ratios of the main intermanifold transitions of Er^{3+} were calculated. Because of his low phonon energies, this crystal could permit up-conversion laser emissions.

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