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LUMINESCENT SPECTROSCOPY OF Pr^{3+} IONS IN SOME PHOSPHATES, BORATES AND SILICATES USING X-RAY SYNCHROTRON RADIATION FROM VEPP-3 STORAGE RING

Kiselev S.A.[1], Pustovarov V.A.[1], M.Bettinelli[2]

[1]Institute of Physics and Technology, Ural Federal University, 19 Mira st., 620002 Ekaterinburg, Russia

[2]Department of Biotechnology, University of Verona and INSTM, UdR Verona, Strada Le Grazie 15, I-37134 Verona, Italy

Corresponding author: sviat-kiselev@yandex.ru

Introduction

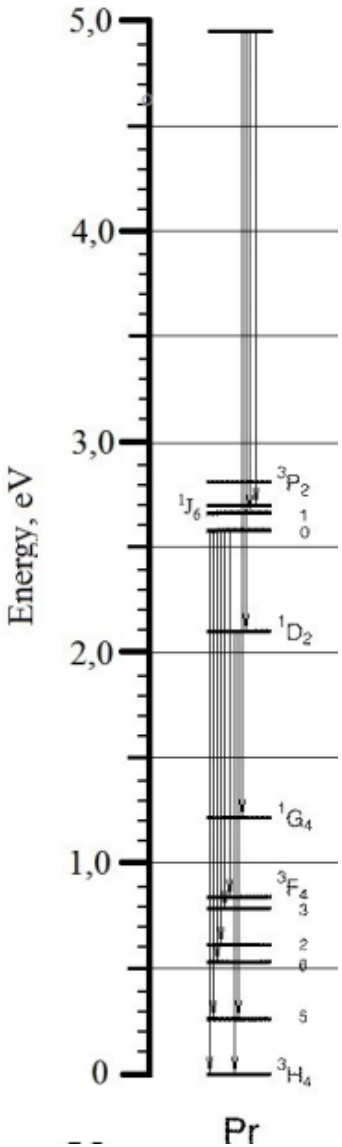
- Praseodymium-ions doped luminescent materials are recently being actively investigated due to demonstration of fast interconfigurational 5*d* – 4*f* optical transitions.
- These transitions appear, when a sufficiently strong crystal field shifts the lowest $4f^1 5d^1$ excited state below the $^1S_0$ level.
- Perfect timing and rather high emission output make researches of praseodymium impurity luminescence relevant.
- In this report we examine spectroscopic luminescent properties of some samples under excitation of X-ray synchrotron radiation.

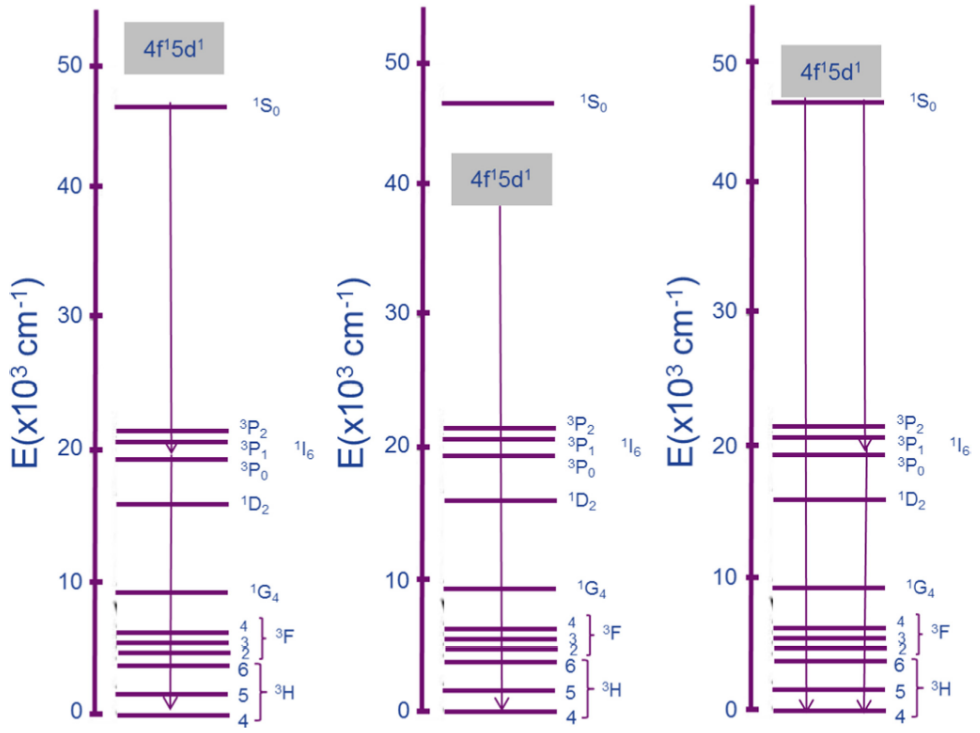
Relevance

- Inorganic scintillator materials with improved characteristics in terms of light output and timing are widely required in modern technologies such as nuclear physics, security, chemistry, space physics, medical imaging, etc.
- Pr^{3+}-doped hosts are doubly demanded in systems working at higher count rate – they are characterized with short wavelengths and fast decay time, especially in comparison with Ce^{3+} ions, which are widely used in modern detecting systems.

Configuration of energy levels in Pr^{3+} ion

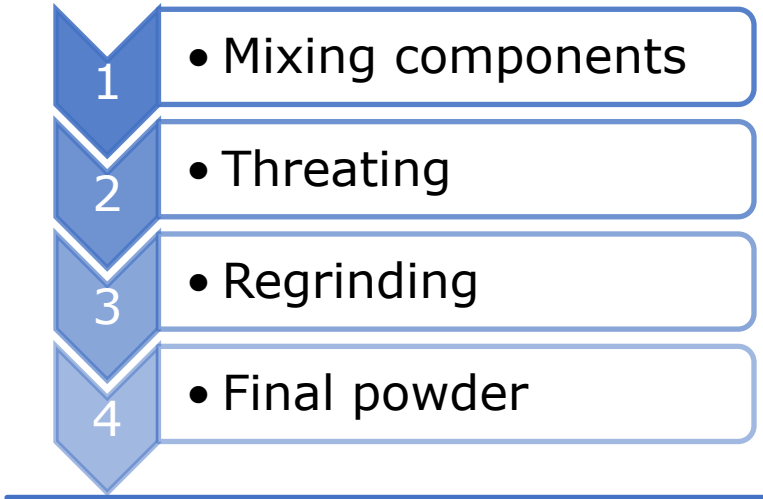
Dieke's energy diagram





Object and experimental details

- Polycrystalline samples of Pr^{3+}doped $KLuP_2O_7$, $Li_6Y(BO_3)_3$, $LiY_6O_5(BO_3)_3$, $LiSrPO_4$, $Sr_9Sc(PO_4)_7$, $K_3Lu(PO_4)_2$, $K_3LuSi_2O_7$ were synthesized using a solid state reaction and XRD verified for phase purity at the Laboratory of Luminescent Materials, University of Verona (Italy).



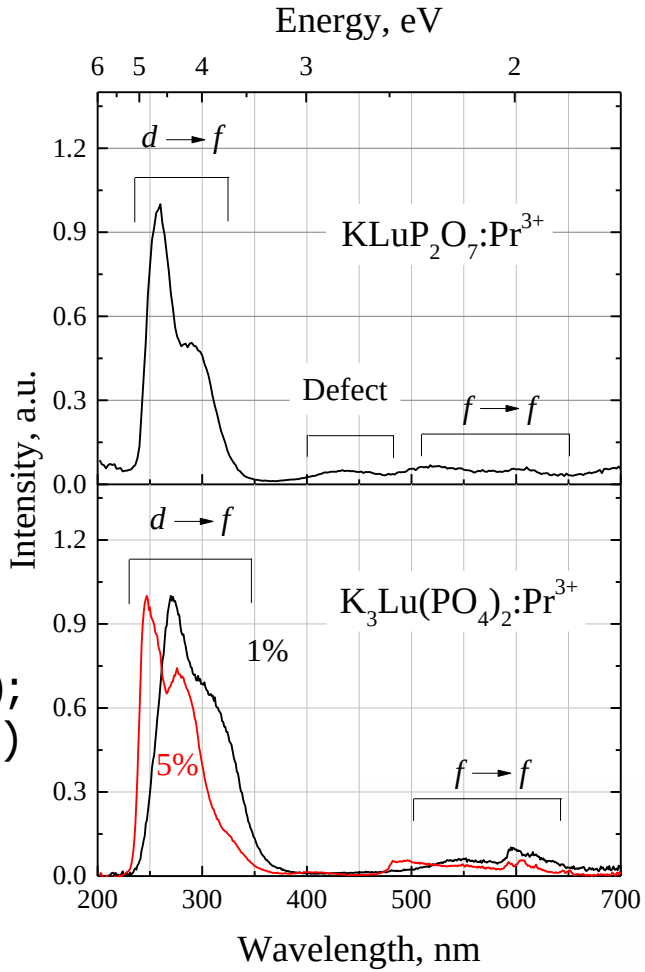
Flowchart of powders' synthesis

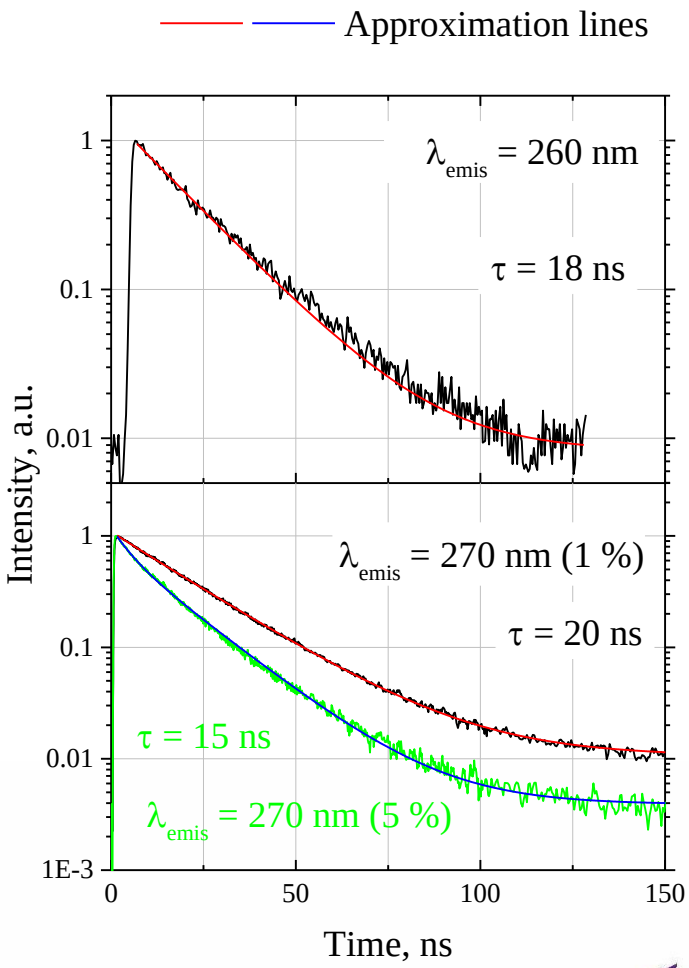
- Mentioned samples were observed though measurements of decay kinetics and emission spectra upon excitation with non-monochromatic X-ray synchrotron radiation (E = 3–60 keV, pulse FWHM ~ 1 ns, frequency ~ 8 MHz) at the beamline #6 of the VEPP-3 storage ring at Budker Institute of Nuclear Physics (Novosibirsk).
- The pulsed cathodoluminescence (PCL) spectra and PCL decay kinetics were measured using Radan-330A pulse electron gun (E = 120 keV, pulse FWHM = 200 ps, rate 5 Hz) at University of Tartu (Estonia).

Phosphates

LO ~
4.0 ph/keV

LO ~
20 ph/keV (1%);
15 ph/kev (5%)



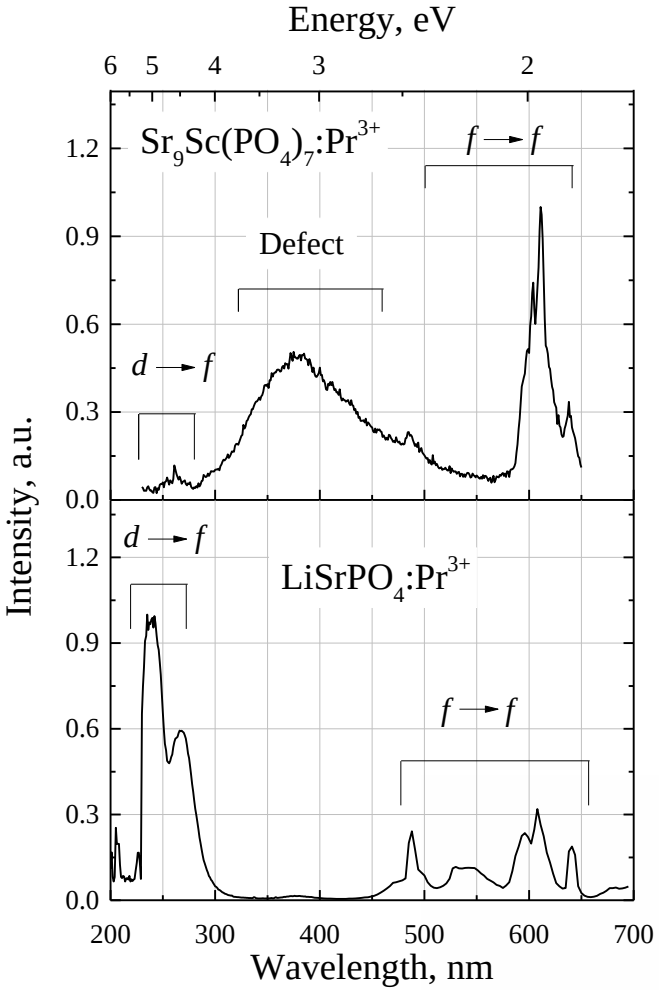


XRL spectra of studied phosphates at T = 295 K

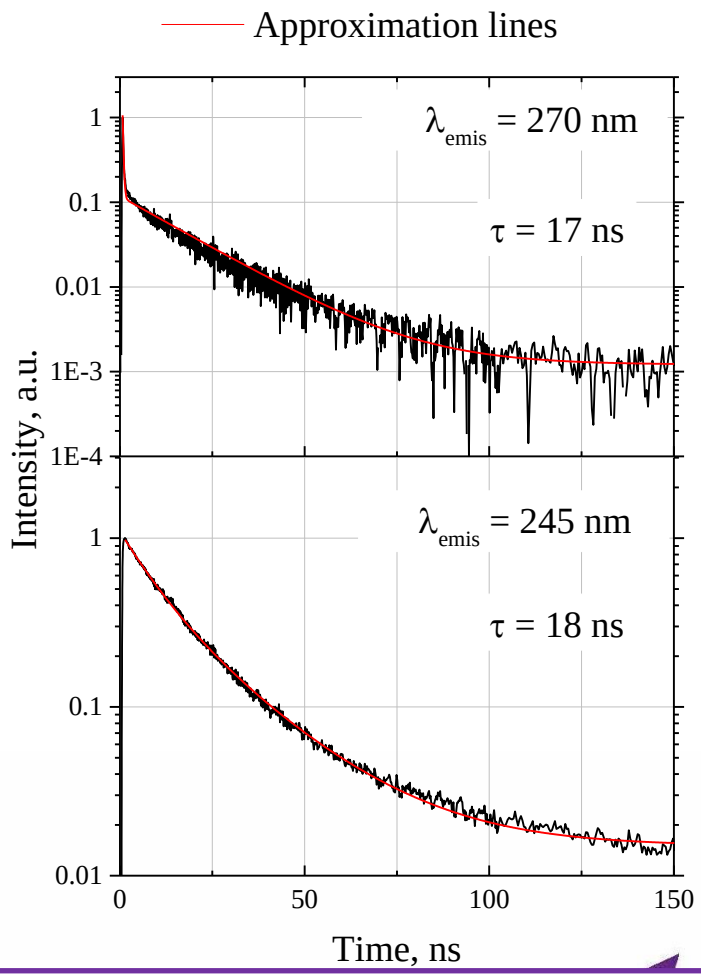
Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Phosphates

LO ~
3.6 ph/keV

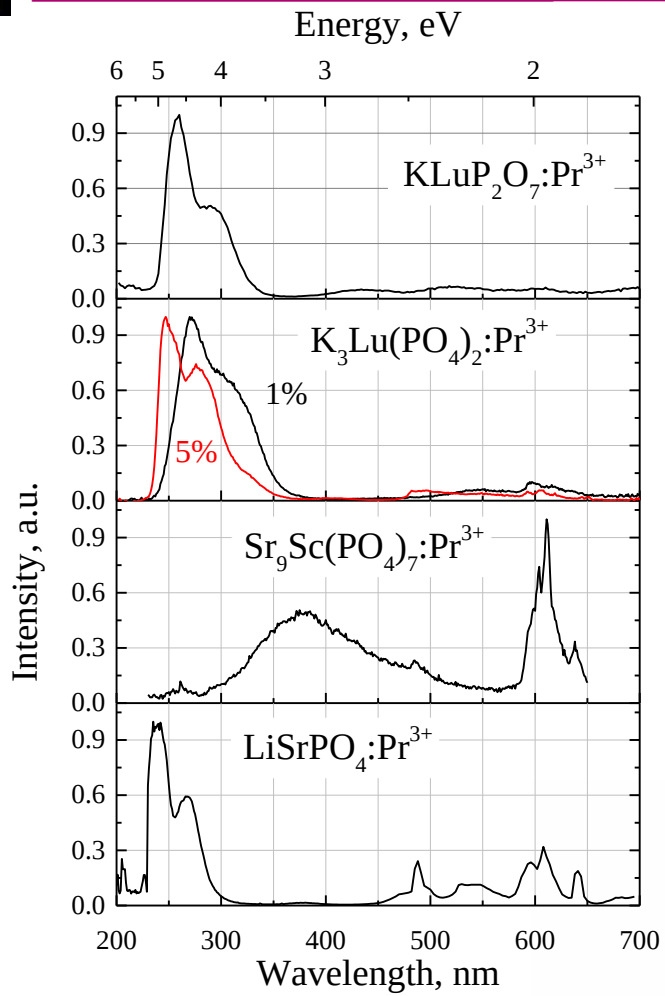


XRL spectra of studied phosphates at T = 295 K

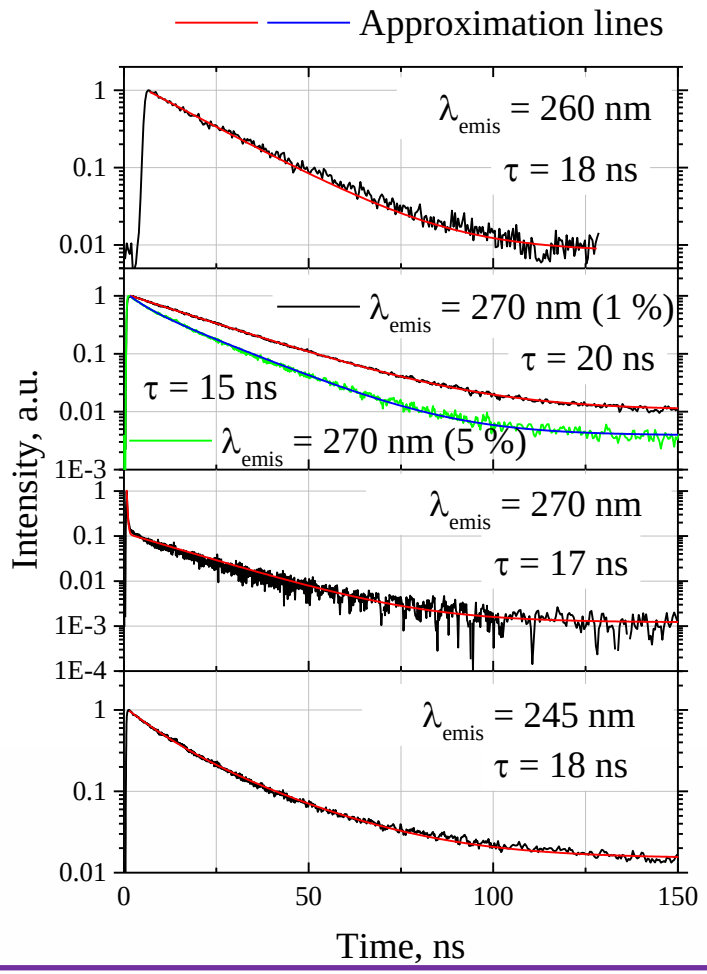


Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Phosphates



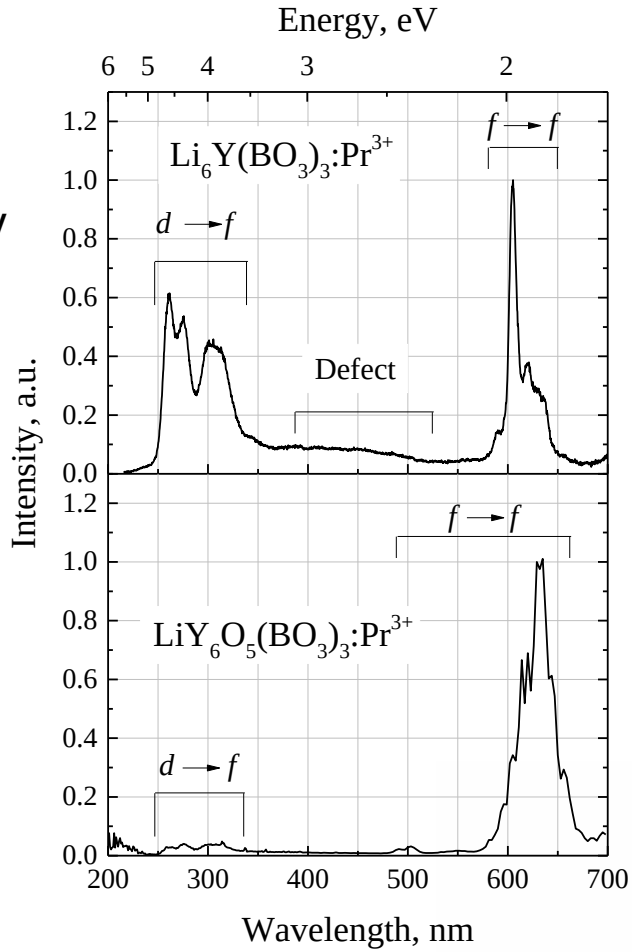
XRL spectra of studied phosphates at T = 295 K

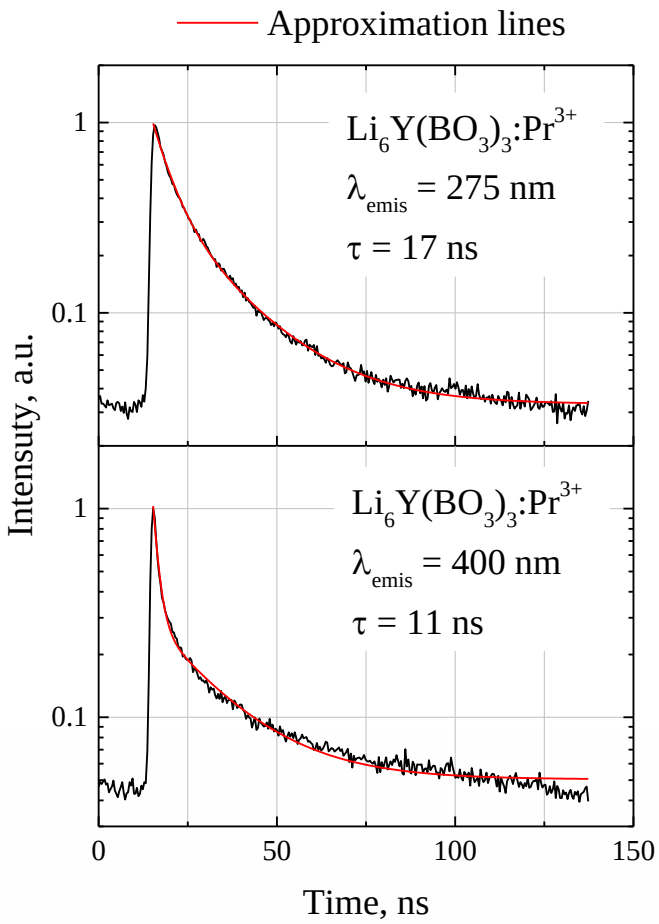


Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Borates

LO ~
3.9 ph/keV



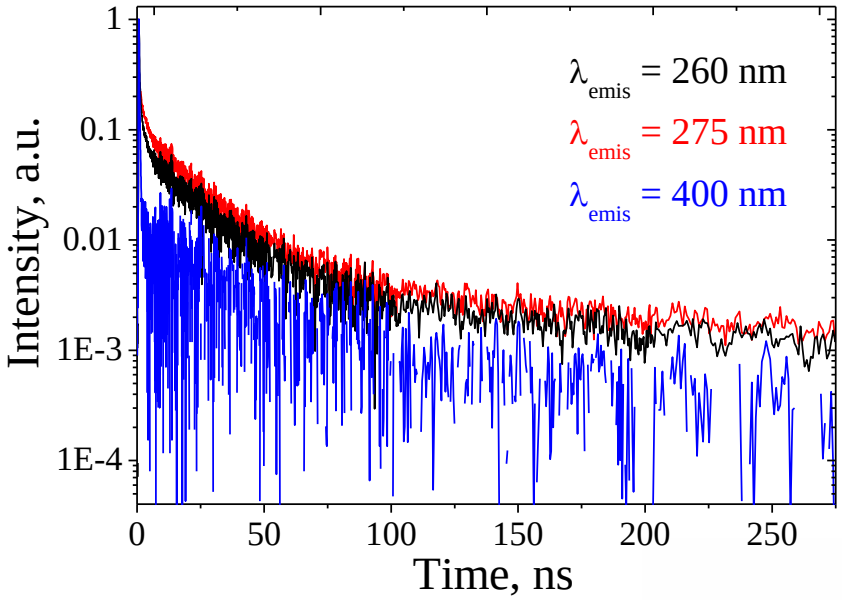


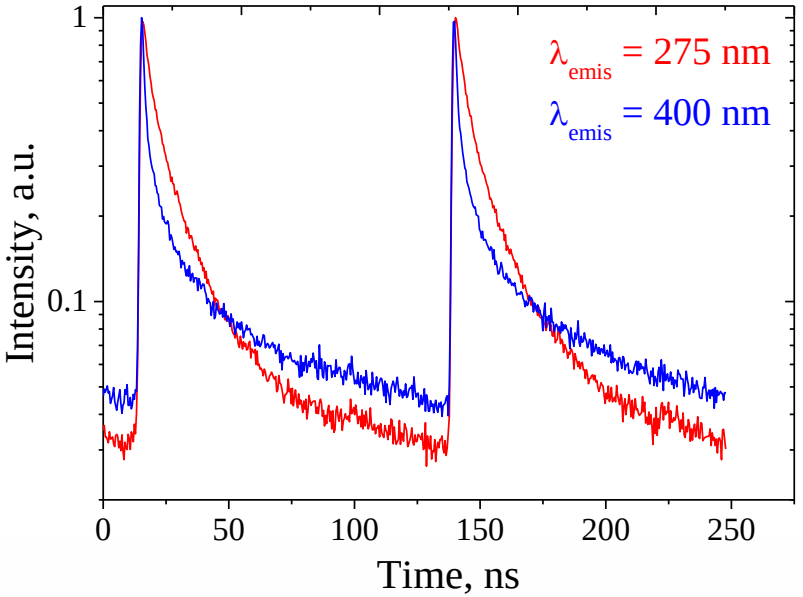
XRL spectra of studied borates at T = 295 K

Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Comparison of PCL and XRL kinetics

$Li_6Y(BO_3)_3:Pr^{3+}$ $4f^15d \rightarrow 4f^2$ emission

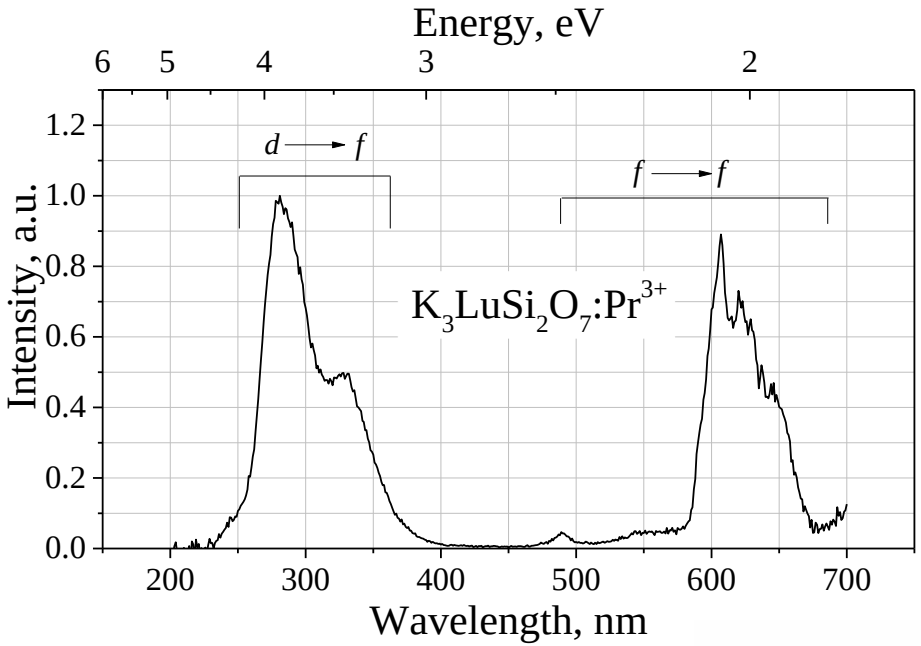


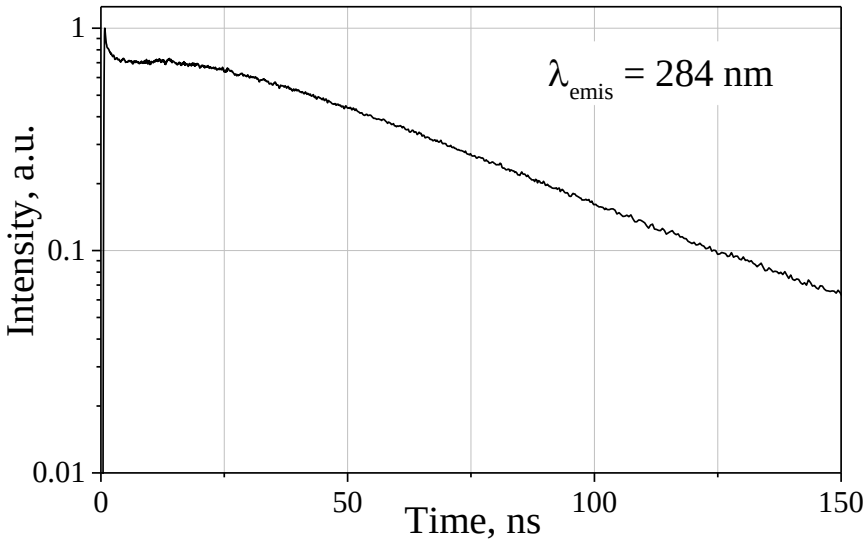


Luminescence decay kinetics with pulse cathode ray shot, T = 295 K

Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Silicates





LO ~ 64.0 ph/keV

XRL spectra of studied silicates at T = 295 K

Luminescence decay kinetics with high frequency X-ray synchrotron radiation, T = 295 K

Comparison

Material	Z_{eff}	λ_{max}, nm	τ, ns	d-f/f-f
$Sr_9Sc(PO_4)_7$: Pr^{3+} (1 %)	27.0	261; 300	17	0.12
$LiSrPO_4$: Pr^{3+} (1 %)	**36.8**	**240; 267**	**18**	**3.25**
$K_3Lu(PO_4)_2$: Pr^{3+} (1 %)	**37.6**	**270; 308**	**20**	**9.10**
$K_3Lu(PO_4)_2$: Pr^{3+} (5 %)	**37.6**	**246; 278**	**15**	**14.28**
$KLuP_2O_7$: Pr^{3+} (1 %)	**41.6**	**258; 292**	**18**	**12.51**
$Li_6Y(BO_3)_3$: Pr^{3+} (1%)	20.0	261; 305	17	0.62
$LiY_6O_5(BO_3)_3$: Pr^{3+} (1%)	32.1	274; 309	-	0.05
$K_3LuSi_2O_7$: Pr^{3+} (1%)	64.9	279; 327	54	1.14

Comparative characteristics of polycrystalline samples doped with Pr^{3+} ion, T= 295 K

Conclusion

- Praseodymium-ions doped luminescent materials are recently being actively investigated due to demonstration of fast interconfigurational 5*d* – 4*f* optical transitions.
- The spectroscopic properties of praseodymium-doped phosphates, borates and silicates are studied in this report.
- Based on luminescence lifetime, *d-f/f-f* ratio and emission energy region parameters the conclusion of most perspective material for application in scintillator systems is made. In our opinion, these materials are $K_3Lu(PO_4)_2:Pr^{3+}$ (5 %), $K_3Lu(PO_4)_2$: Pr^{3+} (1 %), $KLuP_2O_7$: Pr^{3+} (1 %) and $LiSrPO_4$: Pr^{3+} (1 %).
- To produce the entire conclusion of material application potential a thorough analysis is needed implying studying another types of excitation and temperature research.

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Thank you for attention!

Acknowledgements

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