Multicomponent Garnet Scintillators

$(Gd,Y)_3(Gd,Al)_5O_{12}$

[1]Karol Bartosiewicz, [1]V. Babin, [2]K. Kamada, [2,3]A. Yoshikawa, [1]M. Nikl

[1]Institute of Physics AS CR, Cukrovarnicka 10, Prague, 16253, Czech Republic

[2]NICHe, Tohoku University, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai, 980-8579, Japan

[3]Institute for Materials Research (IMR), Tohoku University, Sendai 980-8577, Japan

Fyzikální ústav
Akademie věd ČR, v. v. i.

Outline

1 Introduction and Aims

2 Experiments

3 Results and Discussion

3a $Gd_xY_{3-x}Ga_yAl_{5-y}O_{12}$ (x,y=1,2,3)

3b $Gd_3Ga_3Al_2O_{12}:Ce^{3+}$

3c $Gd_3Ga_3Al_2O_{12}$ doped Eu^{3+} or Tb^{3+}

4 Conclusions

Outline

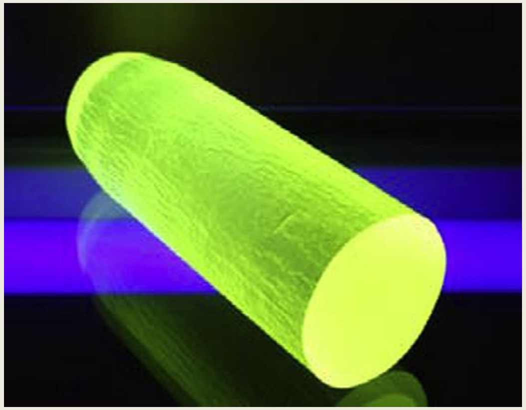
Introduction and Aims

Why did we focus on Gd-based multicomponent garnets?

good chemical and radiation stability, excellent mechanical properties

$Lu_3Al_5O_{12}:Ce^{3+}$

LY 26 000 phot/MeV
Decay time 50-60 ns



LY 46 000 phot/MeV
Decay time 57 ns

$Gd_3Ga_3Al_2O_{12}:Ce^{3+}$

Introduction and Aims

Why did we focus on Gd-based multicomponent garnets?

What is the relationship between host composition and electronic structure?

What is the actual site occupation situation in multicomponent garnets?

What is the influence of manufacturing processes on concentration of point and antisite defects?

How about their temperature dependent traits of light yield, time response and energy resolution?

Temperature dependence of Gd^{3+} emission intensiets and decay times related to its ^6P_x-^8S transition peaking at 312 nm at the set of undoped and Ce-doped matrices

Outline

Experiments

Characterization by:

- ✓ absorption and excitation
- ✓ temperature dependence of PL intensity and decay time

$Gd_xY_{3-x}Ga_yAl_{5-y}O_{12}$ (x,y = 1,2,3)

Characterization by:

- ✓ absorption and excitation
- ✓ temperature dependence of PL intensity and decay time

$Gd_3Ga_3Al_2O_{12}:Ce^{3+}$

$Gd_3Ga_3Al_2O_{12}:Eu^{3+}$

Characterization by:

- ✓ absorption and excitation
- ✓ emission
- ✓ decay time

$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$

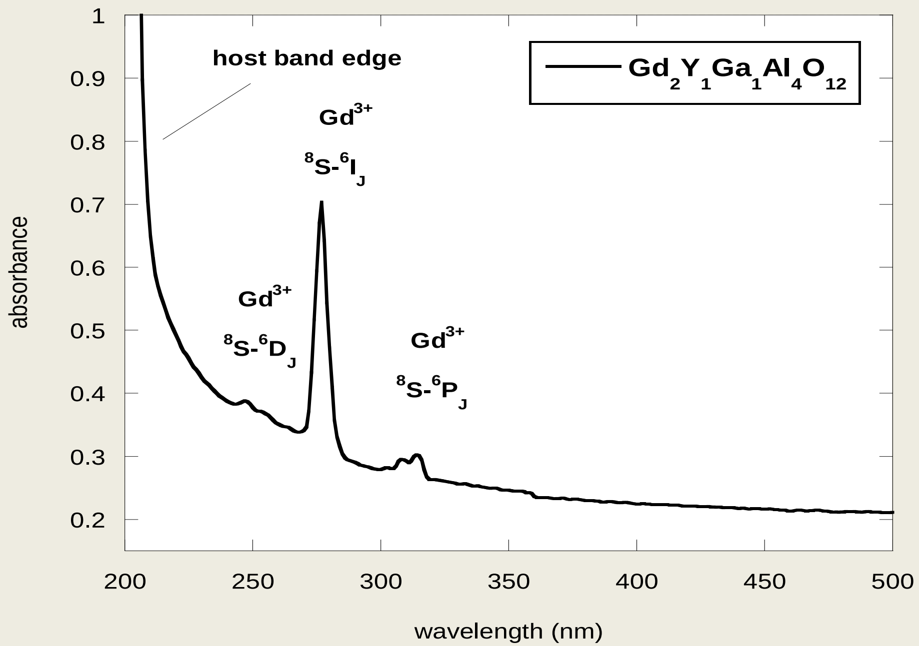
Characterization by:

- ✓ absorption and excitation
- ✓ emission
- ✓ decay time

Outline

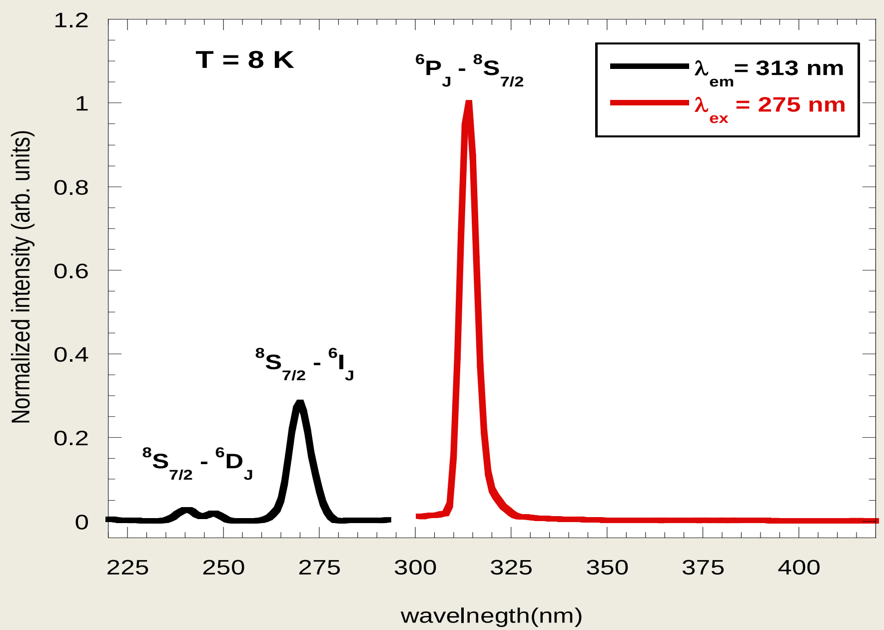
Results and Discussion

Absorption, photoluminescence excitation and emission characteristics



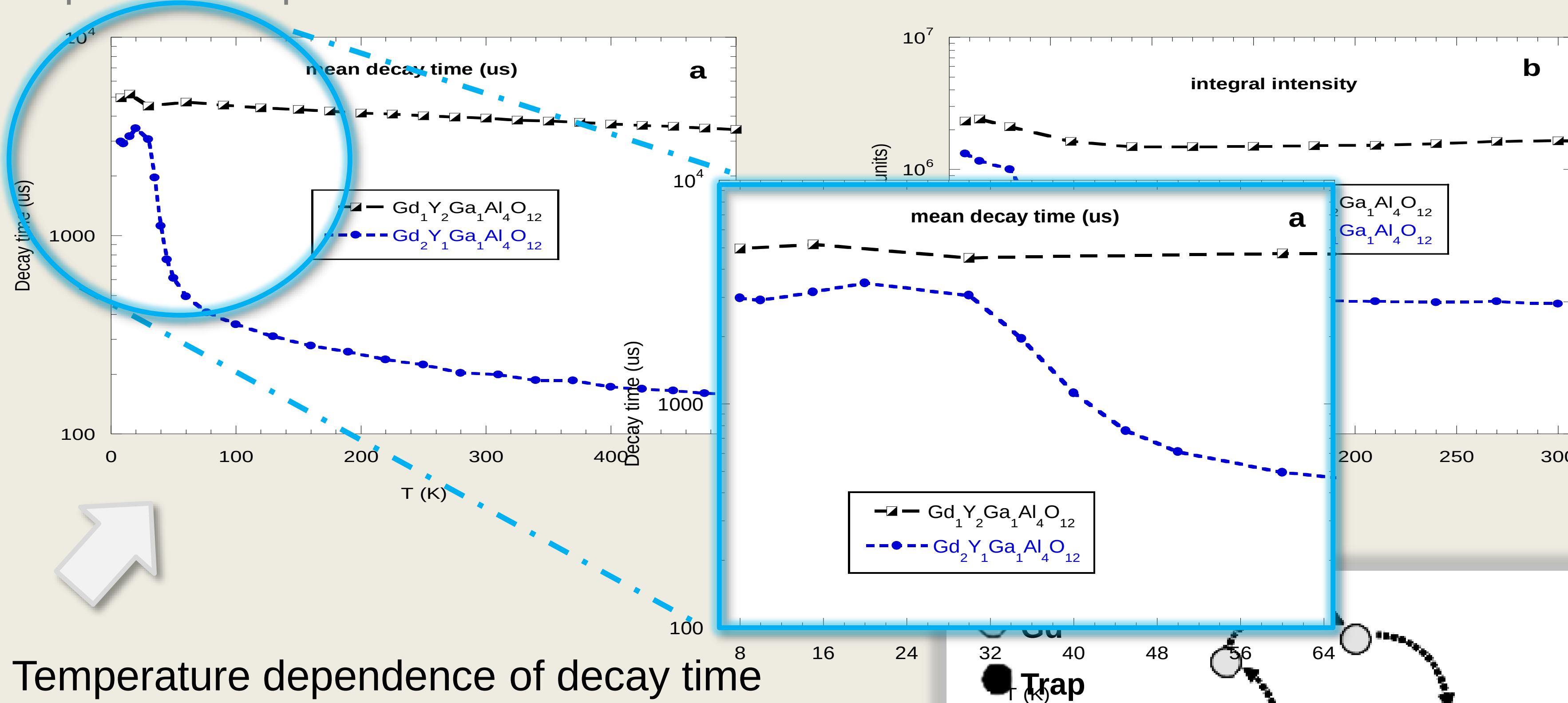
Absorption spectrum of **$Gd_2Y_1Ga_1Al_4O_{12}$**. Intense Gd^{3+}-related peak at 270 nm as well as host lattice absorption region ($\lambda \leq 220$ nm) are evident.

PL excitation and emission spectra of **$Gd_2Y_1Ga_1Al_4O_{12}$.**

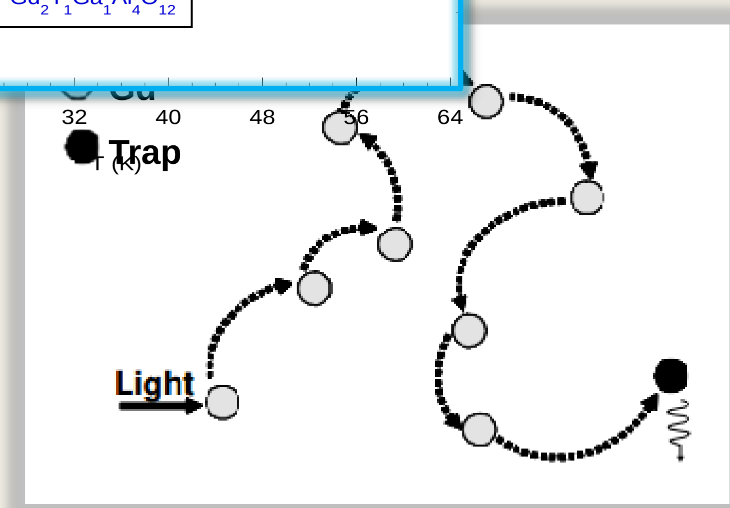


Results and Discussion

Temperature dependence characteristics



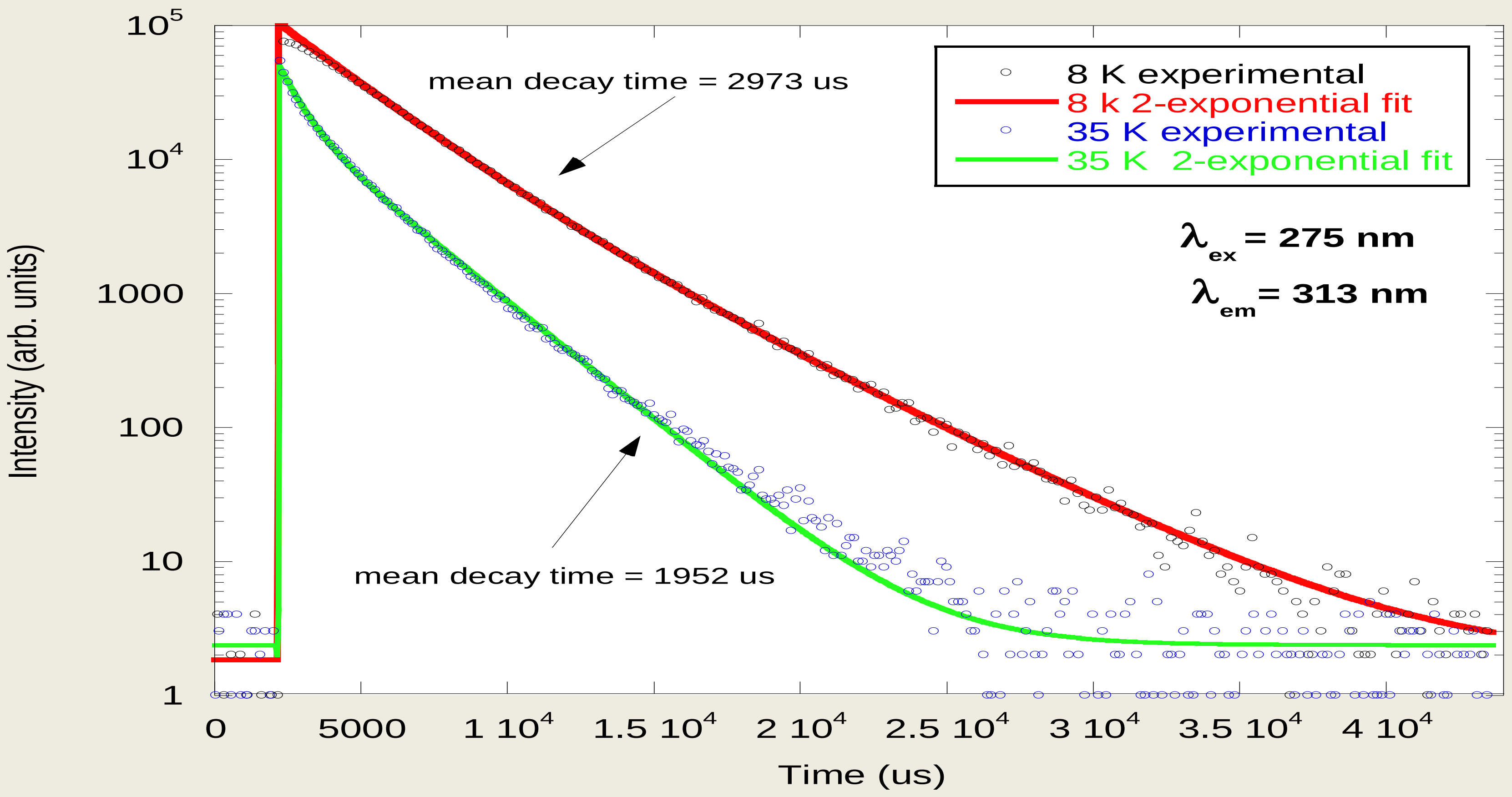
Temperature dependence of decay time (a) and PL intensity (b) in the **$Gd_1Y_2Ga_1Al_4O_{12}$** and **$Gd_2Y_1Ga_1Al_4O_{12}$**



Mechanism for luminescence concentration quenching

Results and Discussion

Temperature dependence characteristic

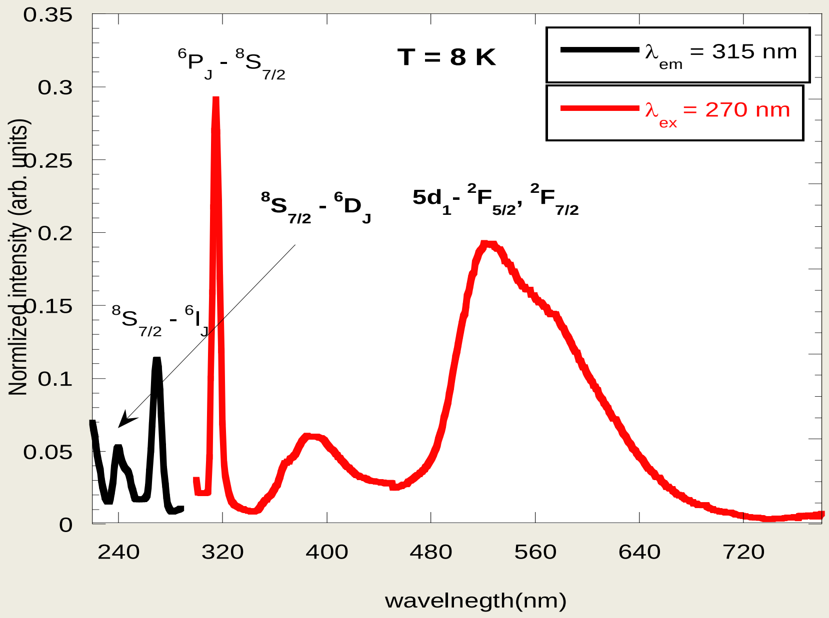


Decay curves of the intrinsic Gd^{3+} emission of **$Gd_2Y_1Ga_1Al_4O_{12}$** single crystals as a function of temperature.

Outline

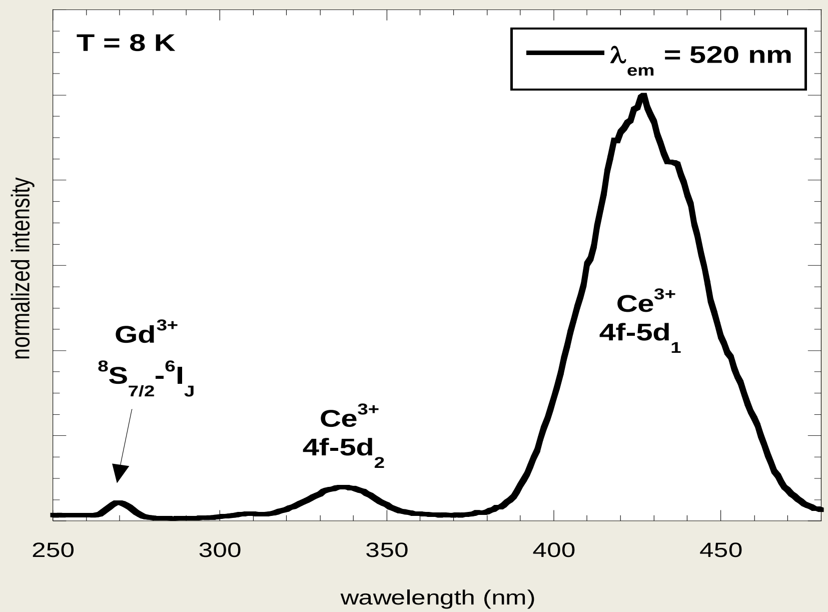
Results and Discussion

Photoluminescence excitation and emission characteristics



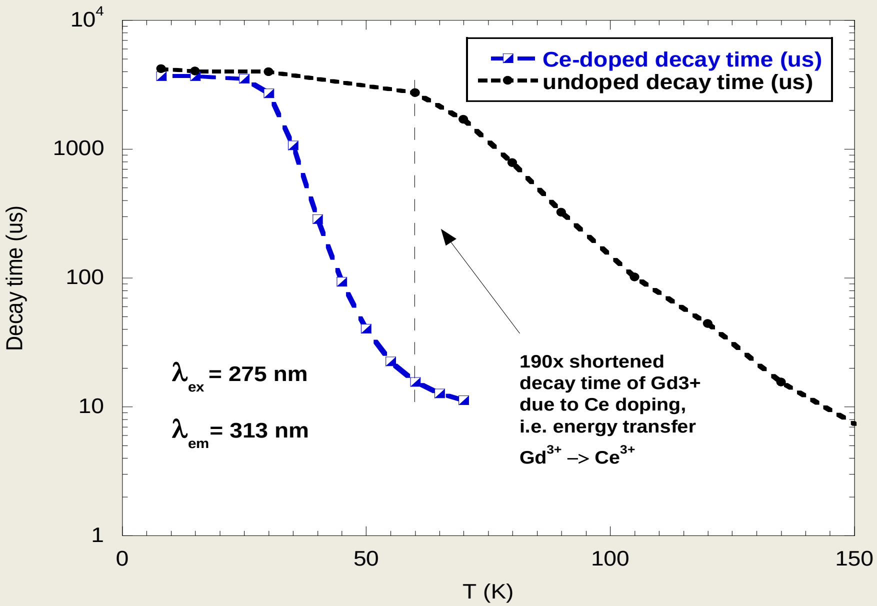
PL excitation and emission spectra of $\mathbf{Gd_3Ga_3Al_2O_{12}:Ce^{3+}}$.
The emission of Ce^{3+} is observed upon excitation at ^8S – ^6I_J absorption band of Gd^{3+}. (ET from Gd^{3+} to Ce^{3+} ions).

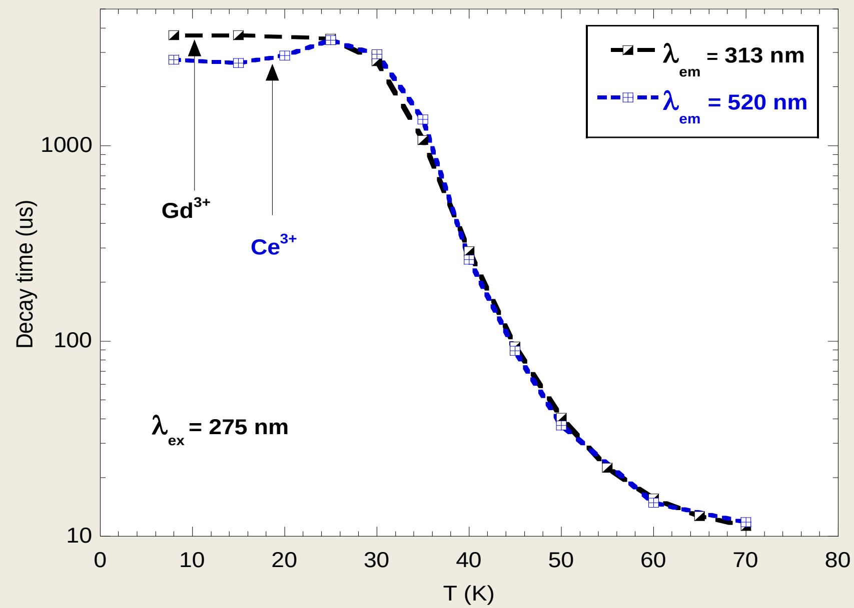
PLE spectrum monitored at maximum of Ce^{3+} emission. Presence of weak line at 270 nm (Gd^{3+} – related) confirm the **energy transfer from Gd^{3+} to Ce^{3+}**



Results and Discussion

Temperature dependence characteristics



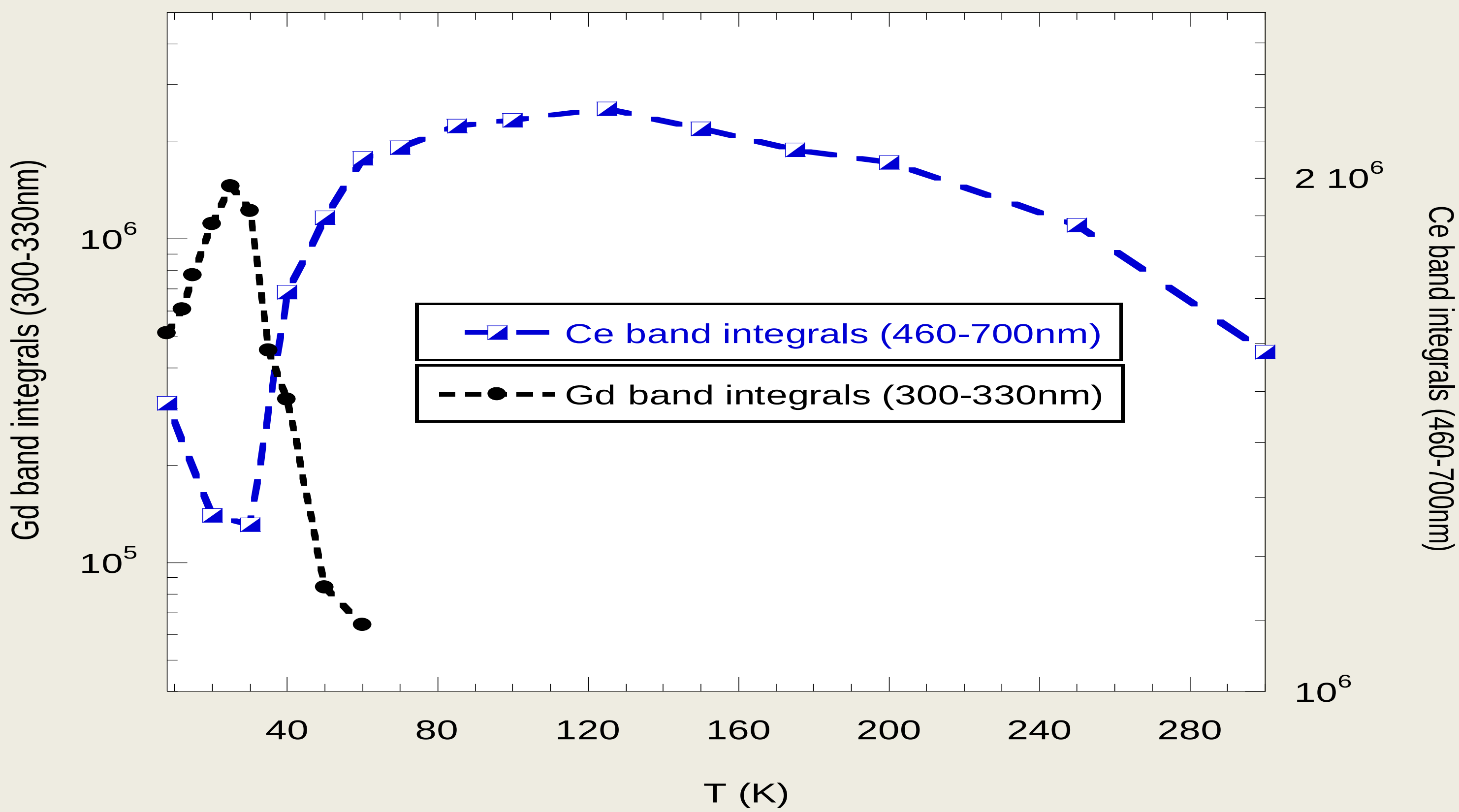


Gd^{3+} decays in undoped and Ce - doped $\mathbf{Gd_3Ga_3Al_2O_{12}}$ as a function of temperature

Gd^{3+} and Ce^{3+} decays in $\mathbf{Gd_3Ga_3Al_2O_{12}{:}Ce^{3+}}$ as a function of temperature

Results and Discussion

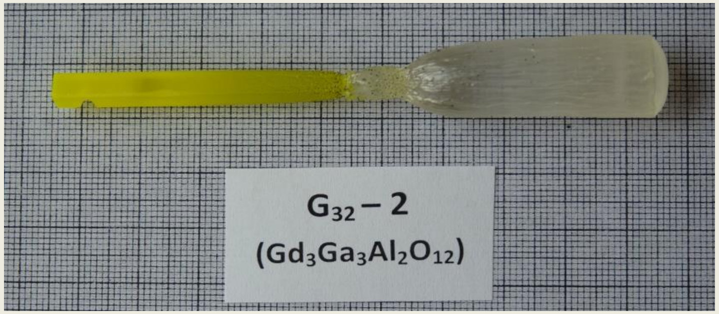
Temperature dependence characteristics

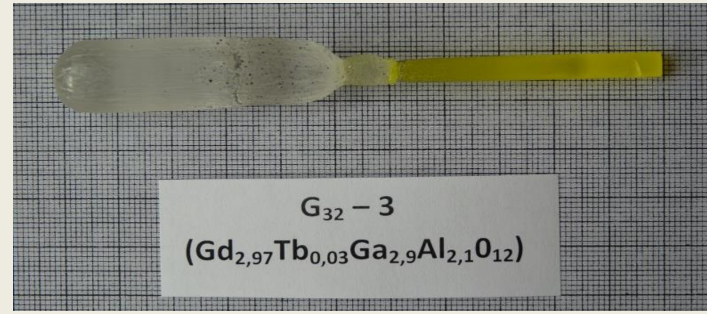


Gd and Ce – related emission bands in **$Gd_3Ga_3Al_2O_{12}$:Ce** upon excitation at $^8S \rightarrow {}^6I_J$ absorption band of Gd^{3+} as a function of temperature

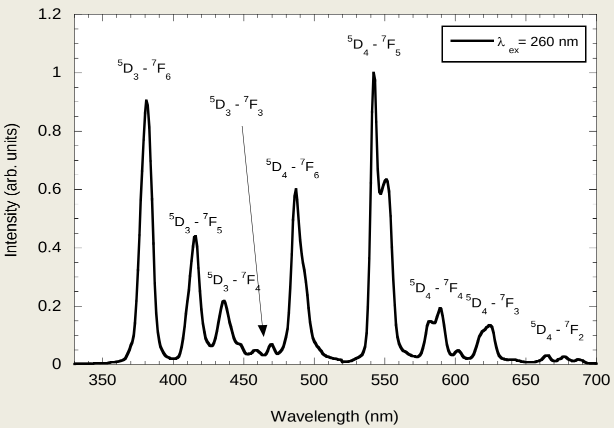
Outline

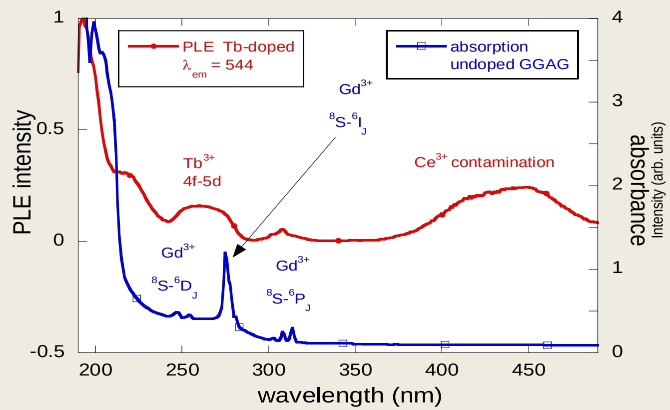
Results and discussion

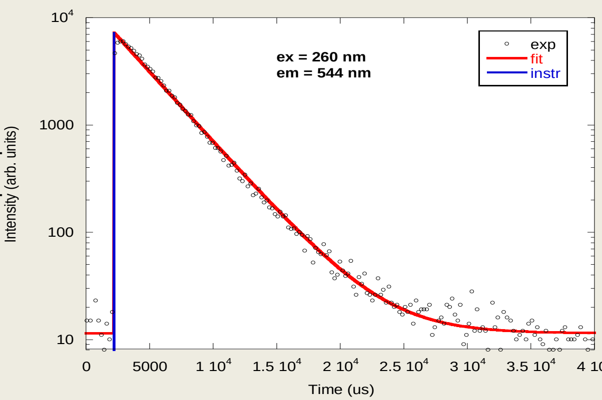




Crystals grown by Czochralski method in **IP Prague laboratory** (seeds from C&A Japan)







In Tb^{3+} grown crystal the emission spectrum shows full set of emission lines starting from $^5D_3$ and $^5D_4$ levels of Tb^{3+}. PLE spectrum shows 4f-5d transition of Tb^{3+} below 280 nm, fingerprint of Gd^{3+} absorption lines at 305-210 nm , the broad band around 450 nm might be due to Ce^{3+} contamination. Decay time of 544 nm line is 3.3 ms, consistent with strongly forbidden character of Tb^{3+} 4f-4f transitions

Outline

Conclusions

- ✓ Energy migration processes over Gd-sublattice were observed in samples with two or more Gd atoms
- ✓ In undoped samples concentration quenching in Gd^{3+} sublattice was observed.
- ✓ The temperature dependence of carried out measurements shown phonon assistance in energy migration
- ✓ Nonradiative energy transfer from Gd^{3+} to Ce^{3+} in the Ce-doped $Gd_3Ga_3Al_2O_{12}$ was proved.

Acknowledgment

For financial support from

Marie Curie Initial Training Network LUMINET, grant agreement no. 316906.

and to you for your attention!