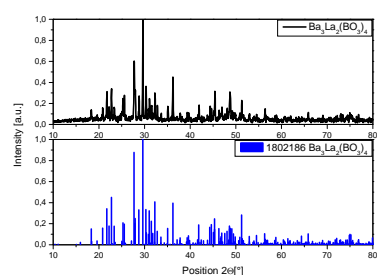




## Background

UV radiation sources are used in various application fields, for example in therapeutic, diagnostic, and cosmetic devices. This is due to the high energy of UV radiation, which is able to induce many photochemical reactions, like bond cleavages or photoisomerisation. The latter reaction type is relevant for vitamin D production in human skin, which is catalysed by 290 to 315 nm radiation. Another wide field of application is disinfection and/or purification of water by UV-C radiation. In general, the 254 nm (and 185 nm) line of Hg low pressure lamps is used to this end. However, Hg is toxic and Hg discharge lamps show a very strong temperature dependence and rather limited lifetime. Therefore, novel UV radiation sources are desired, like the Xe excimer lamp with an emission peak 172 nm. Fluorescent Xe excimer discharge lamps use phosphors that emit in the desired UV range, e.g. at 254 nm to mimic the low-pressure Hg lamp spectrum. A promising class of materials for this purpose are borates, which are well investigated as visible emitting phosphors, but not as UV emitting VUV phosphors yet.



**Fig. 1** Powder diffraction pattern of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Pr}^{3+}$

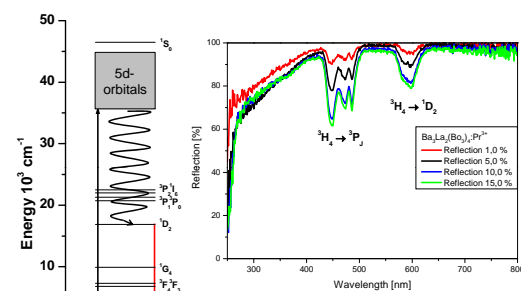
There are several types of borates, like the orthoborates ( $\text{M}_x(\text{BO}_3)_y$ ), oxyorthoborates ( $\text{M}_x(\text{BO}_3)_y\text{O}$ ), metaborates ( $\text{MB}_3\text{O}_6$ ), pentaborates ( $\text{M}_1\text{M}_2\text{B}_5\text{O}_{10}$ ), and heptaborates ( $\text{M}_1\text{M}_2\text{B}_7\text{O}_{13}$ ). Orthoborates, metaborates and pentaborates are already known as luminescent materials.

In this work, ternary orthoborates according to the formula  $\text{M}_3\text{Ln}_2(\text{BO}_3)_4$  ( $\text{M} = \text{Sr}, \text{Ba}$ ;  $\text{Ln} = \text{La}$ ) were studied, to investigate their luminescent properties upon doping by rare earth ions or  $\text{Bi}^{3+}$ .

In  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4$  is no defined  $\text{La}^{3+}$ -positions, but three metal positions, which are partially filled by  $\text{La}^{3+}$  and  $\text{Ba}^{2+}$ .

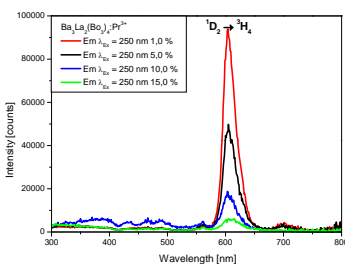
## Synthesis

All presented samples were prepared by the solid state method. As starting materials high purity  $\text{H}_3\text{BO}_3$ ,  $\text{MCO}_3$  ( $\text{M} = \text{Ba}$ ),  $\text{La}_2\text{O}_3$ , and  $\text{Ln}(\text{NO}_3)_3$  in case of  $\text{Ce}^{3+}$  or  $\text{Pr}^{3+}$  were used. Appropriate blends were precalculated for 4 h at  $600^\circ\text{C}$  in air. Afterwards the materials were calcinated for 8 h at temperatures around  $1200^\circ\text{C}$ .

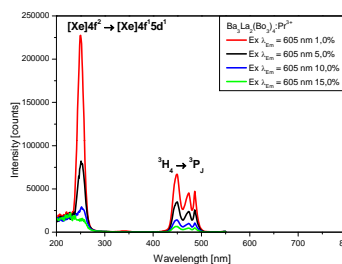


**Fig. 2** Energy diagram of  $\text{Pr}^{3+}$

**Fig. 3** Reflection spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Pr}^{3+}$ -concentration series



**Fig. 4** Emission spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Pr}^{3+}$ -concentration series



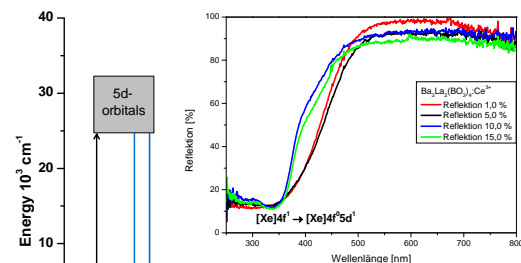
**Fig. 5** Excitation spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Pr}^{3+}$ -concentration series

Above mentioned borates were doped with the activator ions  $\text{Ce}^{3+}$  or  $\text{Pr}^{3+}$ , which are typically known as activator ions for UV emitting phosphors.  $\text{Pr}^{3+}$  can show broad band emission due to  $[\text{Xe}]4f^15d^1-[\text{Xe}]4f^2$  transitions or narrow line emission due to  $[\text{Xe}]4f^2-[\text{Xe}]4f^2$  transitions.  $\text{Ce}^{3+}$  exhibit a broad emission band due to the  $[\text{Xe}]4f^05d^1-[\text{Xe}]4f^1$  transition.

From both ions a concentration series were made to see the maximum of the emission concentration.

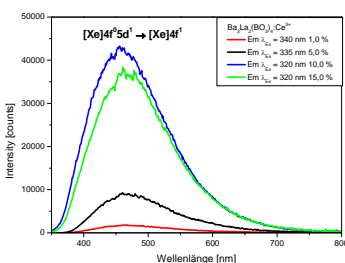
The samples were measured by x-ray diffraction to determine the phase purity. The maximum phonon frequency was determined by Infrared-spectroscopy.

Finally, they were characterised by luminescence and reflection spectroscopy.

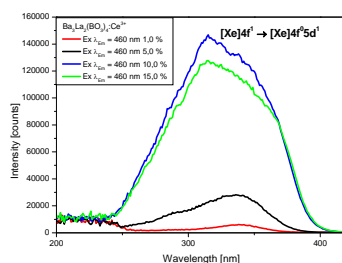


**Fig. 6** Energy diagram of  $\text{Ce}^{3+}$

**Fig. 7** Reflection spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Ce}^{3+}$ -concentration series



**Fig. 8** Emission spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Ce}^{3+}$ -concentration series



**Fig. 9** Excitation spectra of  $\text{Ba}_3\text{La}_2(\text{BO}_3)_4:\text{Ce}^{3+}$ -concentration series

## Conclusions

Single phase ternary orthoborates could be prepared by sintering the respective binary oxides and boric acid in air. In case of  $\text{Pr}^{3+}$  the 5d-band lies between 240 and 280 nm, so it is very close to the 4f energy levels ( $^3P_1$ ). The emission of  $\text{Pr}^{3+}$  takes only place at 605 nm, other transitions are quenched due to multi-phonon-relaxation ( $\omega = 1500\text{ cm}^{-1}$ ). The highest emission intensity occurs at 1%  $\text{Pr}^{3+}$ , at higher concentrations concentration quenching due to cross relaxation is observed.  $\text{Ce}^{3+}$  shows broad band emission with a maximum at 460 nm. The highest emission intensity is observed at 10%  $\text{Ce}^{3+}$ . By increasing the concentration, the emission is governed by concentration quenching.