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Excited-state luminescence properties and laser performance of the Tm^{3+} doped perovskite YAlO_3

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1. Introduction

Polarized absorption and emission spectra have been recorded in a broad spectral range to determine the best pumping and laser emission conditions of the crystals in the infrared domain and to show their potentialities in the blue/green and red regions. These data are completed by lifetime measurements made as a function of the dopant concentration and a discussion of the radiative versus the non-radiative relaxations between the various excited-states is developed on the basis of the Judd-Ofelt formalism. Ponctual excited-state excitation/absorption measurements are also performed to derive cross section values in a spectral region which has been found [1] interesting in this material for photon-avalanche up-conversion.

2. Experimental results

Figure 1a and 1b show the room temperature polarized absorption spectra of a YAP crystal doped by about 5% Tm^{3+} ions. According to Weber [2] these spectra lead to the Judd-Ofelt parameters:

$$\Omega_2 = 0.67 \times 10^{-20} \text{ cm}^2, \Omega_4 = 2.3 \times 10^{-20} \text{ cm}^2, \Omega_6 = 0.74 \times 10^{-20} \text{ cm}^2$$

which give in turn the radiative lifetimes and branching ratios given in Table 1.

Figures 2 and 3 show the room temperature visible emission spectra of a 1% Tm^{3+} doped powder sample obtained after $^1\text{D}_2$ and $^1\text{G}_4$ excitations at 355 and 470 nm respectively. These spectra show the spectral extents and give an idea of the respective intensities of the transitions originating from the $^1\text{D}_2$ and $^1\text{G}_4$ and terminating on the $^3\text{H}_6$ and $^3\text{F}_4$ levels.

Figure 4 gives the room temperature polarized emission spectra of a 5% Tm^{3+} doped crystal as a function of polarization, the spectra being calibrated between each other.

Table 2 gives the room temperature 1/e fluorescence time constants of the emissions originating from the various energy levels as a function of the dopant concentration.

In the end we give in Figures 5a and 5b room temperature polarized excited state excitation (ESE) spectra which were recorded with the aid of a two beam experiment, one laser beam being used to bring the ions in

their 3H_4 excited state, after pumping of the $^3F_2, ^3F_3$ levels and multiphonon relaxation, and the other, which could be triggered at various time delays after the former, being used to probe the fluorescences coming from the 1D_2 and 1G_4 levels. The ESE spectra were recorded around 650 nm, in a wavelength domain where a strong ESA line responsible for photon avalanche in this material should appear^[1]. By comparing the positions of the lines appearing in these spectra with the ones expected, from the energy level scale in this material, for $^3H_4 \rightarrow ^1D_2$ (large bars in the figures) and $^3F_4 \rightarrow ^1G_4$ (small bars in the figures) excited state absorption (ESA) transitions, it seems clear that the former dominates. This was confirmed further by delaying the probe beam by a few μs with respect to the pump beam since in this case the signal disappeared gradually and immediately. Indeed if the lines around 650 nm were assigned to $^3F_4 \rightarrow ^1G_4$ ESA transitions, then, because of the 210 μs feeding time of the 3F_4 metastable state after 3H_4 excitation [3] the ESE signal would increase with the time delay between the two laser pulses. This result is very surprising since the model proposed by the authors of Ref. 1 to account for their photon avalanche process only included the possibility of a $^3F_4 \rightarrow ^1G_4$ ESA transition. We have already planned to work on crystals doped by different amounts of Tm^{3+} ions and by pumping them in different excited states to clarify this question.

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Reference:

1. H. Ni and S.C. Rand; Opt. Lett. 16, 1424 (1993)
2. M.J. Weber
3. R. Moncorgé, H. Manaa, M. Koselja, G. Boulon, C. Madej, J.C. Souriau, C. Borel, Ch. Wyon; this Proceedings, paper MP 30

Figure 1: Room temperature absorption spectra of $YAP:Tm^{3+}$ for light polarized parallel ($\parallel$) and perpendicular ($\perp$) to the c axis of the crystal

TRANSITION	Average wavelength (nm)	$A_{ed}(s^{-1})$	$A_{md}(s^{-1})$	$\tau_R(ms)$	β_R
3F4 $\rightarrow$ 3H6	1800	225.1	0	4.44	1
3H5 $\rightarrow$ 3H6	1205	289.7	109.3	2.48	0.99
3F4	3645	4	0.3		0.01
3H4 $\rightarrow$ 3H6	800	887.8	0	0.92	0.82
3F4	1440	106.8	27.3		0.12
3H5	2380	46.7	10.7		0.05
3F3 $\rightarrow$ 3H6	700	2912.3	0	0.30	0.89
3F4	1145	62.5	82.4		0.04
3H5	1670	193.5	0		0.06
3H4	5600	4.59	0.27		≈ 0
3F2 $\rightarrow$ 3H6	665	675.5	0	0.74	0.50
3F4	1054	309.2	0		0.23
3H5	1483	350.5	0		0.26
3H4	3940	11.44	0		≈ 0
1G4 $\rightarrow$ 3H6	474	1075.2	0	0.44	0.47
3F4	643	201.1	14.9		0.09
3H5	781	534.3	156		0.3
3H4	1163	142.3	39.9		0.08
3F3	1468	69.6	4.4		0.03
3F2	1650	24.8	0		0.01
1D2 $\rightarrow$ 3H6	360	17564	0	0.035	0.61
3F4	450	7098	0		0.25
3H5	513	122.8	0		≈ 0
3H4	654	1031.9	0		0.03
3F3	741	697	119		0.02
3F2	784	1615.9	70.1		0.06
1G4	1496	158.3	0		≈ 0

Table 1: Transitions, average wavelengths, electric and magnetic dipole transition probabilities, radiative lifetimes and branching ratios in YAP:Tm³⁺

YAP: Tm ³⁺	1%	5%	10%
$\tau(^1D_2)$	17 μs	5 μs	—
$\tau(^1G_4)$	59 μs	23 μs	—
$\tau(^3H_4)$	414 μs	290 μs	3.2 μs
$\tau(^3F_4)$	4.4 - 4.9 ms	2.04 ms	730 μs

Table 2: 1/e fluorescence time constants of the emissions originating from the various energy levels in Tm³⁺ doped YAP for various Tm³⁺ concentrations

Figure 4. Room temperature calibrated and polarized infrared emission spectra of a 5% Tm³⁺ doped crystal

Figure 2: Room temperature visible emission spectra of a 1% Tm^{3+} doped YAP powder sample obtained after 355 nm excitation

Figure 3: Room temperature visible emission spectra of a 1% Tm^{3+} doped YAP powder sample obtained after 470 nm excitation

Figure 5: Room temperature ESE spectra recorded with a 5% Tm^{3+} doped YAP sample and comparison with the expected positions of the lines corresponding to the ${}^3\text{H}_4 \rightarrow {}^1\text{D}_2$ (large bars) and ${}^3\text{F}_4 \rightarrow {}^1\text{G}_4$ ESA transitions. (a) π polarization, (b) σ polarization