VUV studies of new potential scintillator material, $Rb_3Lu(PO_4)_2$:Ce

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Wide bandgap orthophosphates and phosphates activated with Ce and Nd are widely recognized as potential UV and VUV scintillator materials. Although alkali rare earth double phosphates $M_3RE(PO_4)_2$ (M = K, Na) have been studied in more detail [1] and some rubidium double phosphates based on lighter RE ions have been described by Melnikov et al. [2] not much is know of $Rb_3Lu(PO_4)_2$. In particular there are, to the best of our knowledge, no studies published on scintillator properties of $Rb_3Lu(PO_4)_2$.

In this note we report initial results of VUV studies on $Rb_3Lu(PO_4)_2$:0.1mol%Ce monocrystals grown at Oak Ridge National Laboratory. The experiments, conducted at Superlumi station of Hasylab at DESY were designed to study physical mechanisms of energy transfer from the host to Ce ions that are highly relevant for perfomance of the material as a scintillator.

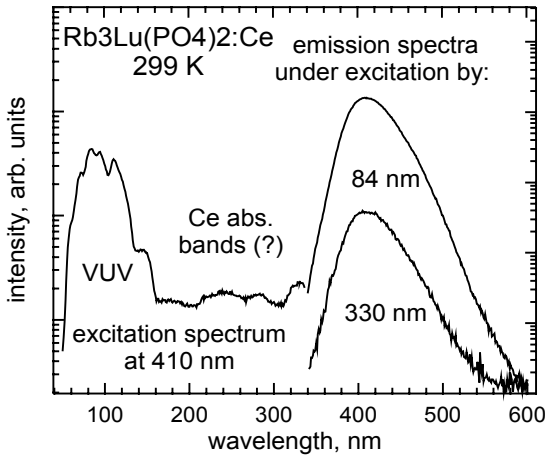

Figure 1: Uncorrected emission (resolution 4.32 nm) and excitation (resolution 0.32 nm) spectra of $Rb_3Lu(PO_4)_2$:Ce measured at 299 K The emission spectra were measured with excitation wavelength set at 84 and 330 nm. The excitation spectrum was measured with the emission wavelength set at 410 nm (maximum of Ce-emission). Note the high VUV response and relatively weak Ce-4f-5d absorption bands. For details see text.

In Figs. 1 and 2 we present excitation and emission spectra of $Rb_3Lu(PO_4)_2$:0.1mol%Ce obtained at 299 K. These spectra were measured with the signal accumulated between the consecutive synchrotron pulses (192 ns). We note that the excitation spectra measured at 410 nm show weak bands below 350 nm that presumably correspond to Ce^{3+} *f-d* bands split by a low symmetry crystal field component. Interestingly these bands are much weaker than the structured VUV band between 50 and 160 nm that reflects processes triggered by over the bandgap excitation of the material.

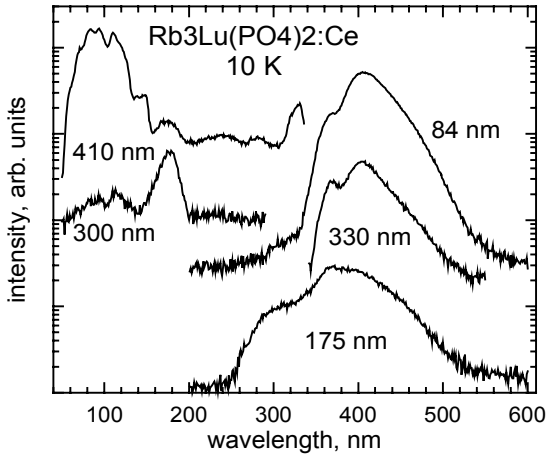

Figure 2: Uncorrected emission and excitation spectra of $Rb_3Lu(PO_4)_2$:Ce measured at 10 K. The spectra were shifted to aid presentation. In addition to the double Ce^{3+} emission band peaking at about 371 and 407 nm there is some very broad "host" emission band overlapping the Ce-emission band. Note the "host" peak at 175 nm in the excitation spectrum measured at emission wavelength of 300 nm. The largest contribution of the "host" emission is in the spectrum obtained for excitation into the "host" peak.

The structure in the band below 160 nm is due to spectral characteristics of the Al grating of the primary monochromator and does not reflect any true physical processes. Nevertheless, since the VUV photons at these wavelengths provide over the bandgap excitation of the host material, the high signal at these wavelengths indicates that Ce ions must be efficient radiative recombination centers. This conclusion is further supported by the emission spectra shown in Fig. 1 showing that emission spectra excited by the VUV

(84 nm) and *f-d* (330 nm) transitions, are both dominated by the same band peaking at about 410 nm and due, presumably, to Ce^{3+} ions in the $Rb_3Lu(PO_4)_2$ host.

At 10 K (see Fig. 2) the Ce-emission band shows two resolved components (371 and 407 nm) due to the spin-orbit split ground state levels of the Ce^{3+} ion. In addition the emission spectrum obtained for the 84 nm excitation shows some additional features due to, most likely, a weak contribution of some other emission bands.

Indeed, the excitation spectrum of additional emission (emission wavelength set at 300 nm) presented in Fig. 2, is different than for Ce emission, showing much less VUV contribution and an additional band peaking at 175 nm ("host" peak). The emission spectrum obtained for excitation into this band and presented in Fig. 2 shows clearly an additional emission band overlapping the Ce-emission band and extending from 250 to, say, 440-450 nm.

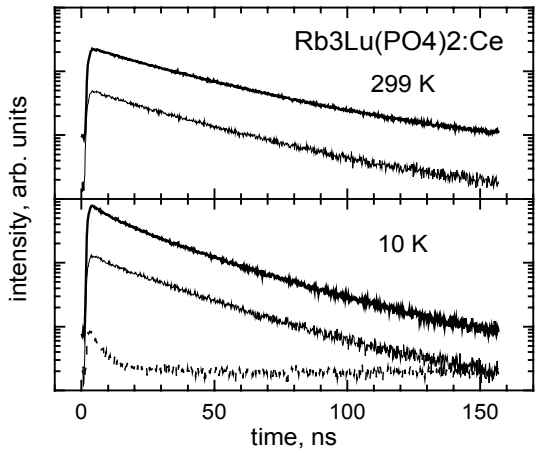

Figure 3: Emission time profiles of $Rb_3Lu(PO_4)_2$:Ce. Thin solid lines depict time profiles of Ce-emission (at 410 nm) excited at VUV (84 nm) and measured at 299 (upper panel) and 10 K (bottom panel). Thick solid lines depict time profiles of Ce-emission under excitation into the f-d band (330 nm) at 299 (upper panel) and 10 K (bottom panel) Broken line (bottom panel) depicts "host" emission (at 300 nm) excited into the "host" peak (at 175 nm) at 10 K. Note that "host" emission is absent at ambient temperatures.

Finally in Fig. 3 we present emission time profiles of Ce- and "host" emissions under VUV- and Ce absorption band excitations at 299 and 10 K. We note that all the profiles, except "host" emission profile shown by a broken line in the bottom panel of Fig. 3, are nearly single-exponential with the decay time constant on the order of 30-40 ns. Since the Ce-emission wavelength in $Rb_3Lu(PO_4)_2$ is slightly longer than in, say, YAP, LuAP or BaF_2 longer decay time is to be expected. The "host" peak excited "host" emission shows both a faster component and a higher background indicative of much slower components. The presence of slower components is further supported by much higher contribution of the "host" emission in "gated" delayed spectra (not shown).

All the results presented in this note clearly suggest that there is a dominant mode of direct and efficient energy transfer from the host of $Rb_3Lu(PO_4)_2$ to the activator Ce-ion; most likely due to recombination of electron-hole pairs via Ce-ions. There is, however, no evidence of any traps that usually accompany recombination of free charge carrriers. There also is no evidence of any significant competition from other processes, such as exciton-mediated nonradiative energy transfer, even at lower temperatures. We conclude that $Rb_3Lu(PO_4)_2$ is a very promising scintillator material and it is interesting and important to evaluate material under gamma excitation.. For many applications, however, larger crystals should be grown.

References

[1] B. Finke, PhD Thesis, Univeristy of Greifswald (Germany) 1984; L. Schwarz, Dr. Habil. Thesis, University of Greifswald (Germany) 1985.

[2] P.P. Melnikov, V.B. Kalinin, V.A. Efremov, L.N. Komissarova, Izv. Akad. Nauk SSR, Nieorg. Mat. 17 (1981) 1452.