TARTU ÜLIKOOL
FÜÜSIKA INSTITUUT

# Spectroscopic study of complex oxides solid solution $Lu_xY_{1-x}PO_4:Ce^{3+}$

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Supervisors M.Brik, D. Spassky
University of Tartu

MARIE CURIE ACTIONS

# Potential application

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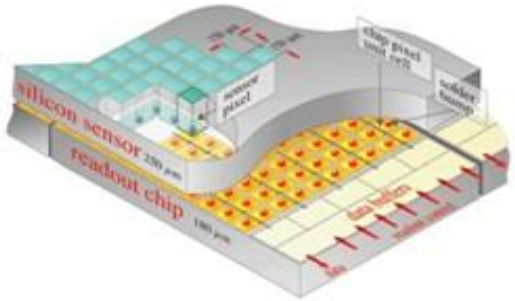
scintillating detectors



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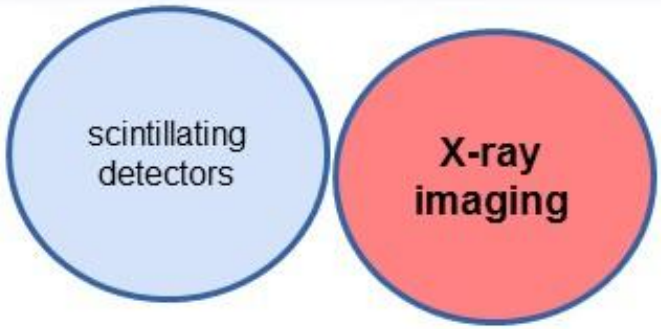

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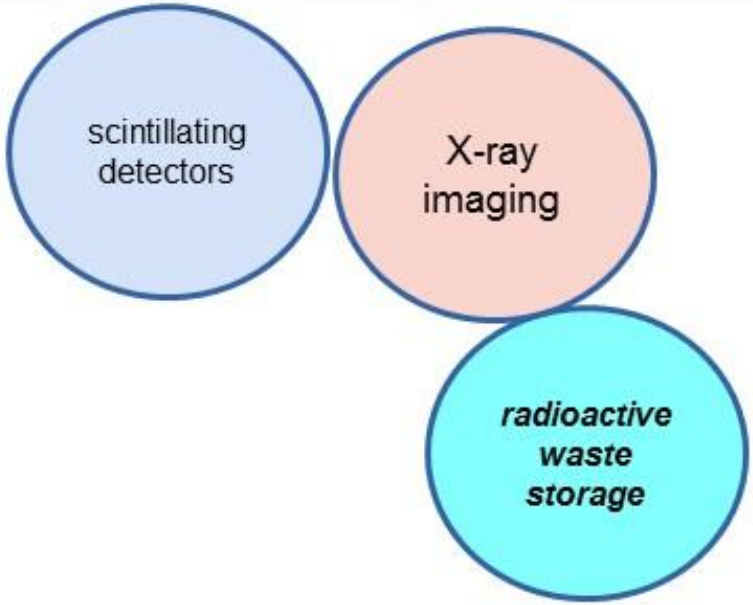


# Potential application

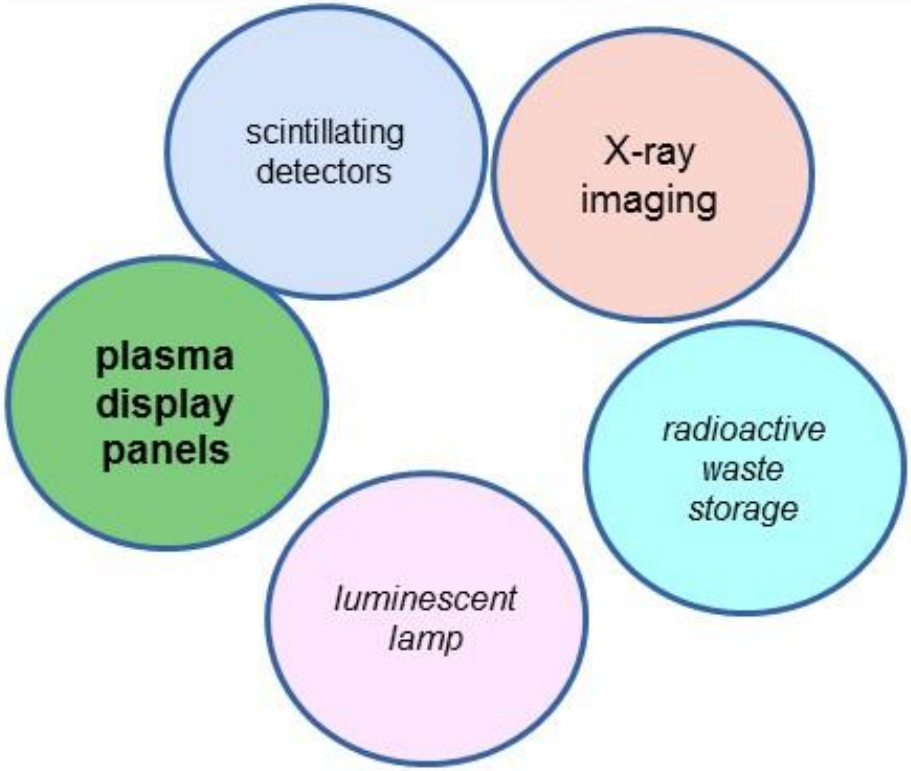
scintillating detectors

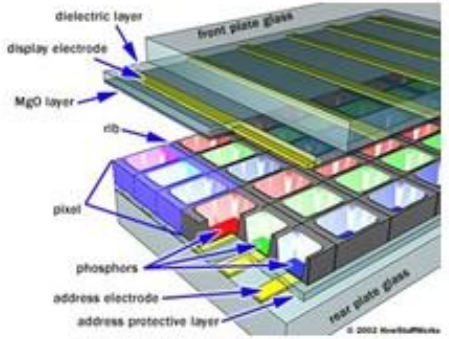
X-ray imaging

*radioactive waste storage*

***luminescent lamp***

# Potential application



# Properties of solid solution

- Solid solutions may have properties that differ from properties of its components.

- In solid solution of metals the increase of resistivity has been observed. This effect is ascribed to clusterisation.

Clusterisation - local regulation of the solid solution with creation of areas with primary content of one of the components.

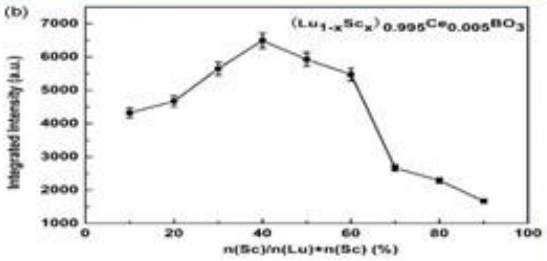
# Clusterisation of solid solutions

In solid solutions the clusters may appear, which constrains the thermalization length of hot electrons and holes and therefore influence on the energy transfer to the emission centers.
This phenomenon may result in the increased light yield.

**The superior light yield was observed for:**

# Clusterisation of solid solutions

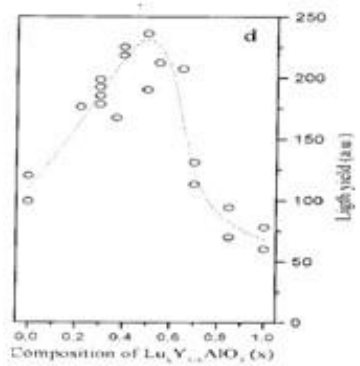
Wu et al. / J. All. Comp. *509 (2011) 366.*




In solid solutions the clusters may appear, which constrains the thermalization length of hot electrons and holes and therefore influence on the energy transfer to the emission centers.
This phenomenon may result in the increased light yield.

**The superior light yield was observed for:**

- $(Lu,Gd)_2SiO_5:Ce^{3+}$
- $(Lu,Gd)_2SiO_5:Ce^{3+}$
- $Lu_xY_{1-x}BO_3:Eu^{3+}$
- $Lu_{1-x}Sc_xBO_3:Ce^{3+}$
- $Y_3(Al_{1-x}Ga_x)_5O_{12}:Ce^{3+}$
- $Lu_xY_{1-x}AlO_3:Ce^{3+}$



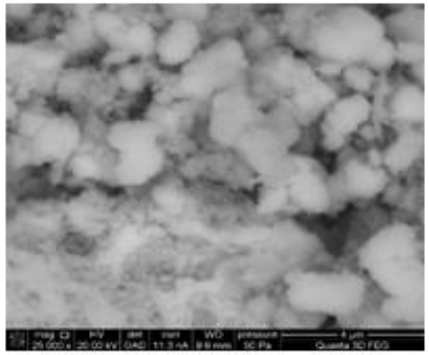

Belsky, et al, IEEE TNS 48 (2001) 1095.

# Aim of research

properties of solid solutions $Lu_xY_{1-x}PO_4$ doped with $Ce^{3+}$.

Special attention will be paid to the processes of energy transfer to the emission centers in the studied compounds.

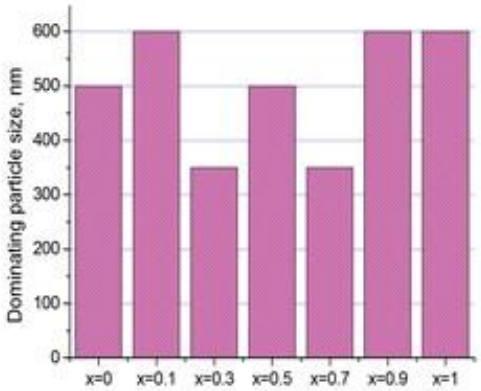
# Crystal strucrure



The luminescence properties of a series of phosphate solid solutions with general formula $Lu_xY_{1-x}PO_4$ were studied (**x** = 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1) doped with 0.5 mol % $Ce^{3+}$.

Samples were synthesized by **sol-gel method**.

According to the data of **grain-size analysis** of the synthesized powders on the laser diffraction particle size analyzer Shimadzu SALD-2201 the dominating size of the particles of all compositions is around **350-600 nm.**



# Aim of research

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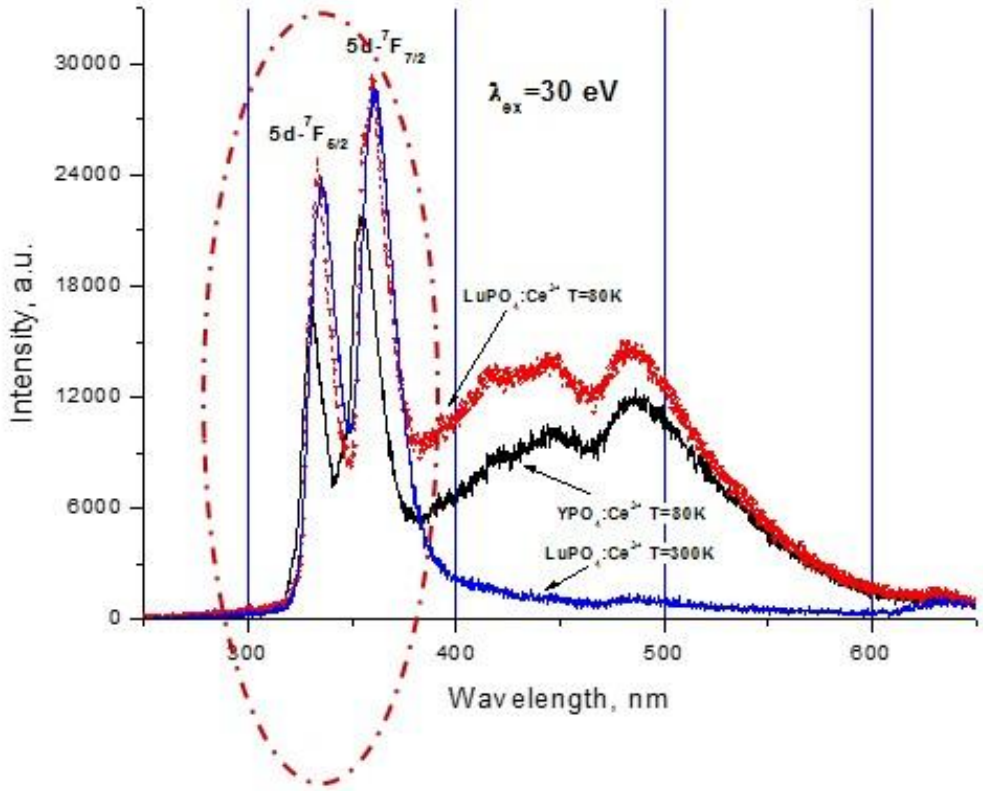
# The luminescence spectra consist of:




- the pronounced doublet peaking at 335 and 360 nm, which is connected with 5d-4f transitions in $Ce^{3+}$

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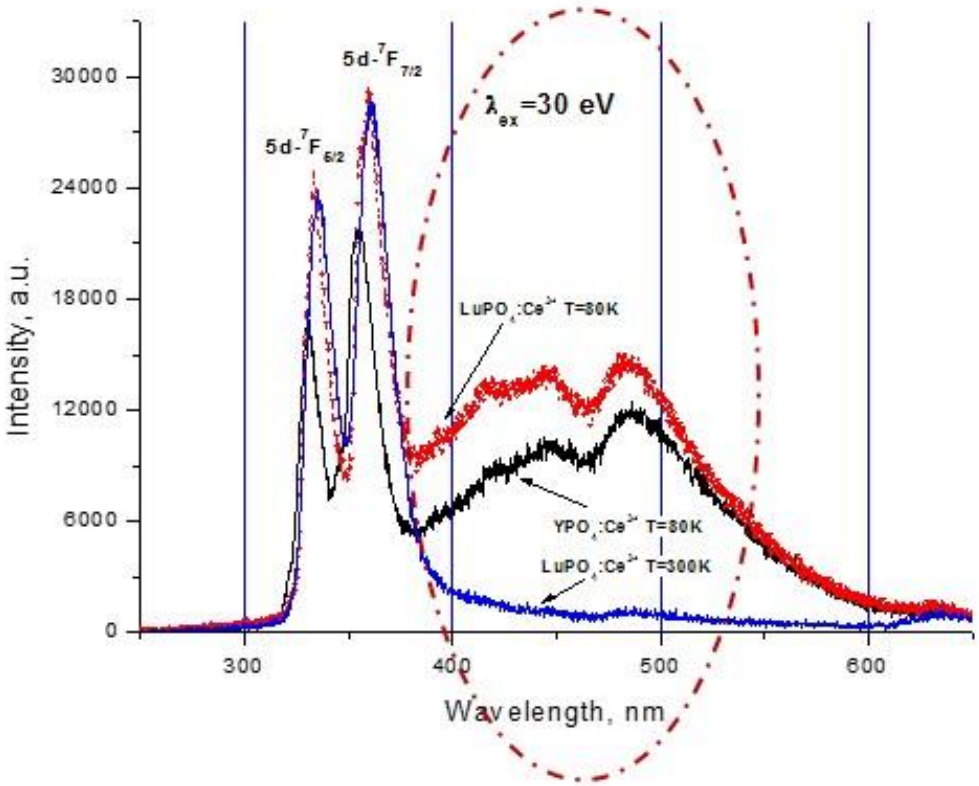
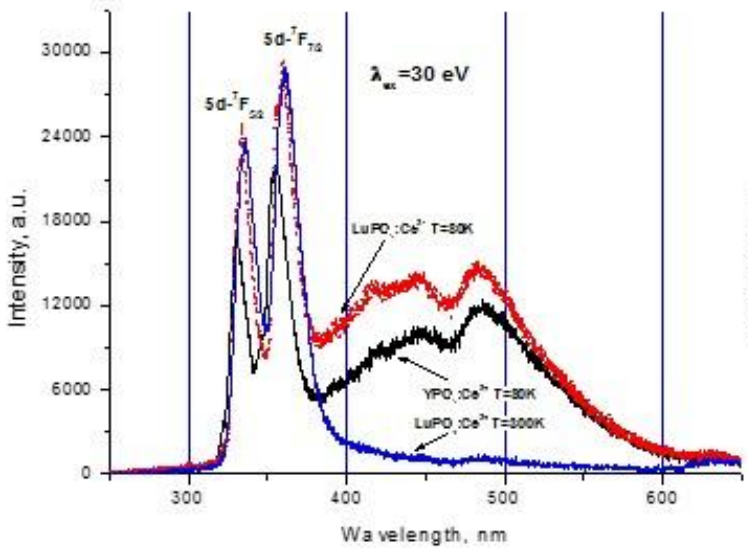
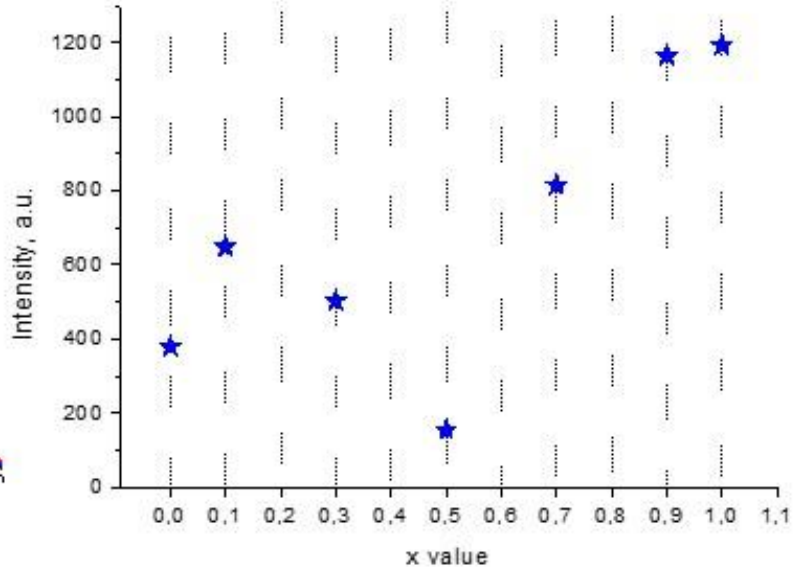



- At T=80K the two broad bands were detected in 385 - 600 nm range, which are associated with defect-related emission.

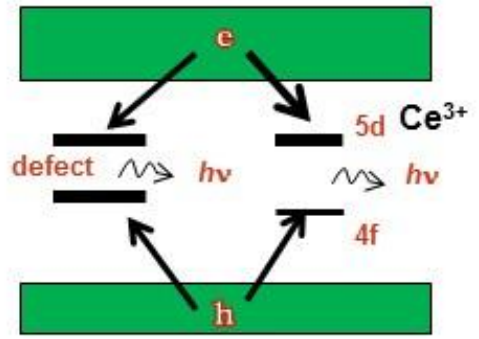
# The luminescence spectra

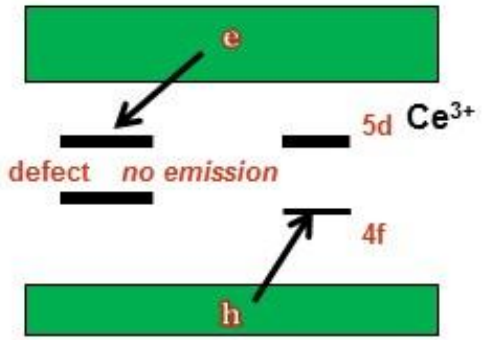


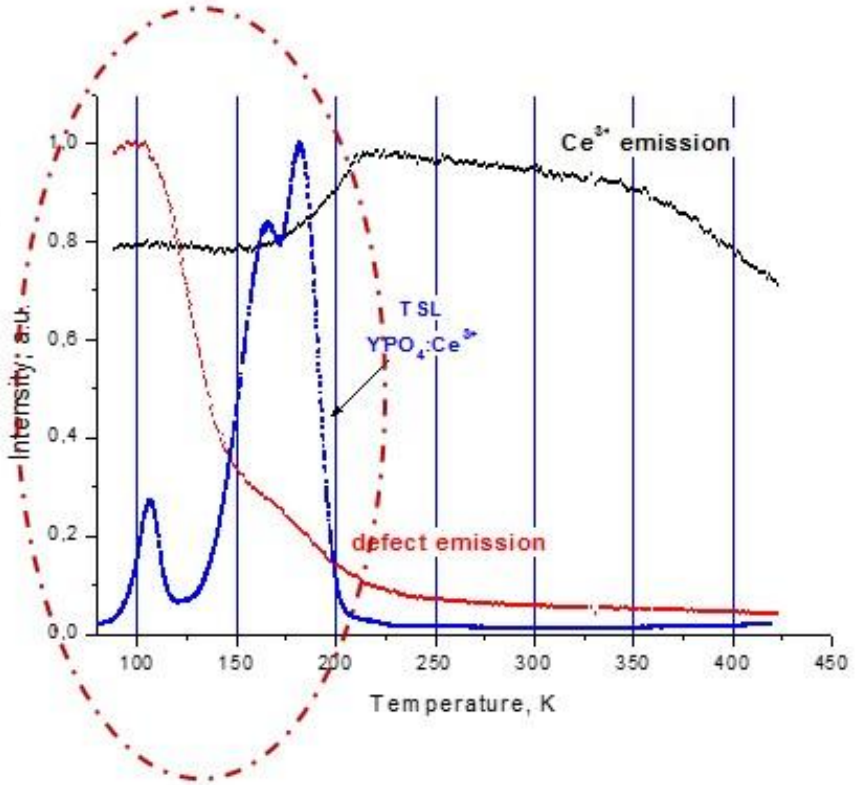




It was detected the decrease of the emission intensity for intermediate values of x the (opposite effect to the expected one).

# Temperature study

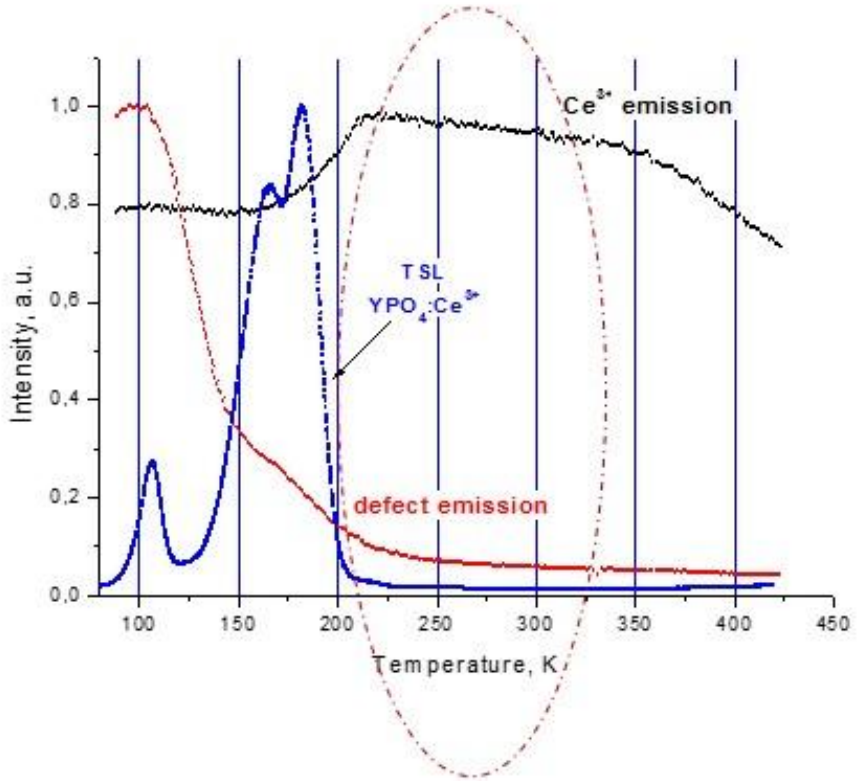


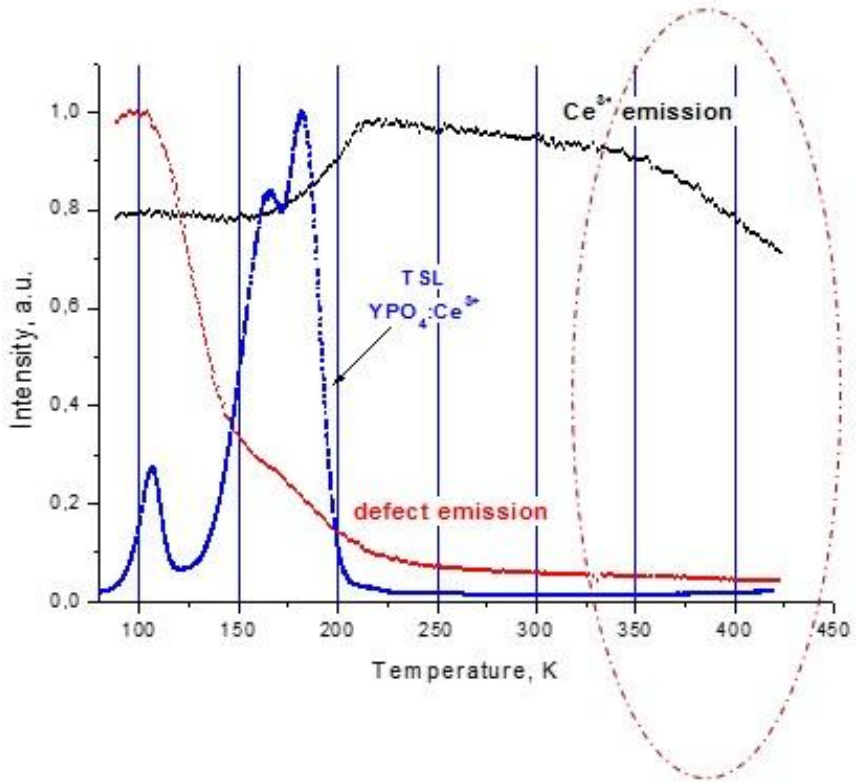
# Temperature study

**200 < T < 350 K:**
insignificant change of $Ce^{3+}$ emission



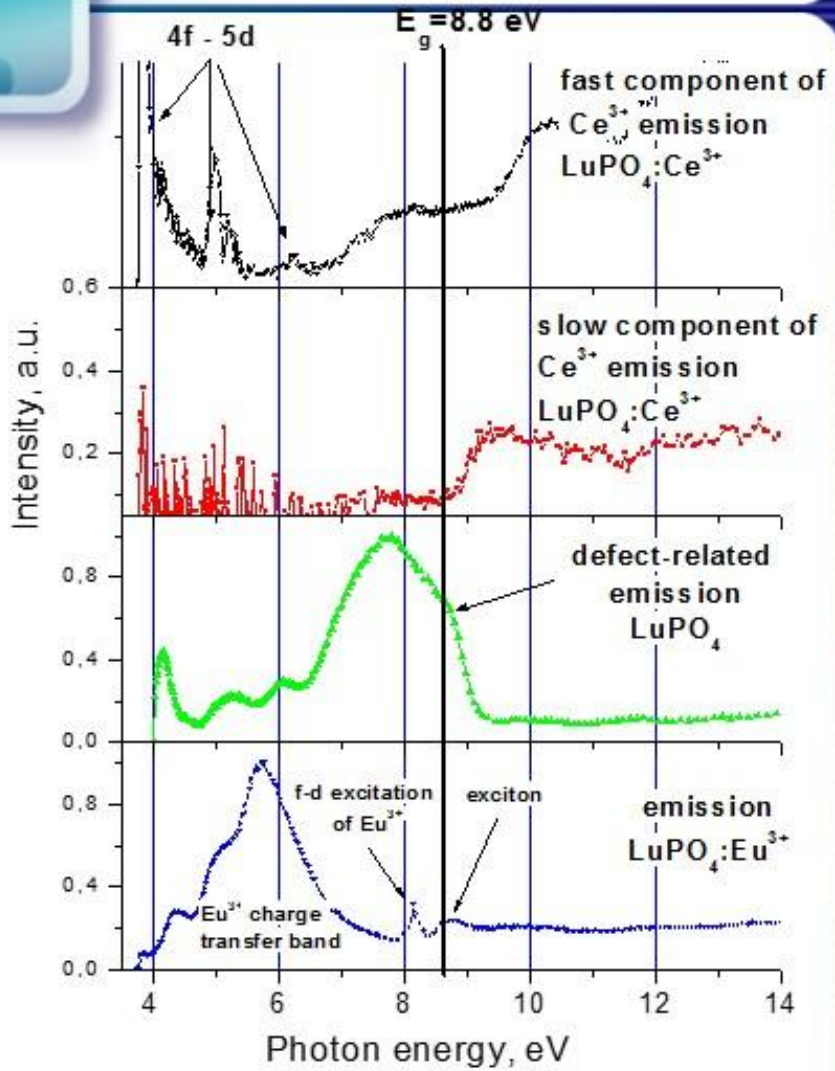
# Temperature study

**T > 350 K:**
temperature quenching of the $Ce^{3+}$ emission



# The luminescence excitation spectra

- the five bands peaking at 3.9, 4.9, 5.2, 5.5 and 6.1 eV corresponding to 4f-5d intracenter transitions in $Ce^{3+}$ ions.
- The rise of luminescence in excitation spectrum measured in the "slow" time window starts at E > 8.8 eV. The rise is connected with the creation of separated electrons and holes and can be used for the estimation of bandgap value $E_g$ = 8.8 eV.
- the exciton is created at the edge of fundamental absorption region and reveals in the excitation spectrum of $LuPO_4:Eu^{3+}$ as a peak at 8.6 eV. Additional narrow low-energy peak at 8.2 eV is tentatively connected with the f-d transitions in $Eu^{3+}$.
- the broad band in the region 7-9 eV is found in the "fast" component of excitation spectra of $Lu_xY_{1-x}PO_4:Ce^{3+}$ as well as in the excitation spectra of defect-related emission in undoped phosphates. The energy transfer from the defect states to $Ce^{3+}$ is proposed to explain the origin of the band in the excitation spectra of $Lu_xY_{1-x}PO_4:Ce^{3+}$.



# Future plans

## It is planned to carry out :

1. Luminescence properties of the set of phosphates solid solutions were investigated. It was detected the decrease of the emission intensity for intermediate values of x (opposite effect to the expected one).

2. The unit cells parameters were calculated. The calculations shows the decrease of these parameters and the result is further confirmed experimentally by the shift of the $Ce^{3+}$ - related emission peaks with x.

3. The temperature dependence of both the $Ce^{3+}$ and defect emission were studied. The competition between emission from $Ce^{3+}$ ions and defect-related emission occurs at $T < 200$ K and is attended by the trapping of electrons in vicinity of the defect-related states.

4. Luminescence excitation spectra have been analyzed. Time-resolved spectroscopy allowed to separate the slow processes of luminescence excitation connected with sequential capture of separated charge carriers on $Ce^{3+}$ ion and the fast processes connected with the direct excitation of luminescence center.

## It is planned to carry out :

- theoretical calculations of the structural, electronic, optical and elastic properties of the studied phosphate solid solutions in order to obtain detailed information on their band structure (the bandgap energy, optical functions (reflectivity, permittivity) and position of dopant energy levels in the band gap will be calculated as well).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# Thank you for attention