Comparative analysis of two LYSO crystal bars by photoluminescence and Raman spectroscopy

Anatoli Popov

Institute of Solid State Physics, University of Latvia, Riga, Latvia

and ISSP UL CERN team:

Vladimir Pankratov, Anna Ivanova, Viktorija Pankratova

Dr. Anatoli I. Popov
Leading research scientist
Institute of Solid State Physics,
University of Latvia
H= 31, > 200 paper, > 3000 citations

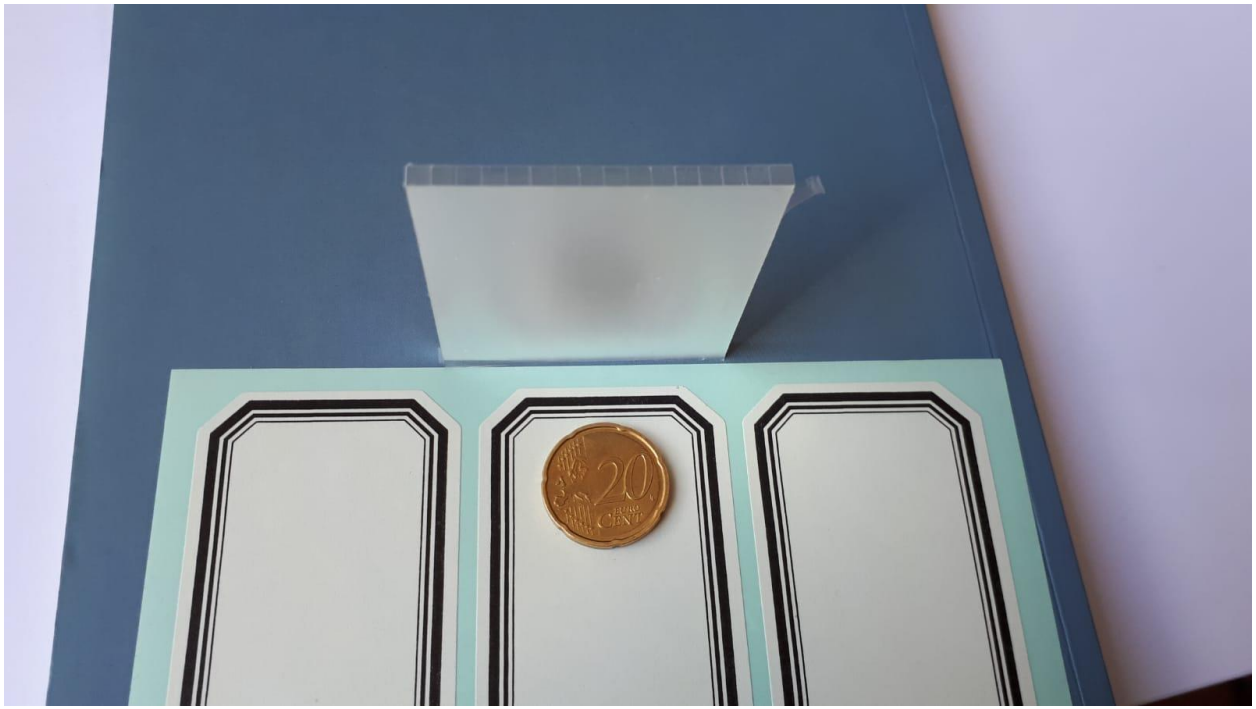
1978 - 1984	**M.S.+B.S. degrees: Department of the Molecular and Chemical Physics (1978-1982), Department of General and Applied Physics (1982-1984), Moscow Institute of Physics and Technology, MIPT, Dolgoprudnyi, Московский Физико-технический институт, МФТИ**
1990	**Ph D in Physics, Institute of Physics, The Latvian Academy of Sciences**
1993	**Dr in Physics, Institute of Solid State Physics, University of Latvia**

RESEARCH INTERESTS

Radiation damage of insulators. Point defects. Optical properties of insulators. Luminescence. VUV, IR and FTIR spectroscopy. Synchrotron radiation spectroscopy (VUV, XD, XAS, EXAFS, FTIR). Neutron imaging and spectroscopy. **Scintillators.** Storage phosphors. Dosimetry and radiation imaging etc.

Established Collaboration with EUROfusion, CERN, ILL, ESS, MAX-IV, DESY

Luminescence test parameters

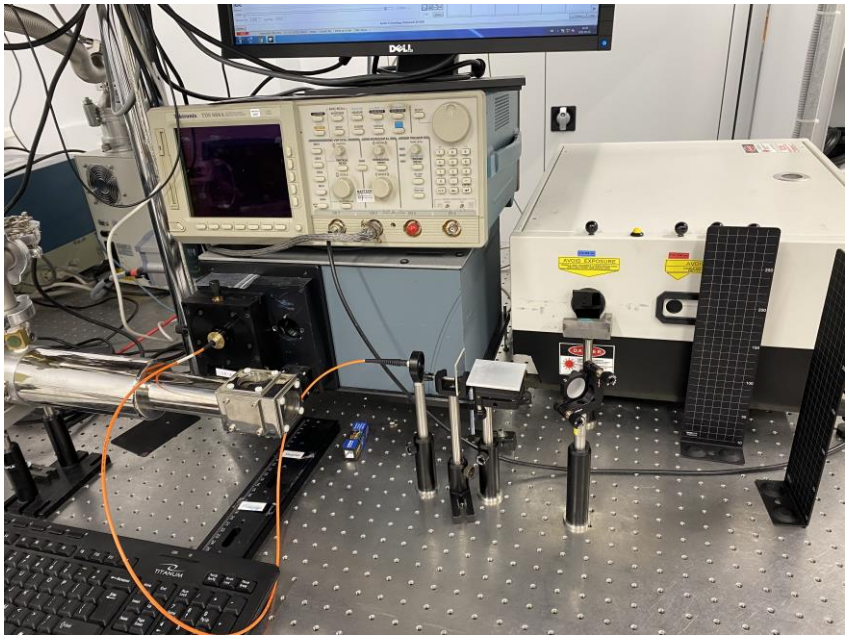


LYSO ($Lu_{2-x}Y_xSiO_5$) **LYSO matrix sample from [Adi Bornheim](#) (Caltech))**

- Luminescence spectra have been taken at previously established conditions
  - Excitation: 264 nm (Ce1), 294 nm (Ce1), 325 nm (Ce2)
  - Two cerium sites, designated Ce1 (seven oxygen ligands) and Ce2 (six oxygen ligands)

LYSO luminescence test

(Viktorija Pankratova and Vladimir Pankratov)



Laser Ekspla NT ns tunable

Manufacturer: Ekspla
Model: NT 342/3UV
Description
•Nd:YAG Q-switched laser including second and third harmonic generator and OPO
•Spectral range: 210-2300 nm
•Scanning accuracy: 0.1 nm – 1 nm depends on spectral region
•Pulse width: 5 ns,
•Repetition rate: 10 Hz,
•Output pulse:
- ≥ 7 mJ @450 - 1000 nm,
- ≥ 25 mJ @450 - 500 nm,
- ≥ 2 mJ @220 - 410 nm,
- ≥ 3 mJ @250 - 300 nm.

•Linewidth: < 4.5 cm^{-1}

LYSO luminescence test (V. Pankratova)

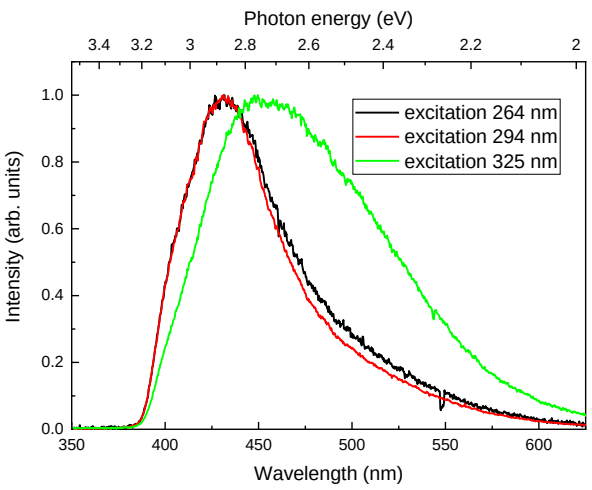
264 nm (Ce1 4f-5d$_3$)

294 nm (Ce1 4f-5d$_2$)

325 nm (Ce2: Ce^{3+} 4f-5d, resolved at low temperatures with emission at 480 nm)

Ce1 (seven oxygen ligands) and Ce2 (six oxygen ligands)

center:



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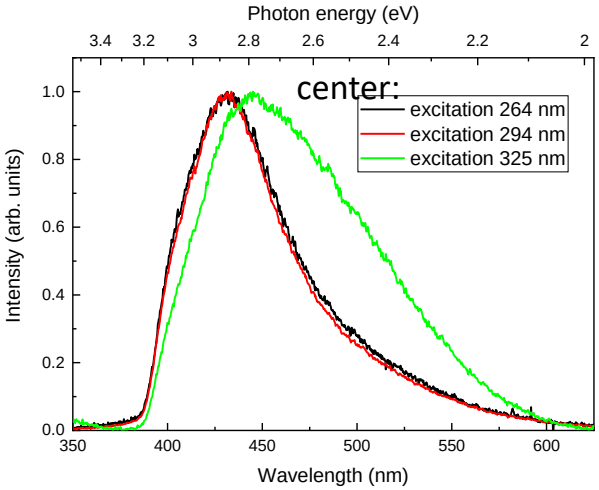
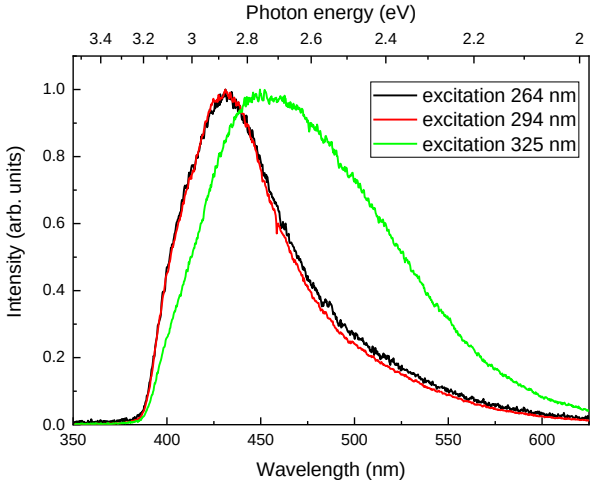




Luminescence test parameters

- **2 LYSO:Ce samples from different vendors (approx. 6 cm in length)**
- Spectra have been taken at previously established conditions
  - Excitation: 264 nm (Ce1), 294 nm (Ce1), 325 nm (Ce2), 365 (Ce1)
  - Two cerium sites, designated Ce1 (seven oxygen ligands) and Ce2 (six oxygen ligands)
  - In the energy transition process, the Ce1 energy transition values of $5d \rightarrow 4f^2F_{5/2}$ and $5d \rightarrow 4f^2F_{7/2}$ are 3.17 eV and 2.93 eV, respectively, corresponding to 392 nm and 424 nm while the Ce2 energy transition values ($5d \rightarrow 4f^2F_{5/2}$ and $5d \rightarrow 4f^2F_{7/2}$) are 2.72 eV (457 nm) and 2.53 eV (490 nm).

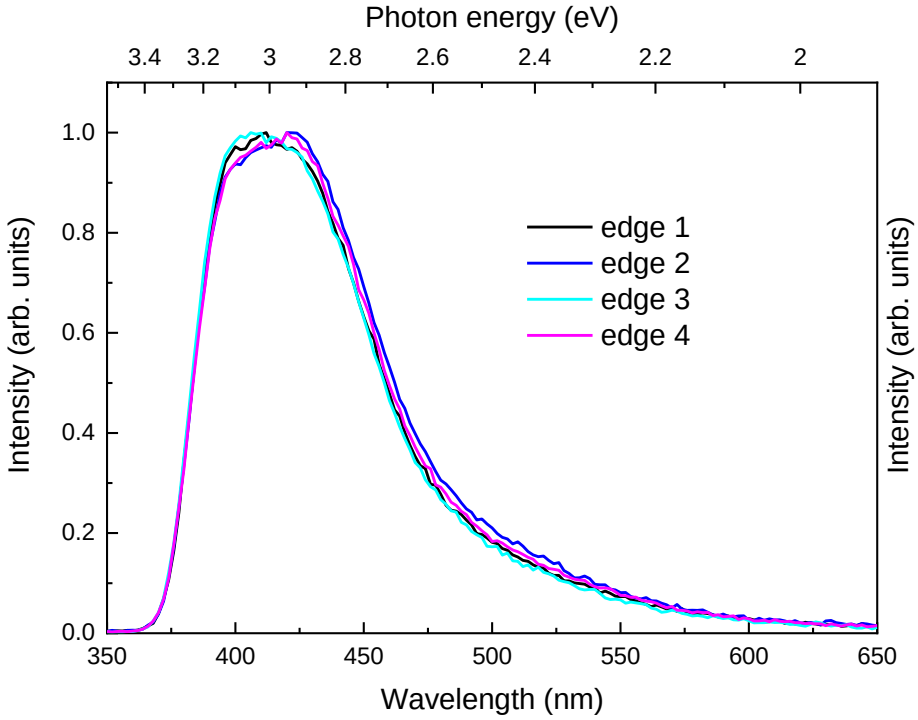
Sample #247: luminescence spectra

264 nm (Ce1 4f-5d$_3$)

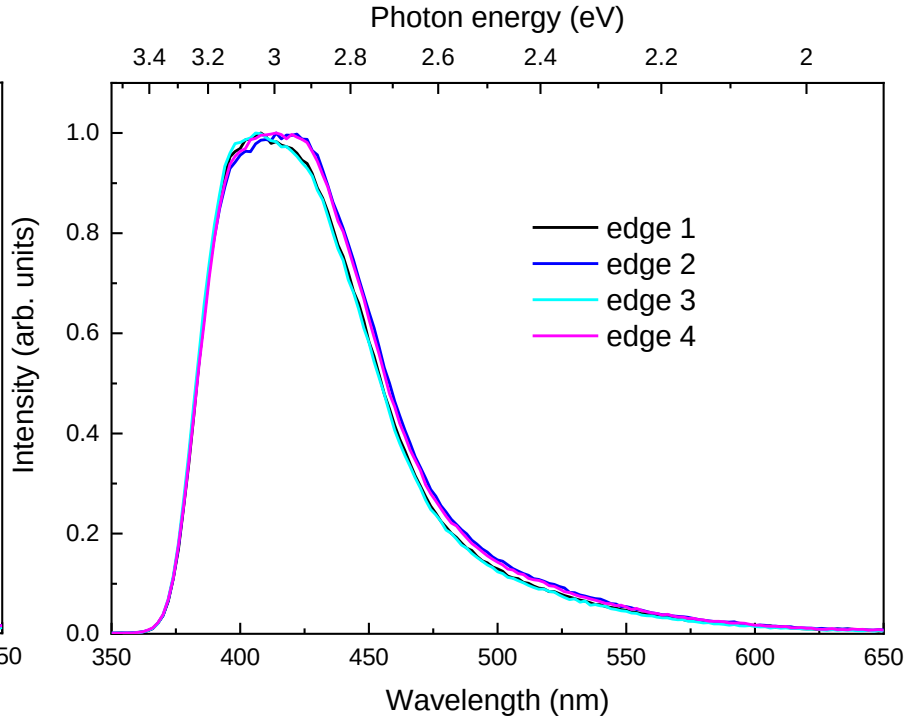
294 nm (Ce1 4f-5d$_2$)

325 nm (Ce2: Ce^{3+} 4f-5d, resolved at low temperatures with emission at 480 nm)

Ce1 (seven oxygen ligands) and Ce2 (six oxygen ligands)

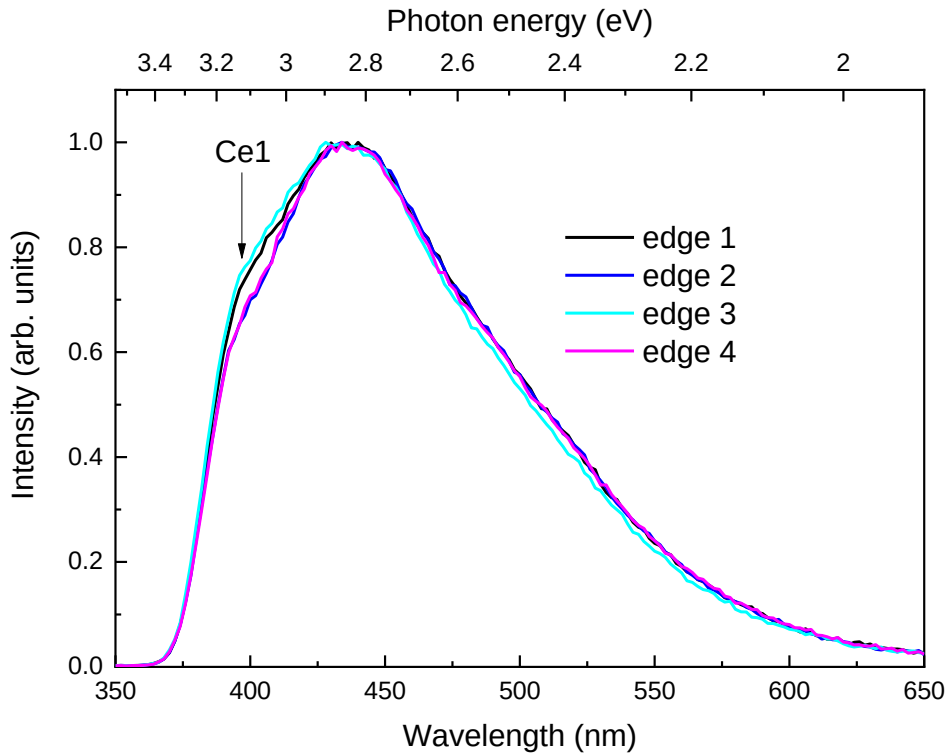


Excitation at 264 nm (Ce1)



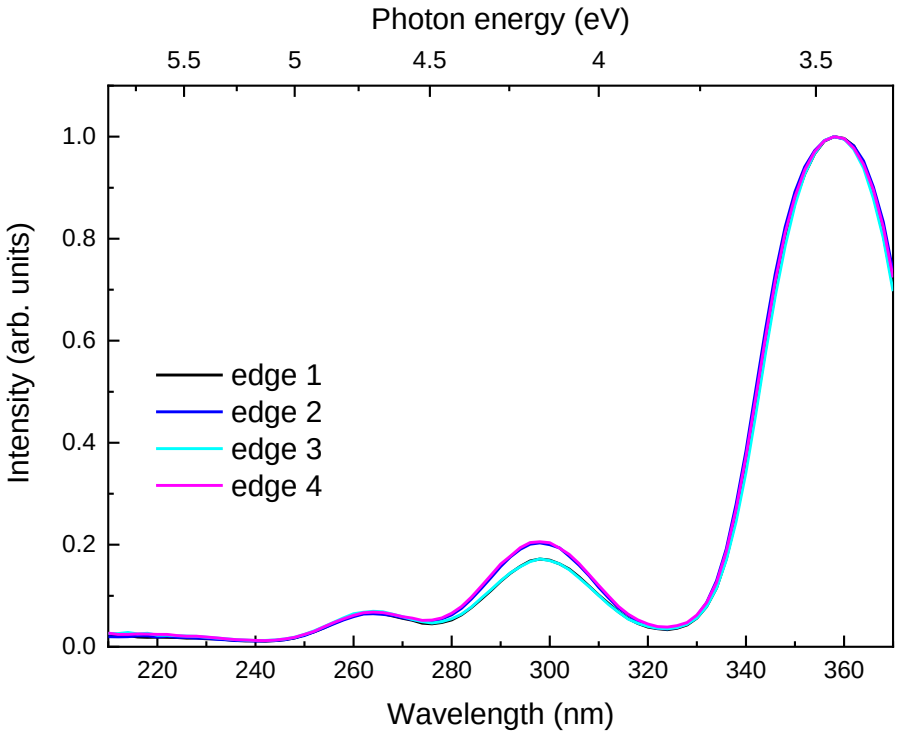
Excitation at 294 nm (Ce1)

Sample #247: luminescence spectra

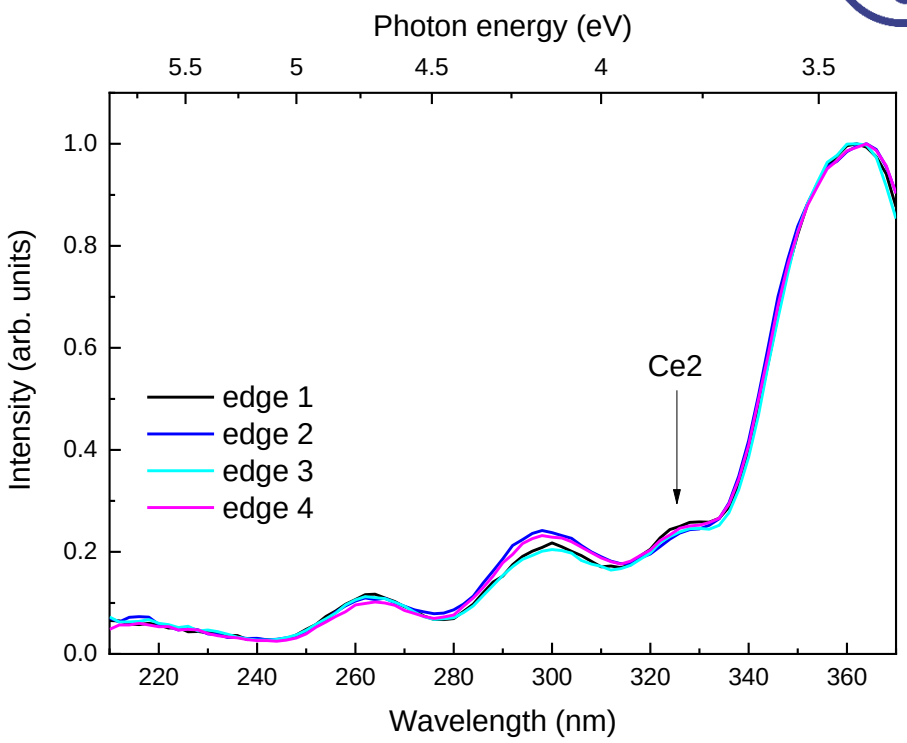


Excitation at 325 nm (Ce2)

Sample #247: luminescence excitation



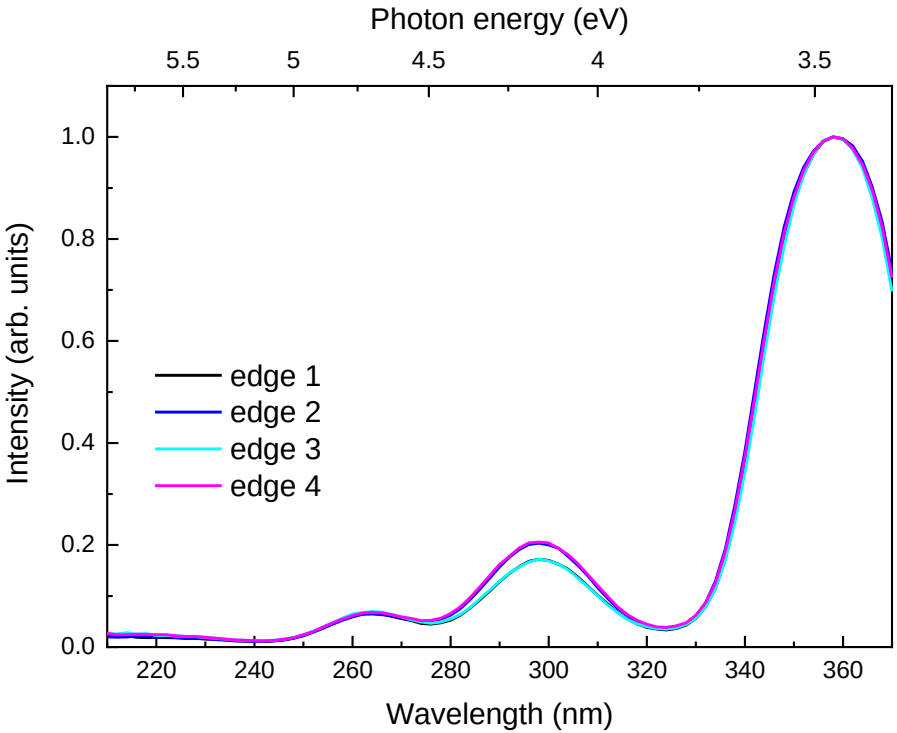
Measured at emission at 390 nm



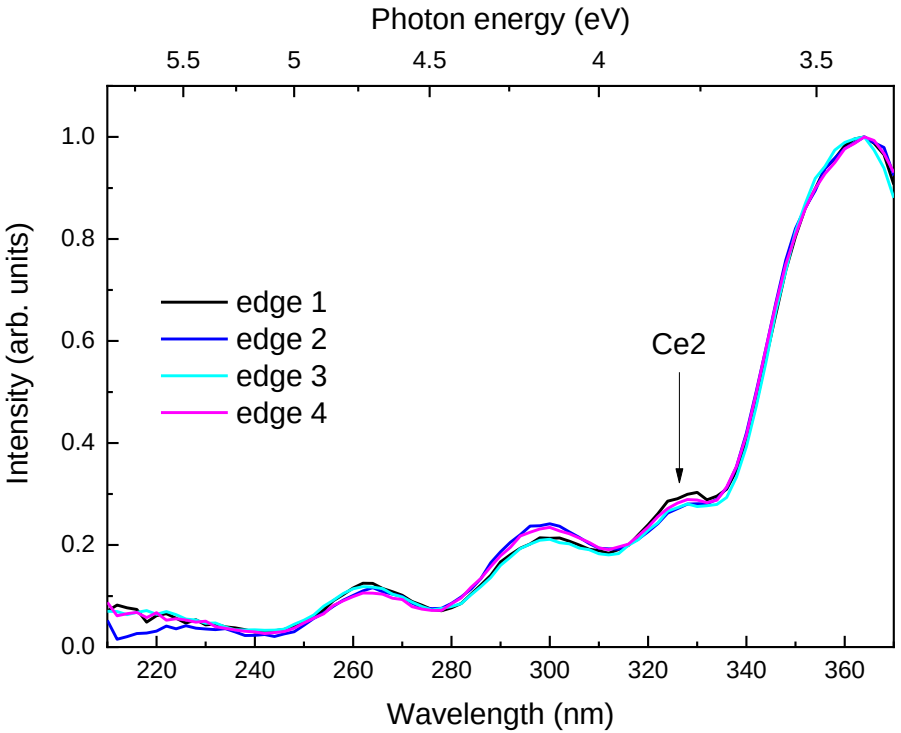
Measured at mission at 500 nm

Excitation: 264 nm (Ce1), 294 nm (Ce1), 325 nm (Ce2)

Sample #247: luminescence excitation

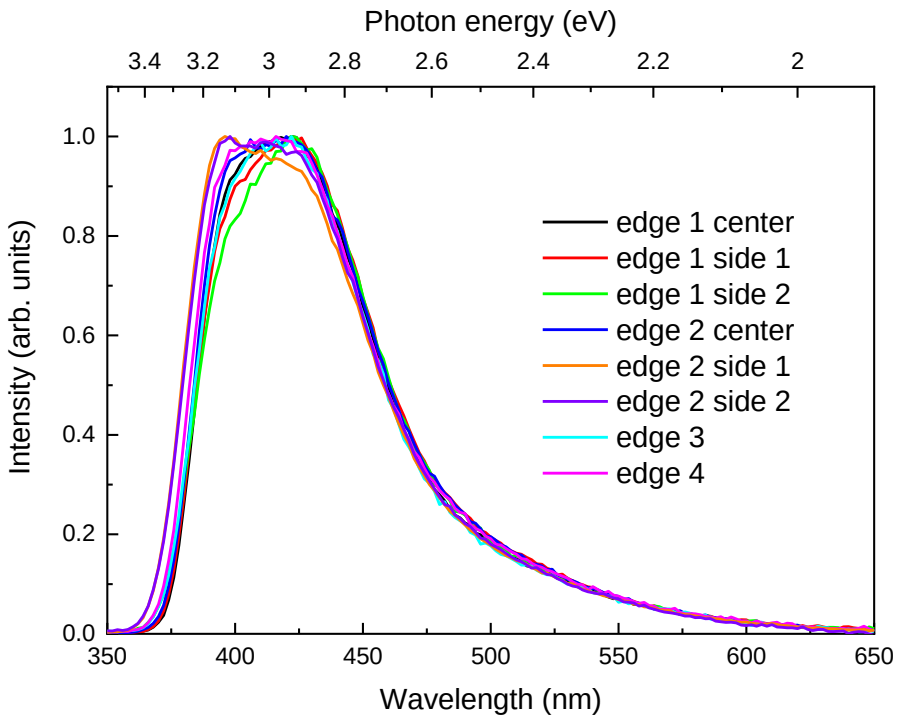


Emission at 390 nm (three bands correspond to Ce1 excitation)

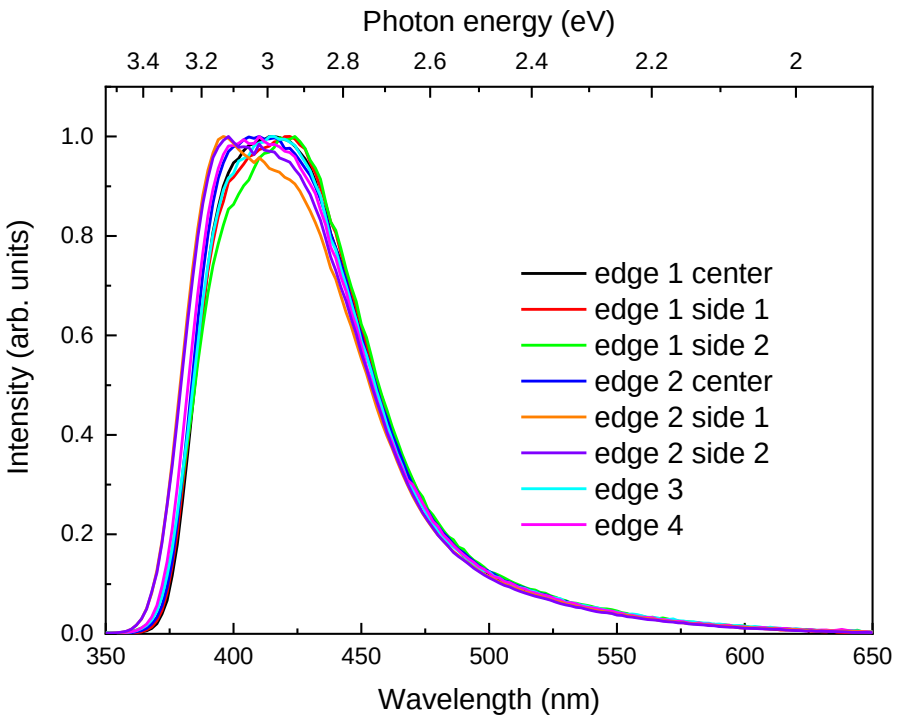


Emission at 520 nm

Sample #349: luminescence spectra

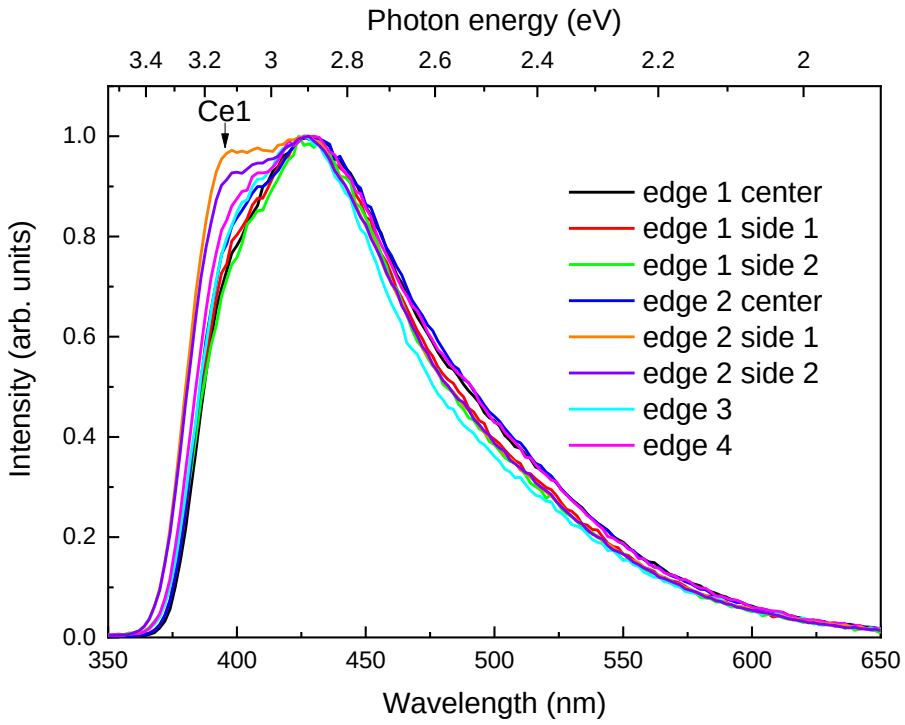


Excitation at 264 nm (Ce1)



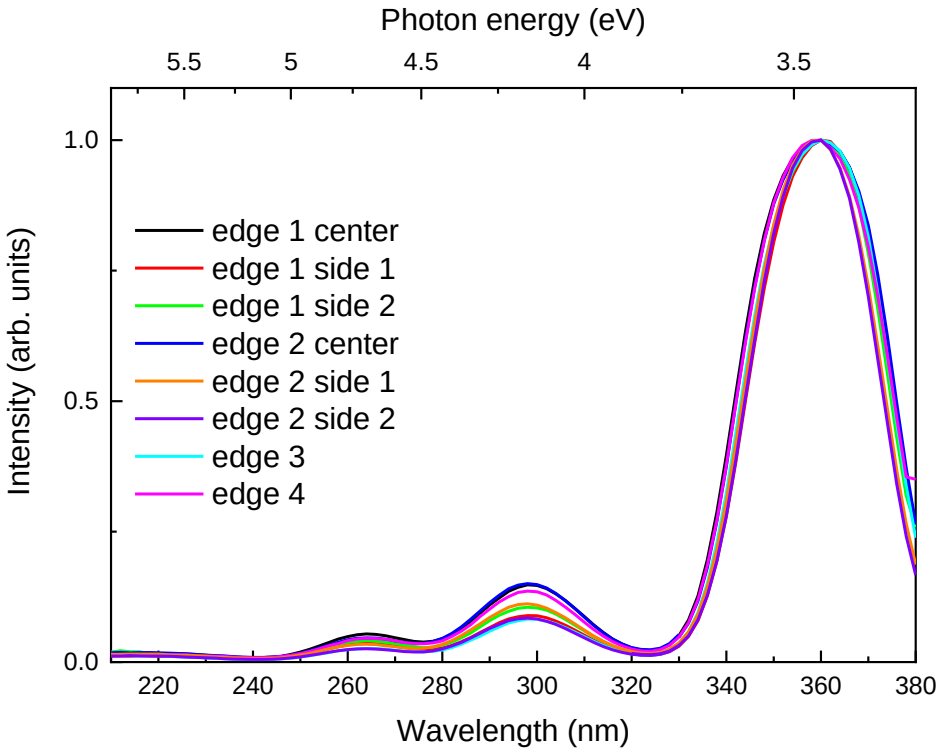
Excitation at 294 nm (Ce1)

Sample #349: luminescence spectra

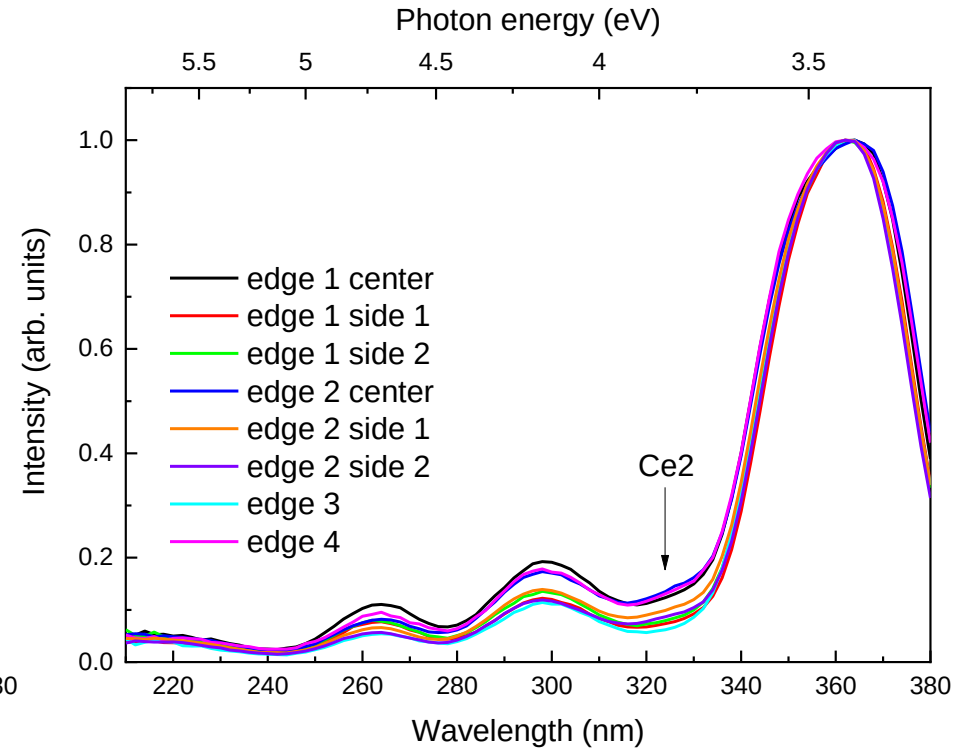


Excitation at 325 nm (Ce2)

Sample #349: luminescence excitation

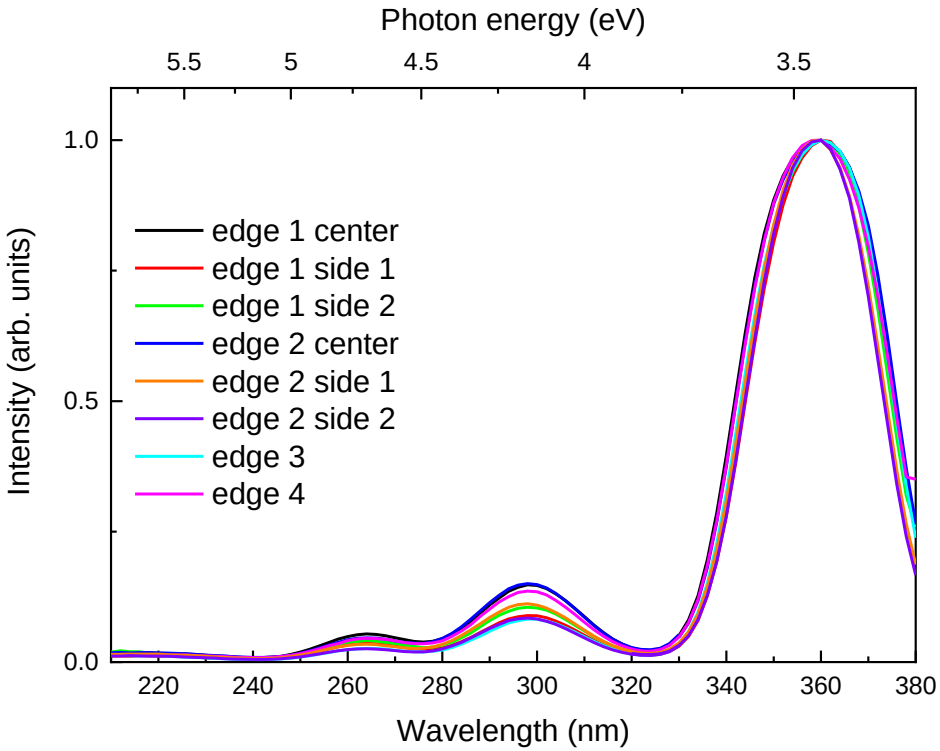


Emission at 390 nm (three bands correspond to Ce1 excitation)

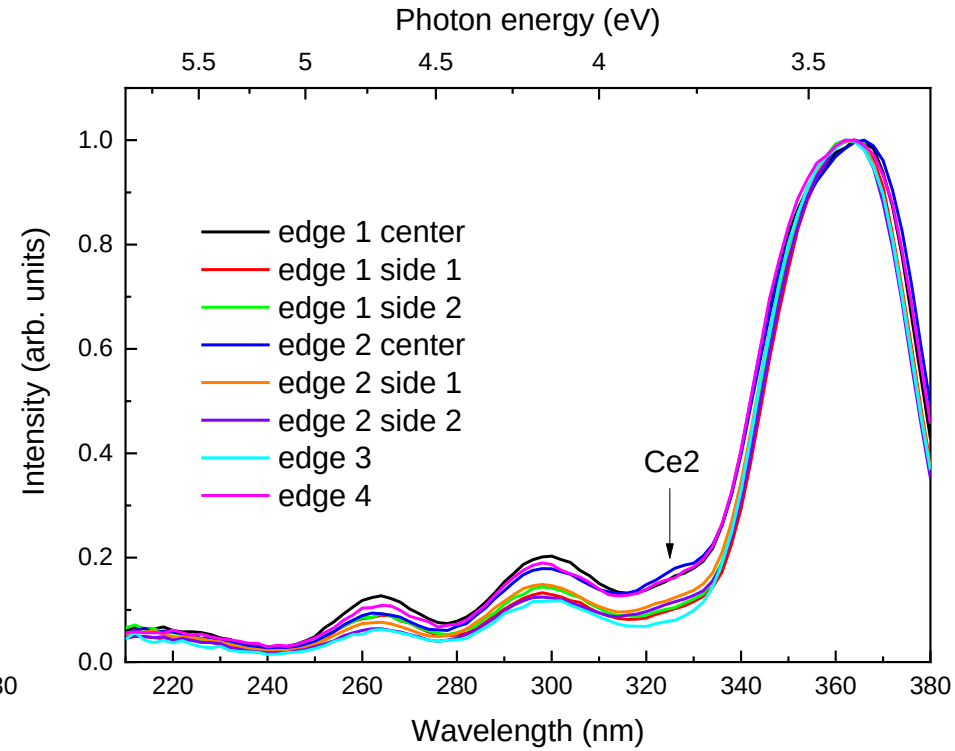


Emission at 500 nm

Sample #349: luminescence excitation

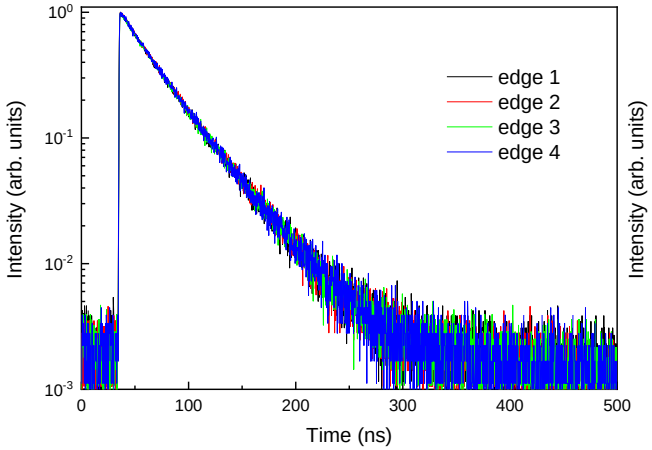


Emission at 390 nm (three bands correspond to Ce1 excitation)

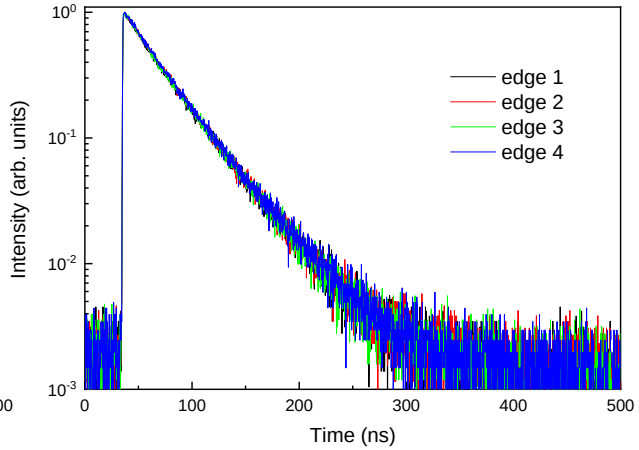


Emission at 520 nm

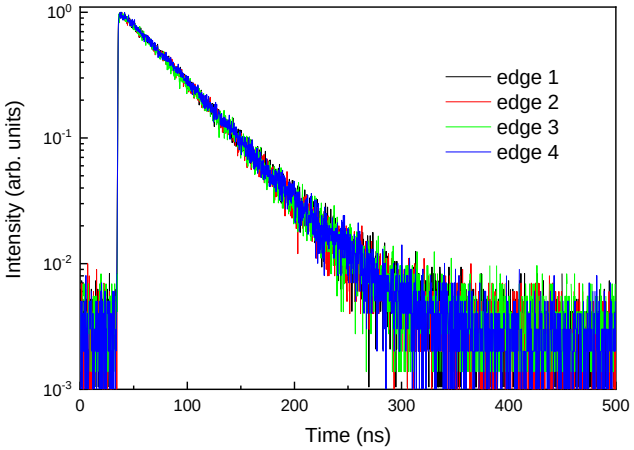
LYSO #247 decay kinetics (excitation 375 nm, 50 ps)- measurements of intrinsic Ce3+ emission



Emission wavelength 390 nm



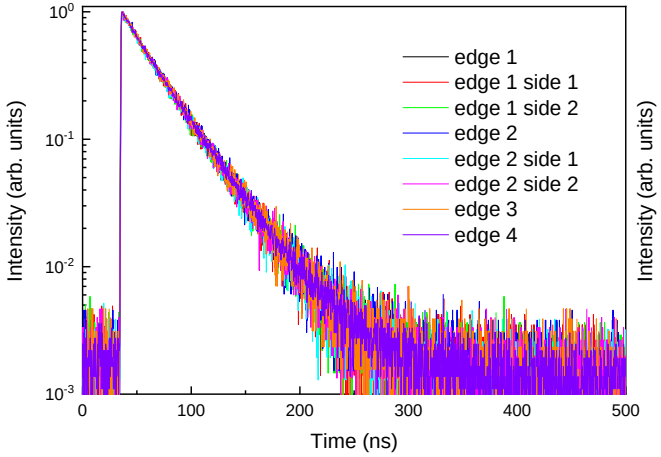
Emission wavelength 400 nm



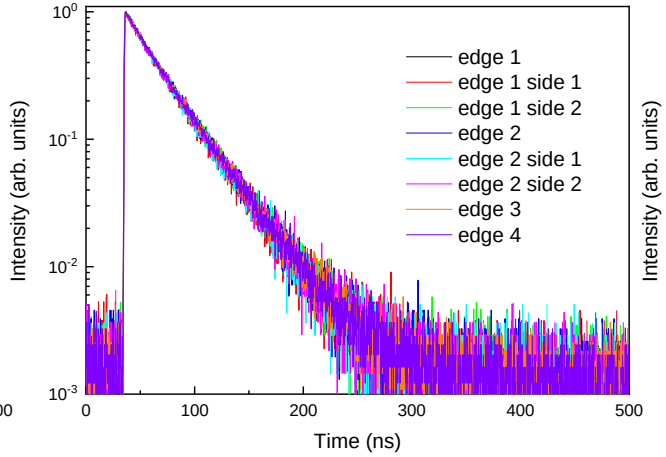
Emission wavelength 480 nm

- the Ce1 energy transition values of $5d \rightarrow 4f^2F_{5/2}$ and $5d \rightarrow 4f^2F_{7/2}$ are 3.17 eV and 2.93 eV, respectively, corresponding to 392 nm and 424 nm while the Ce2 energy transition values ($5d \rightarrow 4f^2F_{5/2}$ and $5d \rightarrow 4f^2F_{7/2}$) are 2.72 eV (457 nm) and 2.53 eV (490 nm).

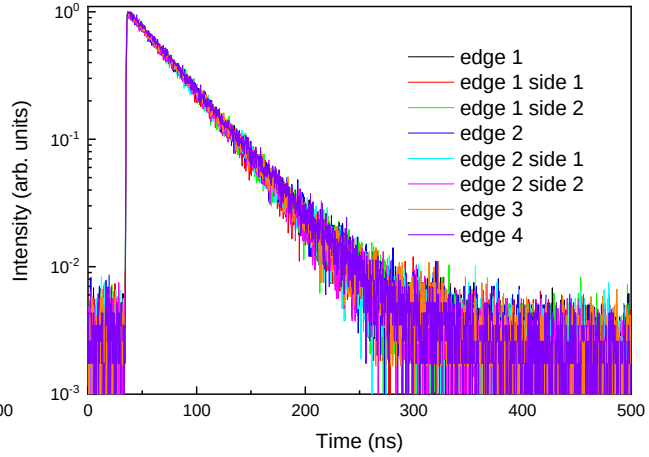
LYSO #349 decay kinetics (excitation 375 nm, 50 ps)



Emission wavelength 390 nm



Emission wavelength 400 nm



Emission wavelength 480 nm

LYSO #349 decay times

Emission	Side 1		Side 1 Edge 1		Side 1 Edge 2		Side 2		Side 2 Edge 1		Side 2 Edge 2		Side 3		Side 4	
	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_2, ns	τ_2, ns	τ_2, ns	τ_2, ns
390 nm	26.5±0.6	41.5±1.2	20±2	35.6±0.7	18±2	35.7±0.5	17±3	35.4±0.4	20±2	35.9±0.7	20±2	36.1±0.7	19±3	35.6±0.6	24.2±1.0	39.5±0.8
400 nm	25.4±1.0	40.4±1.0	17±2	35.4±0.5	19±2	36.3±0.5	22±3	36.8±0.9	13±2	34.7±0.3	16±2	35.5±0.4	20.8±1.3	37.5±0.5	19.6±1.4	36.9±0.5
480 nm	43.35±0.09		41.92±0.11		42.45±0.11		43.43±0.12		42.48±0.11		42.80±0.11		42.99±0.11		43.28±0.11	

LYSO #247 decay times

Emission	Side 1		Side 2		Side 3		Side 4	
	τ_1, ns	τ_2, ns	τ_1, ns	τ_2, ns	τ_2, ns	τ_2, ns	τ_2, ns	τ_2, ns
390 nm	24.8±1.3	42.3±0.9	24.0±1.4	41.6±0.7	26.4±1.4	43.4±1.0	23±2	40.7±0.7
400 nm	22.2±1.3	41.2±0.5	26.6±1.3	43.9±1.1	23.8±1.3	42.3±0.7	26±2	43.0±1.0
480 nm	46.81±0.12		46.37±0.12		46.20±0.14		46.72±0.12	

According to literature LYSO:Ce decay times of Ce^{3+} are as follows:

- Ce1: 35-38 ns [1], 35,4 ns [2]
- Ce2: 59 ns [1], 56 ns [2]

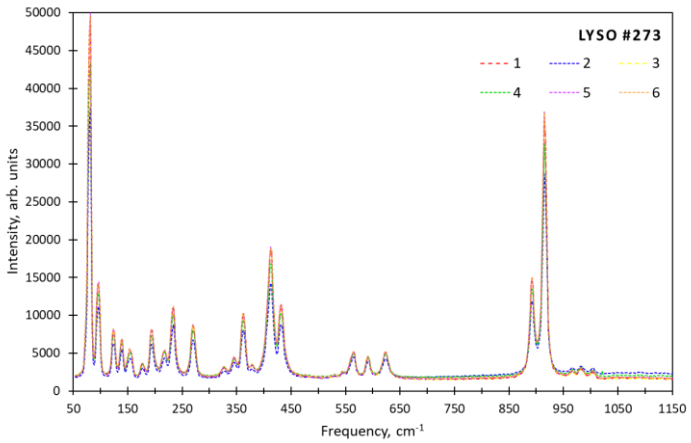
Difference between our and literature data are from different excitation type.

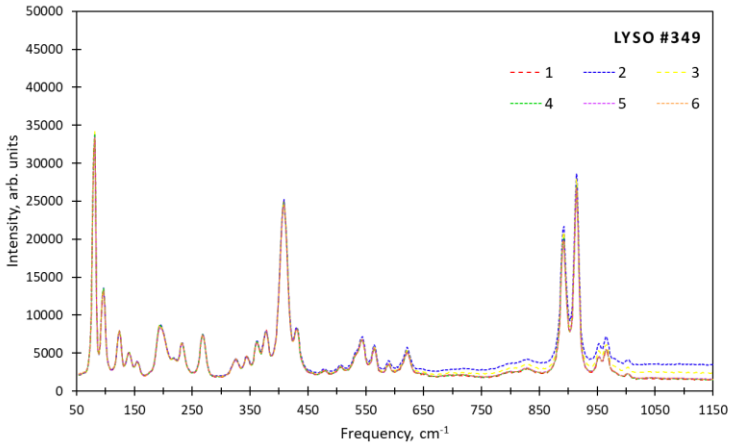
1. Martins, A. F. *et al.* Spectroscopic analysis of LYSO:Ce crystals. *Spectrochim. Acta - Part A Mol. Biomol. Spectrosc.* **172**, 163–167 (2017).

2. Wojtowicz, A. J. *et al.* Scintillation properties of selected oxide monocrystals activated with Ce and Pr. *Opt. Mater. (Amst).* **28**, 85–93 (2006).

LYSO:Ce Raman spectra Homogeneity test

- Spectra of crystalline samples were acquired at RT, air conditions
- Optical microscope was used to centre the laser beam (532 nm)
- Each of two crystals was measured 6 times along the principial crystal direction





Both crystals were proved to be homogenous.
Both crystals have the same frequencies of the main vibrational modes, with a slight difference in the intensities.

Conclusion

- Using luminescence spectroscopy we have performed a detailed comparative analysis of two LYSO crystal bars.
- the main characteristics known from the literature are confirmed, all used set-ups available at ISSP LU can be used for further comparative analysis.

- Future plans include

A) preparation of small pieces

B) radiation damage studies

C) low-temperature (LNT-RT) TSL

D) VUV synchrotron luminescence

E) EPR

F) Theoretical modelling (with and without Ce^{3+} of $Lu_{2-x}Y_xSiO_5$)