Photon cascade emission in LaF_3:Ce, Pr crystals

R.Theis and A.J.Wojtowicz

Institute of Physics, N. Copernicus University, Grudziadzka 5, 87-100 Torun, Poland

Although the crystals of lanthanum fluoride doped separately with Ce^{3+} and Pr^{3+} have been extensively investigated for the last forty years there is no report on crystals activated with Ce and Pr simultaneously. In this paper we report new results that are relevant to the interesting problem of the Pr cascade emission and Pr-Ce competition in LaF_3 crystals. Photon cascade emission (PCE) in Pr^{3+}- doped fluorides, including LaF_3, was first reported by Piper et al [1].

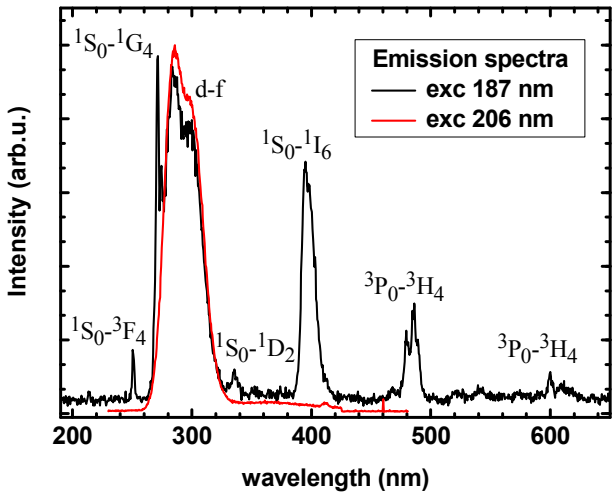

Figure 1: Uncorrected UV and VIS emission spectra of LaF_3:Ce, Pr at 297 K. The excitation was set at 187 (black) and 206 nm (red line). Resolution was 2.7 nm.

In Fig. 1 we show the emission spectra of the LaF_3:Ce,Pr sample excited at 206 and 187 nm measured at 298 K. Both spectra reveal the well known 5d-4f cerium emission but, under the 187 nm excitation, additional lines at 251, 271, 334, 396, 480 and 600 nm are observed. Those lines are associated with the well known f-f transitions of Pr^{3+} ion that originate at the $^1S_0$ level populated by non-radiative relaxation from the Pr^{3+} 5d-level [2]. The final states reached by these transitions, such as $^3P_0$ (after relaxation from $^1I_6$), $^1D_2$ release second cascade photon via transitions to lower states including the ground state $^3H_4$ [3].

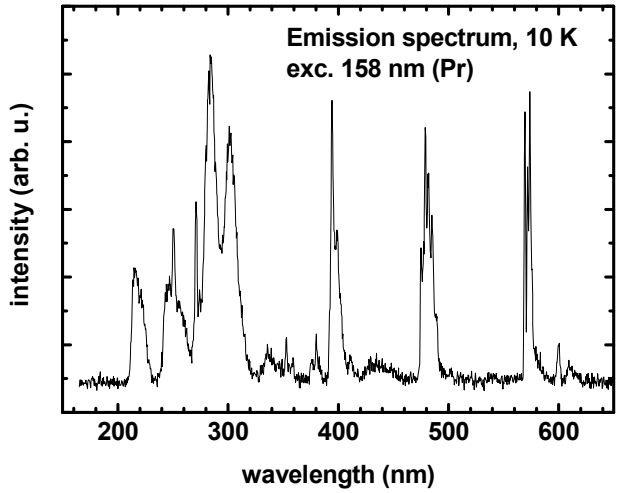

Figure 2: Uncorrected emission spectrum of LaF_3:Ce, Pr at 10 K. The excitation was set at 158 nm. Resolution was 2.7 nm.

We note that the loss to the cascade process, represented by d-f and $^1S_0$ transitions terminating at lower $4f^2$ states and generating only one photon is even higher at 10 K (see Fig. 2). In addition to the lines represented in Fig. 1, there are also additional Pr d-f bands at 216 and 250 nm.

It is interesting to note that the two Pr UV emission lines at 251 and 271 nm, representing direct f-f transitions from the $^1S_0$ state, and two Pr d-f bands at 216 and 250 nm, with no possibility of the second visible cascade photon, are covered by absorption of the Ce ion shown in Fig. 3. We may therefore consider a scenario, in which the UV loss photons (216, 250, 271 nm) are converted to the more useful visible photons by an adequate codopant ion.

From this point of view the Ce codopant ion is hardly the best choice as its emission in LaF_3 covers a range of UV wavelengths at about 280 to 320 nm. We note however that it behaves as expected since there is a significant contribution of Ce emission (see Fig. 2) although the excitation at 158 nm clearly favours Pr. One possible solution to consider is to choose a different ion (such as Tb) or even two codopant ions such as Ce and Tb that would efficiently absorb loss photons and convert them to useful photons in the visible.

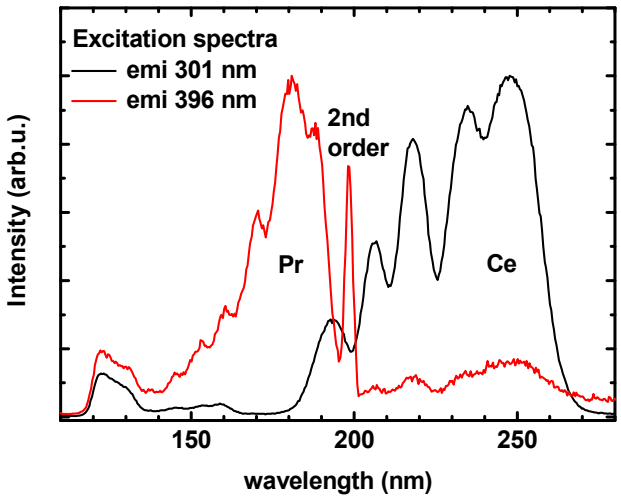

Figure 3: Excitation spectra of Pr f-f emission (red line) and Ce d-f emission (black line) at 297 K. Resolution was 0.32 nm.

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References

[1] W. Piper, J.A. DeLuca, F.S.Ham, J.Lumin. 8, 344 (1974)
[2]) W.J. Shipper, G. Blasse, J.Lumin. 59, 377 (1994)
[3] S. Kück,, I. Sokólska, M. Henke, M. Döring, T. Scheffler J.Lumin. 102-103, 176 (2003)