Fyzikální ústav
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The Temperature Dependent Studies of Rare-Earth (Dy^{3+}, Sm^{3+} and Tb^{3+}) Activated $Gd_3Ga_3Al_2O_{12}$ Garnet Single Crystal

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Outline

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Introduction and Aims

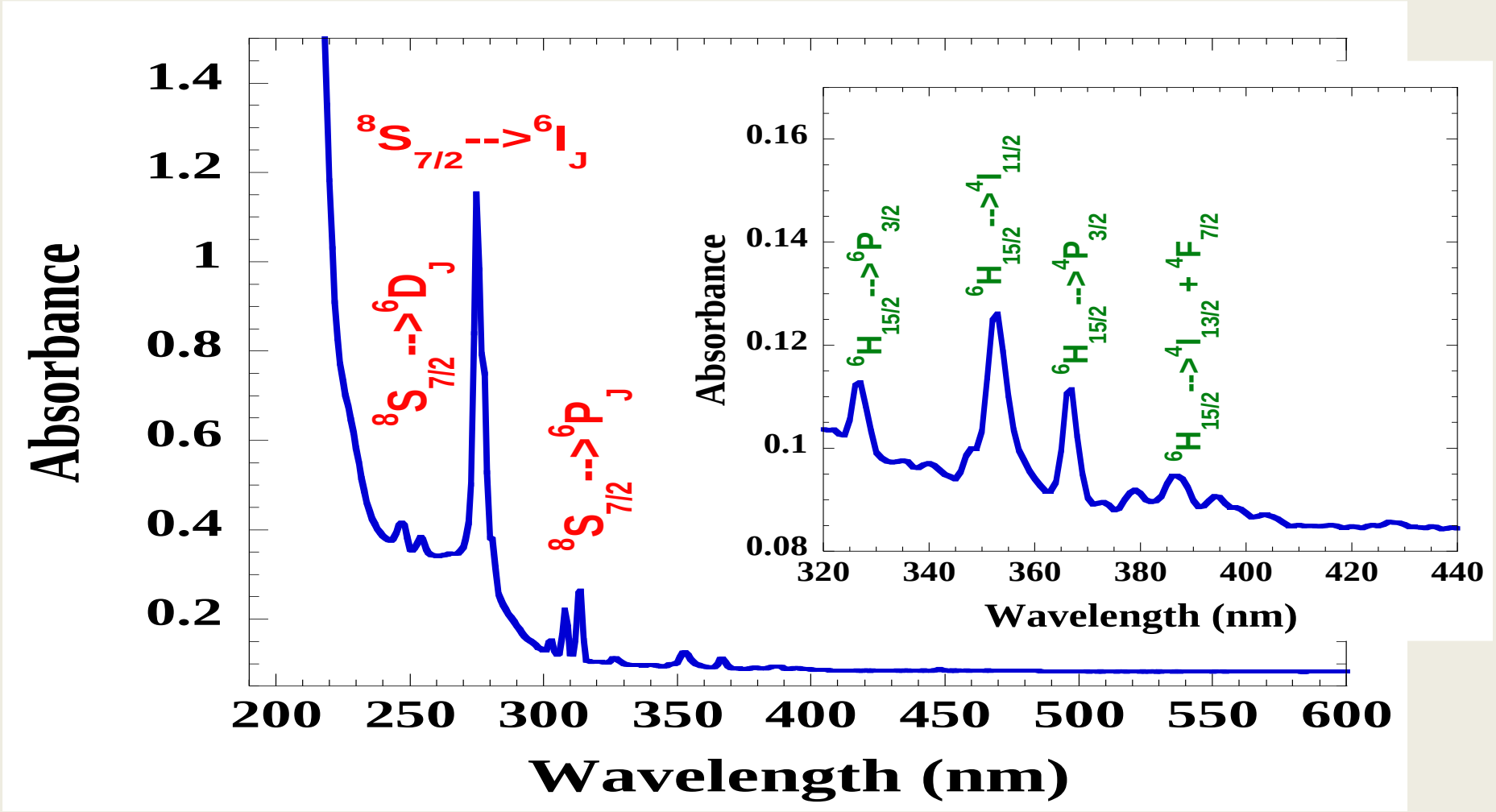
- ✓ $Y_3Al_5O_{12}:Nd^{3+}$ solid laser material since 1960s
- ✓ $YAG:Ho^{3+}$ and $YAG:Er^{3+}$ IR laser materials for medical surgery
- ✓ Nowadays RE activated YAG is intensively studied for application as LED phosphors
- ✓ In recent years Pr^{3+} and Ce^{3+} activated $(Y,Gd)_3(Ga,Al)_5O_{12}$ crystals have been intensively studied for application as a scintillating materials
- ✓ **GGAG** host lattice doped with other RE ions has been much less explored. However, GGAG may hold a number of merits for optical applications:
  - the intrinsic $^8S_{7/2}\rightarrow{}^6I_J$ transition of Gd^{3+} can be utilized as a new excitation source for some types of RE activators, and enhanced luminescence via $Gd^{3+}\rightarrow RE^{3+}$ energy transfer
  - GGAG lattice is more covalent than YAG which may produce a new emission features and result in improved emission intensity

Introduction and Aims

The aim of this work is to study the effect of temperature on the luminescence properties of the Dy^{3+}, Sm^{3+} and Tb^{3+} in $Gd_3Ga_3Al_2O_{12}$ single crystal as well as to reveal the mechanism responsible for thermal quenching.

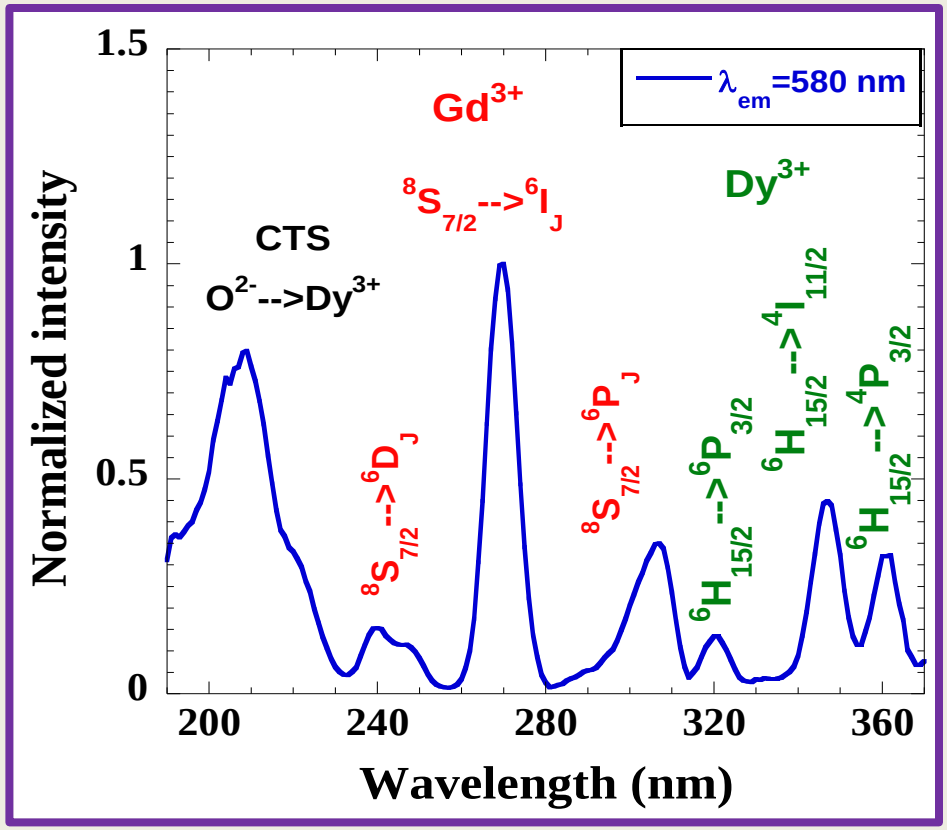
Outline

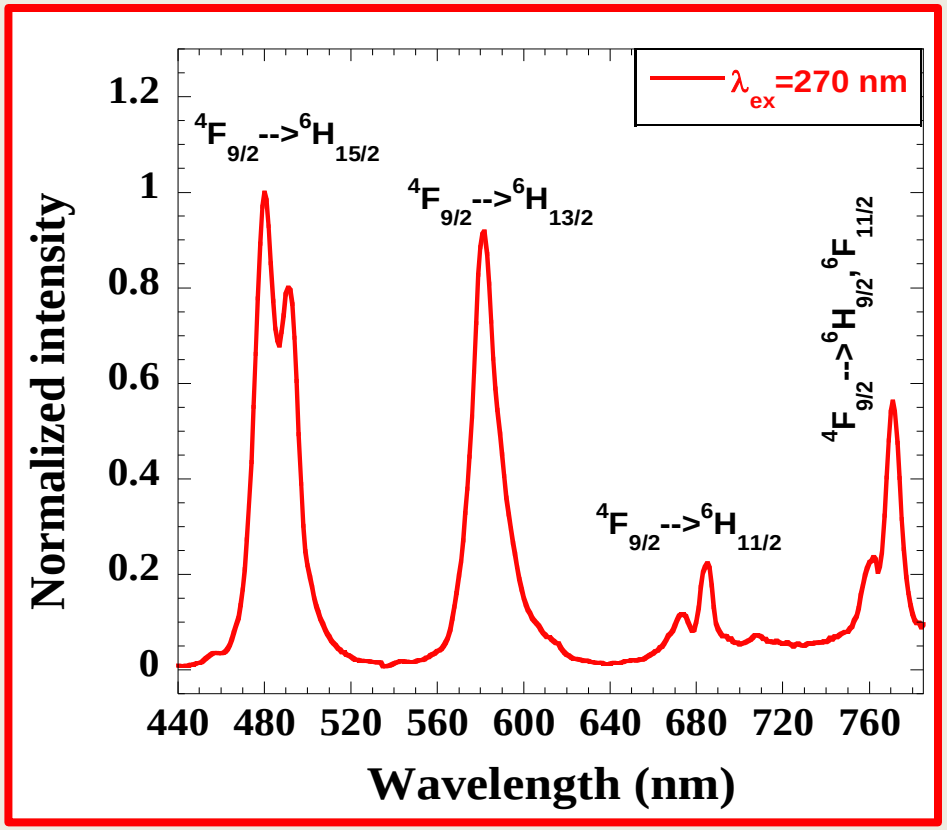
$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%



Absorption spectrum of the Dy^{3+} activated $Gd_3Ga_3Al_2O_{12}$ single crystal. Dy^{3+} concentration in the sample is 0.5 mol %.

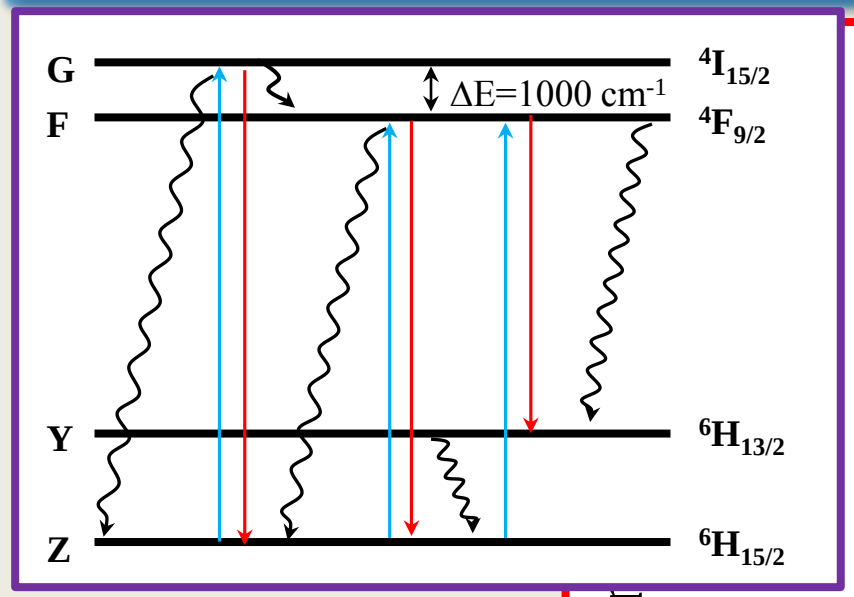
$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%



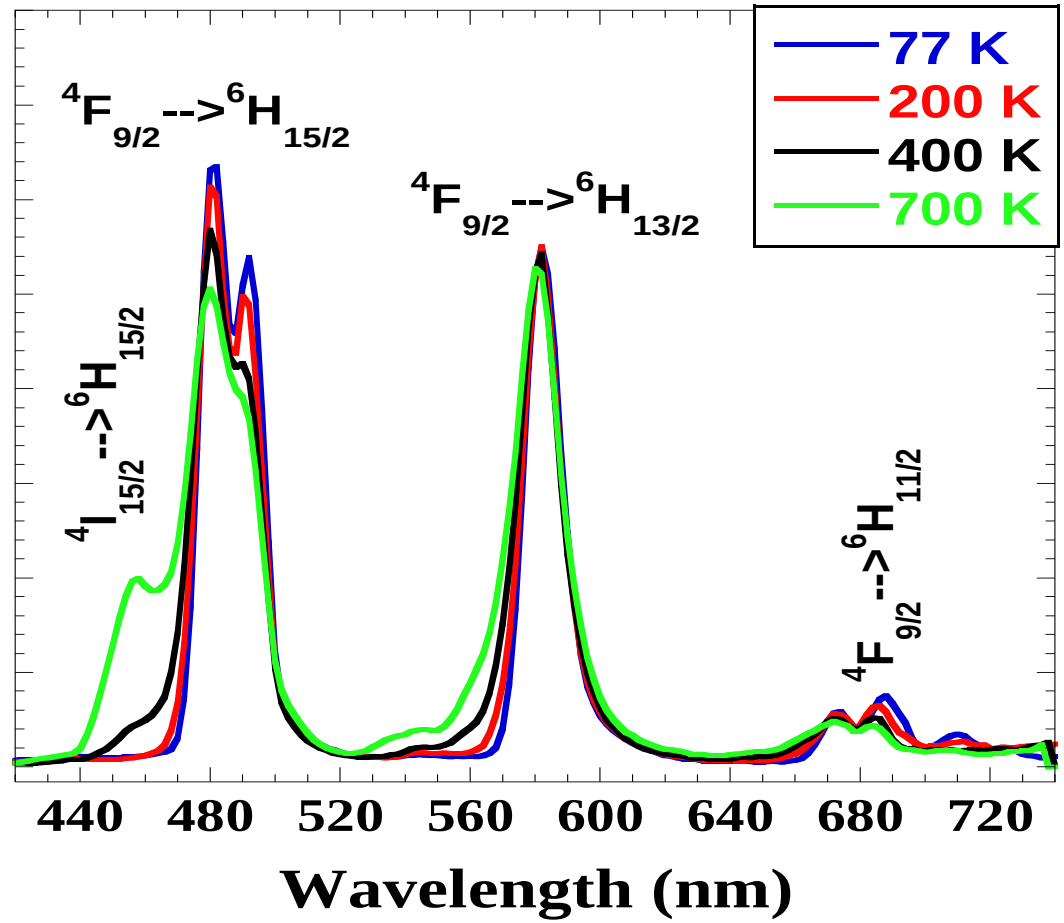


RT excitation (**λ_{em}=580 nm**) and emission (**λ_{ex}=270 nm**) spectra of GGAG:Dy^{3+}

$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%

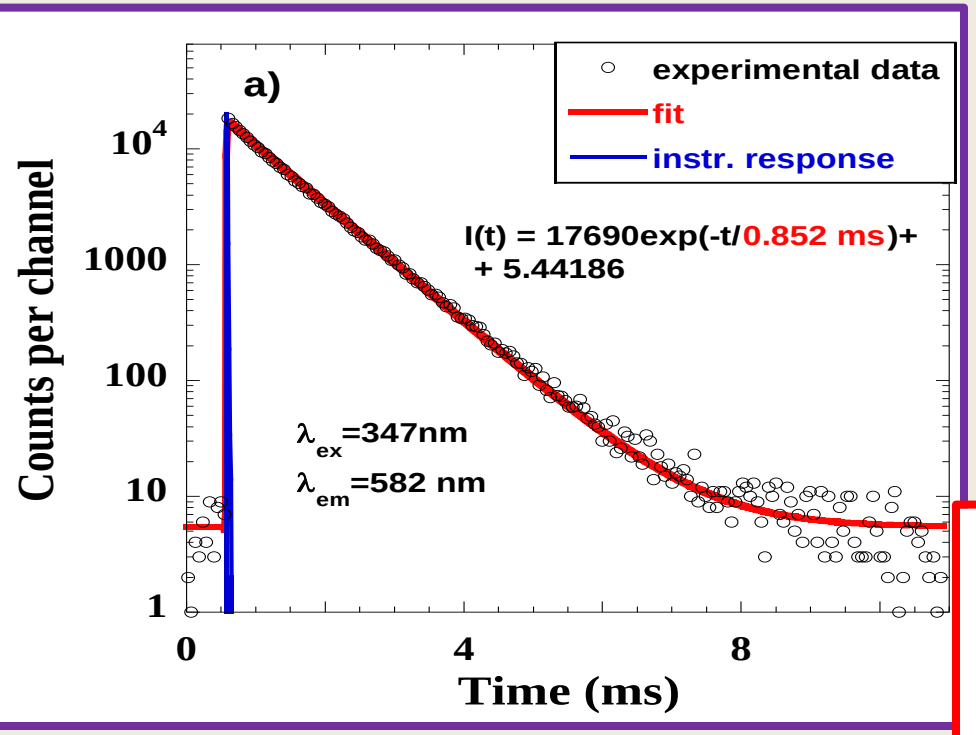


simplified energy diagram of Dy^{3+};
-**blue arrows -** absorption
-**black wiggly arrows -** non-radiative de-excitation mechanism
-**red arrows -** radiative de-excitation mechanism



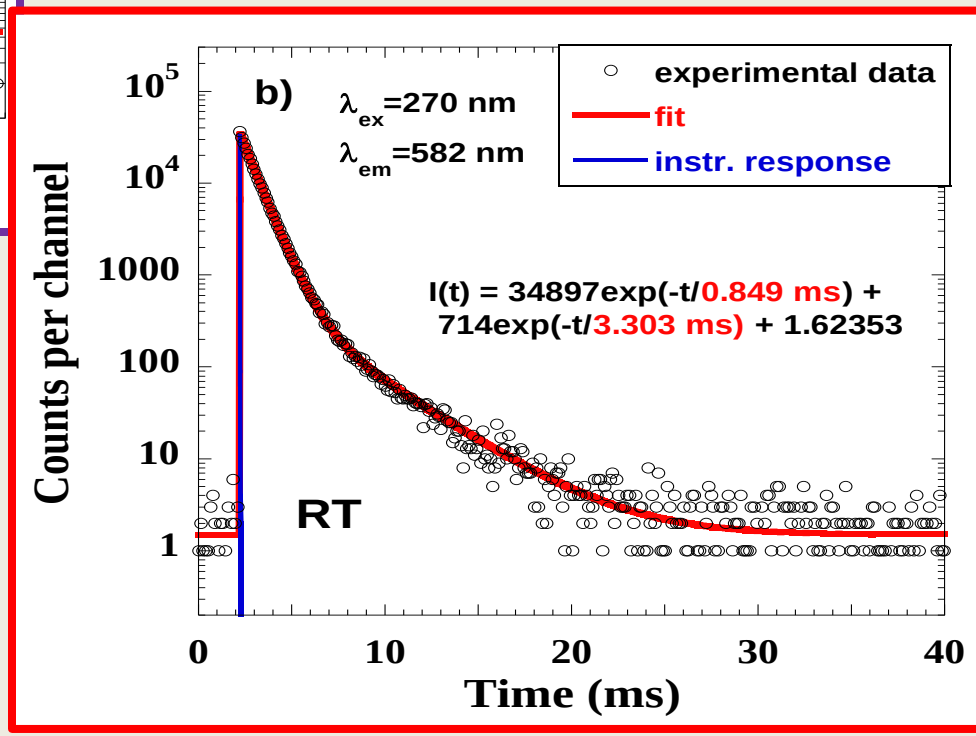
Emission spectra for $Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ under exciation into Gd^{3+} ions at 270 nm recorded in the range between 77 and 700 K.

$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%

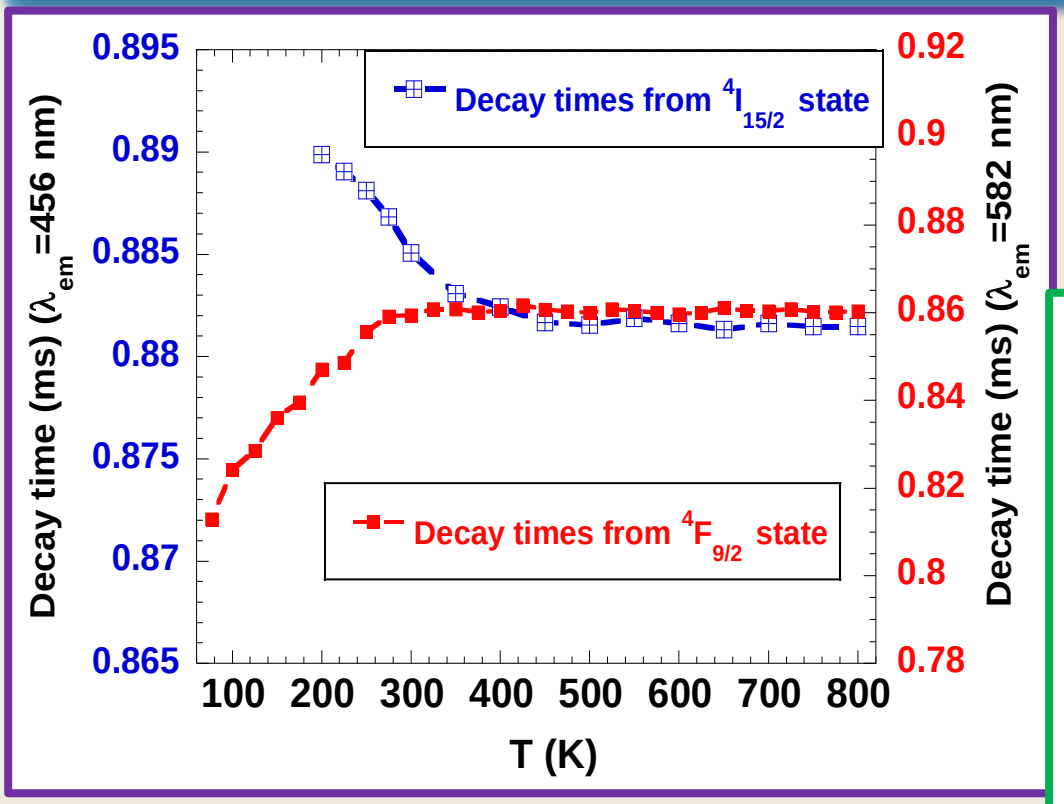


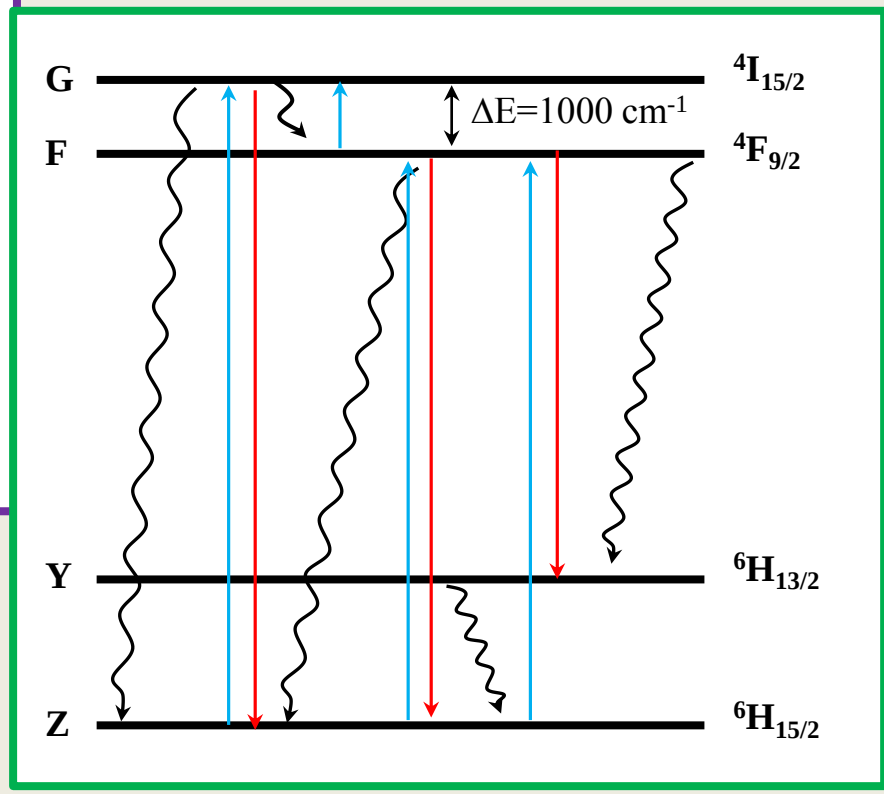
decay curve of Dy^{3+} emission at 582 nm under excitation into Gd^{3+} at 270 nm.

decay curve of Dy^{3+} emission at 582 nm under excitation into Dy^{3+} at 347 nm.



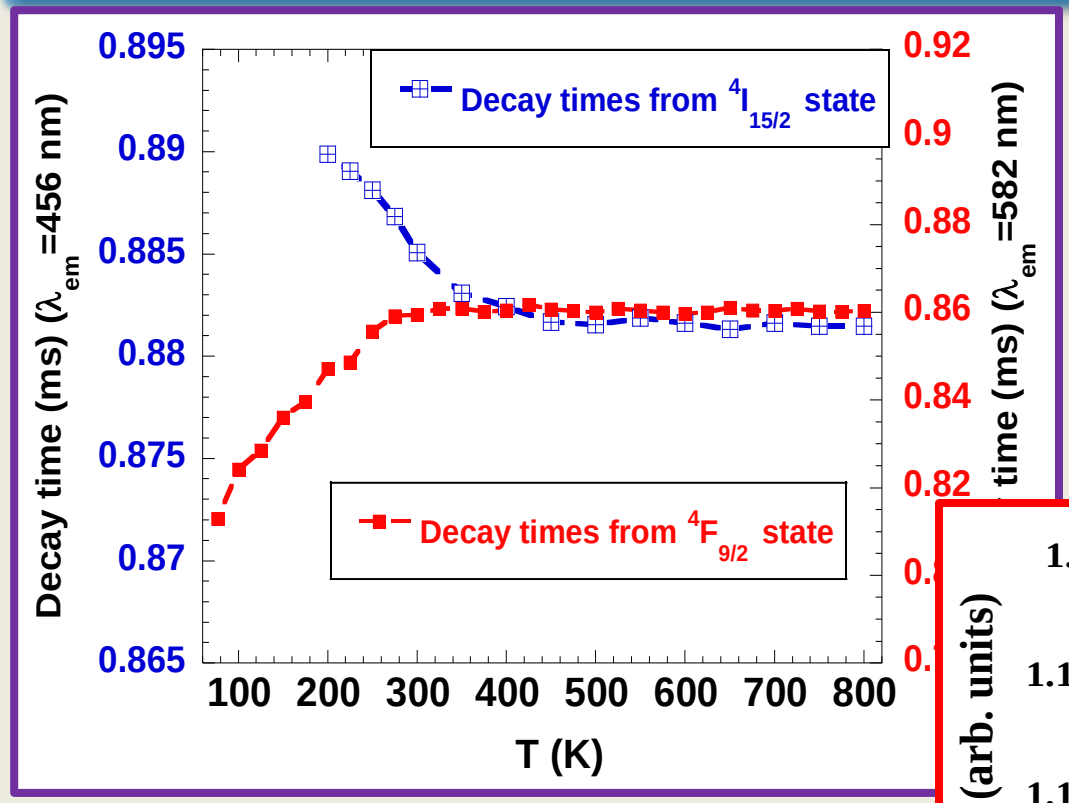
$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%



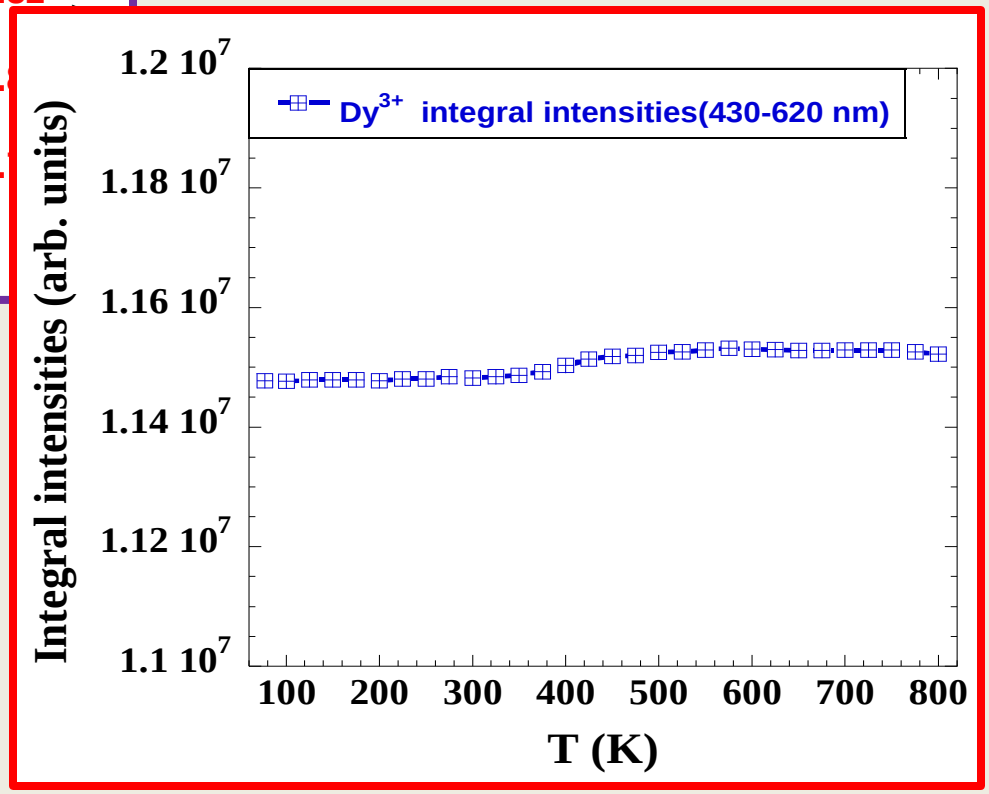


temperature dependence of the photoluminescence decay times of Dy^{3+} $^4F_{9/2} \rightarrow {}^6H_{13/2}$ and $^4I_{15/2} \rightarrow {}^6H_{15/2}$ emission transitions at 582 and 456 nm, respectively, under excitation into Dy^{3+} ion at 347 nm.

$Gd_3Ga_3Al_2O_{12}:Dy^{3+}$ 0.5%

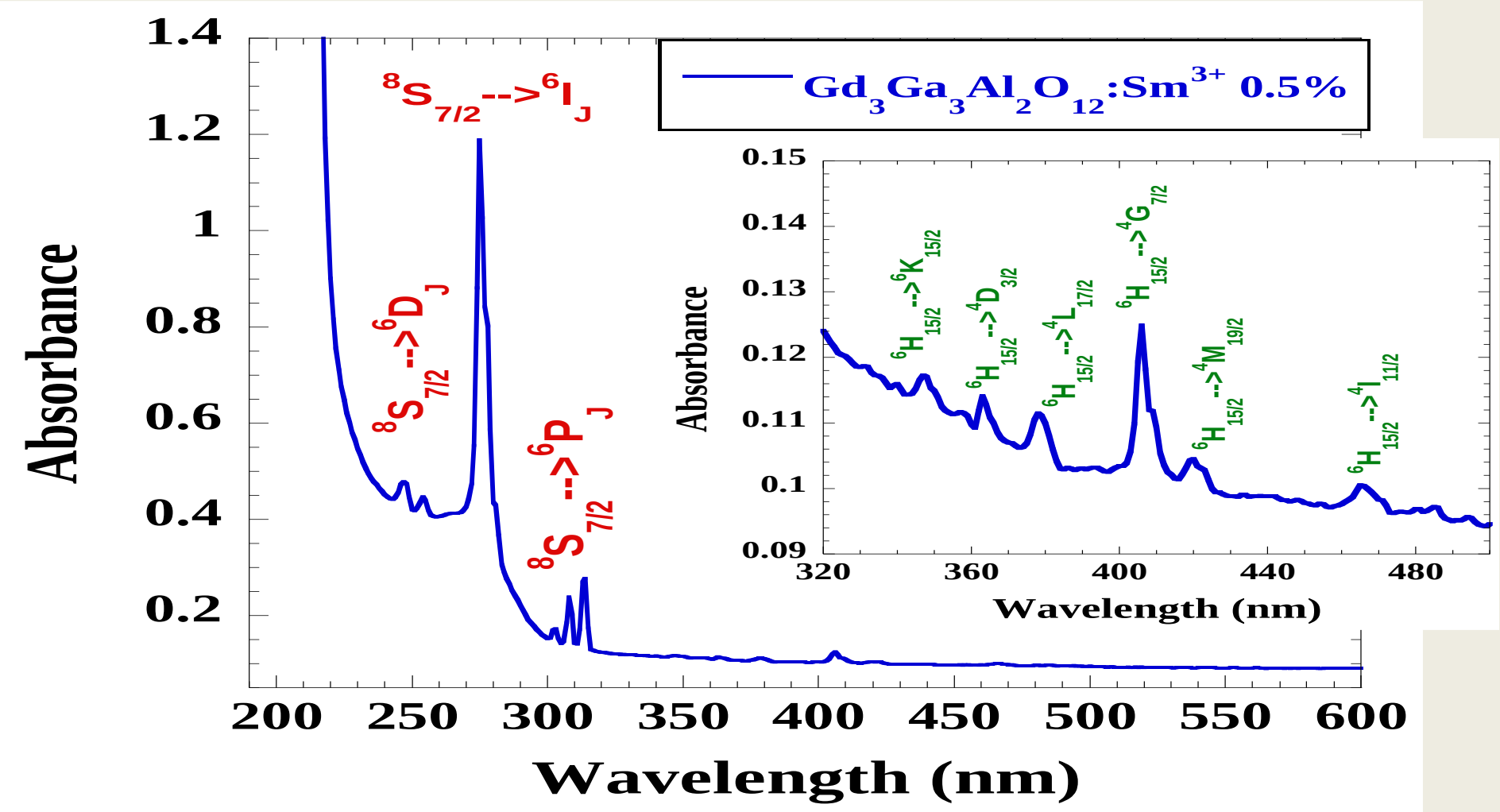


temperature dependence of the PL integral intensities of Dy^{3+} emission under excitation into Gd^{3+} ions at 270 nm.



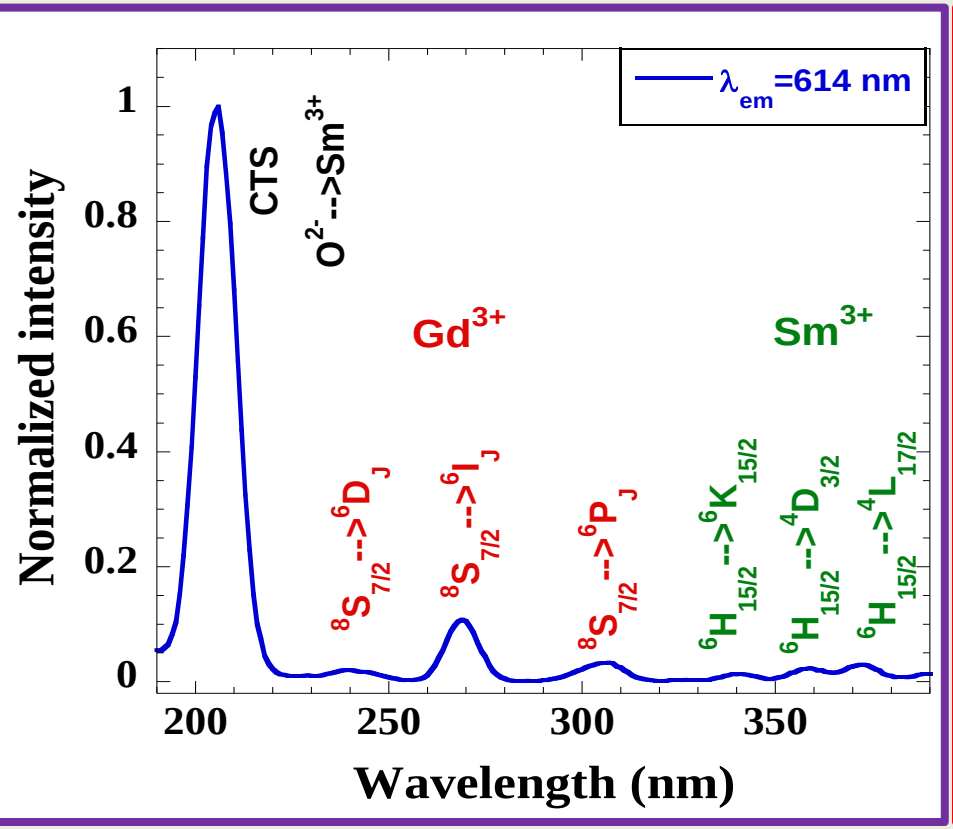
temperature dependence of the photoluminescence decay times of Dy^{3+} $^4F_{9/2}\rightarrow{}^6H_{13/2}$ and $^4I_{15/2}\rightarrow{}^6H_{15/2}$ emission transitions at 582 and 456 nm, respectively, under excitation into Dy^{3+} ion at 347 nm.

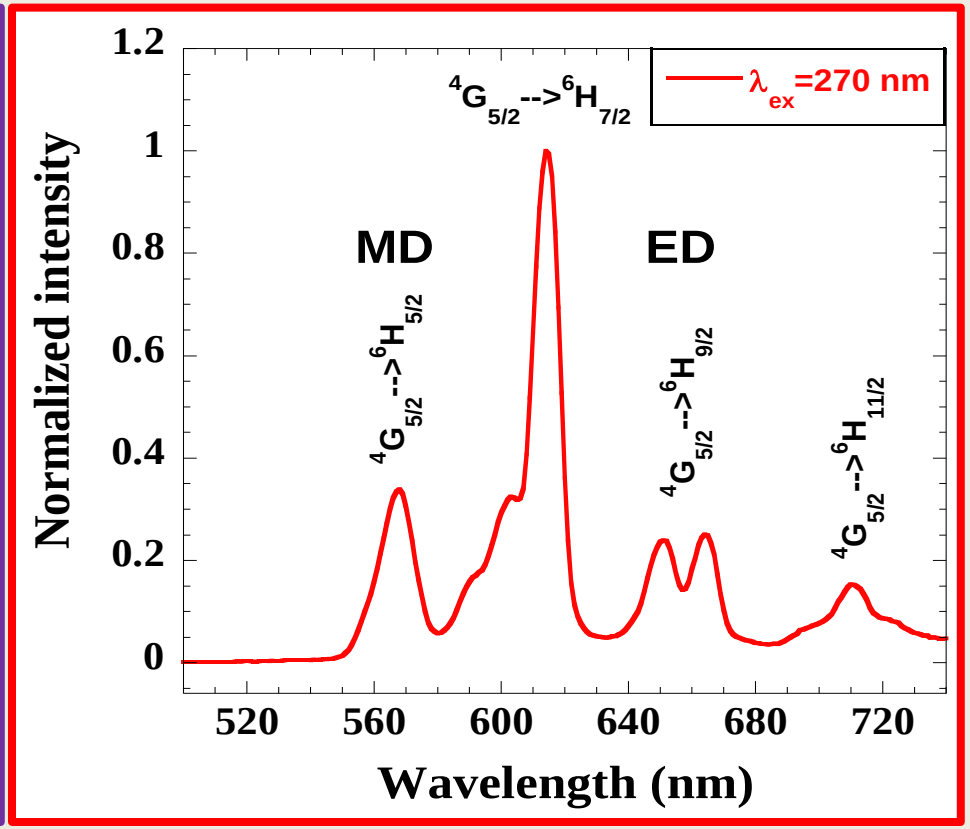
$Gd_3Ga_3Al_2O_{12}:Sm^{3+}$ 0.5%



Absorption spectrum of the Sm^{3+} activated $Gd_3Ga_3Al_2O_{12}$ single crystal. Sm^{3+} concentration in the sample is 0.5 mol %.

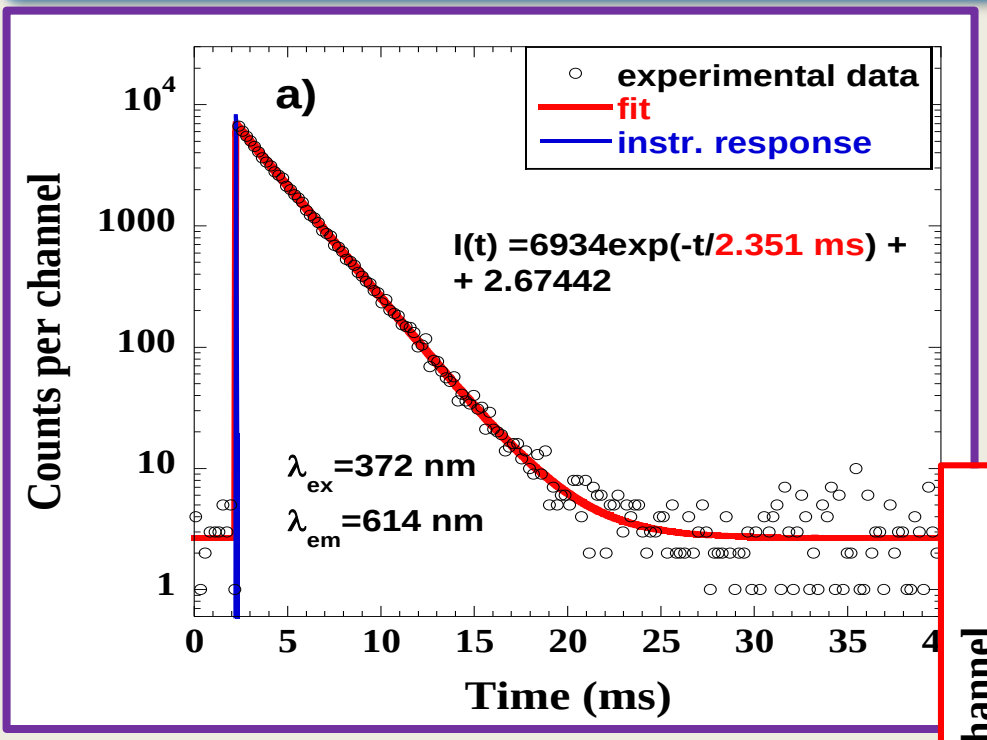
$Gd_3Ga_3Al_2O_{12}:Sm^{3+}$ 0.5%



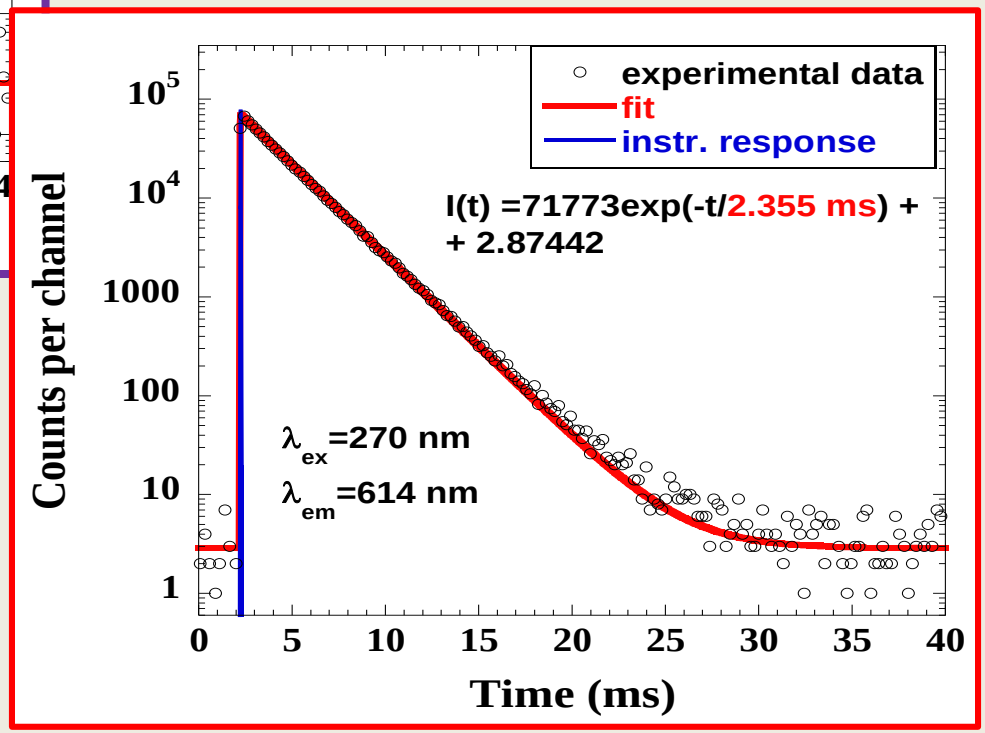


RT excitation (λ_{em}=614 nm) and emission (λ_{ex}=270 nm) spectra of GGAG:Sm^{3+}

$Gd_3Ga_3Al_2O_{12}:Sm^{3+}$ 0.5%

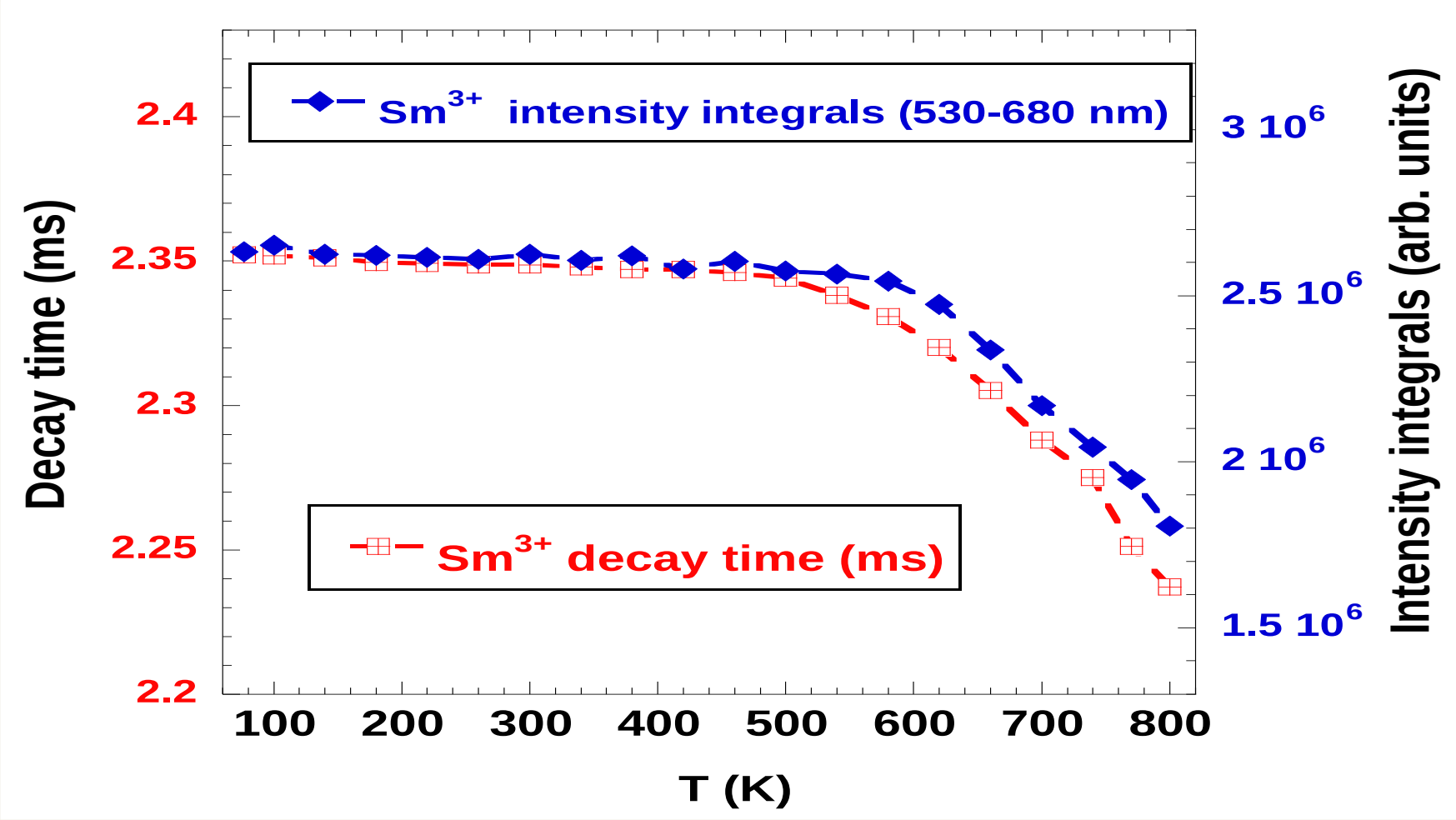


decay curve of the Sm^{3+} emission at 614 nm under excitation into Gd^{3+} at 270 nm



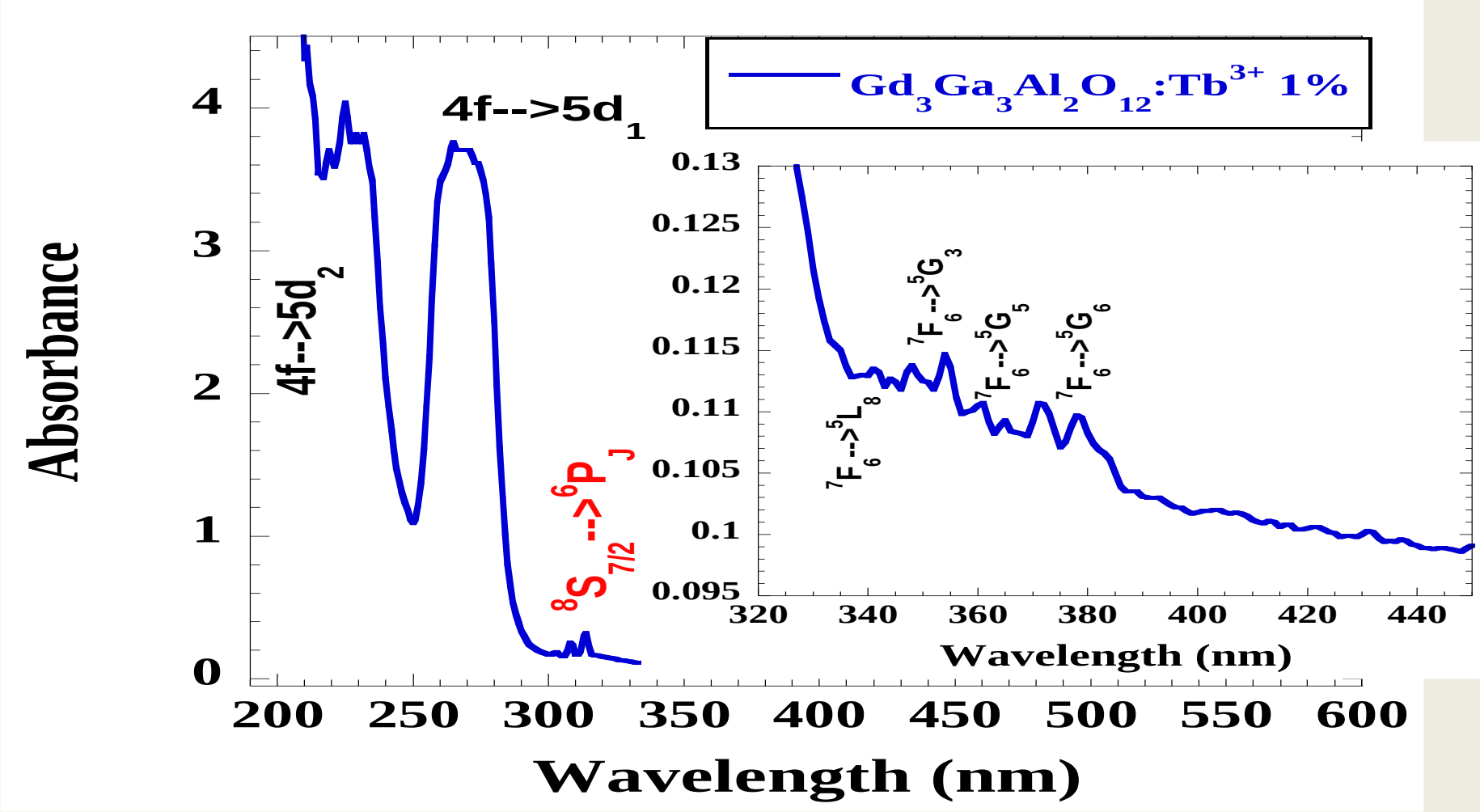
decay curve of the Sm^{3+} emission at 614 nm under excitation into Sm^{3+} at 372 nm

$Gd_3Ga_3Al_2O_{12}:Sm^{3+}$ 0.5%



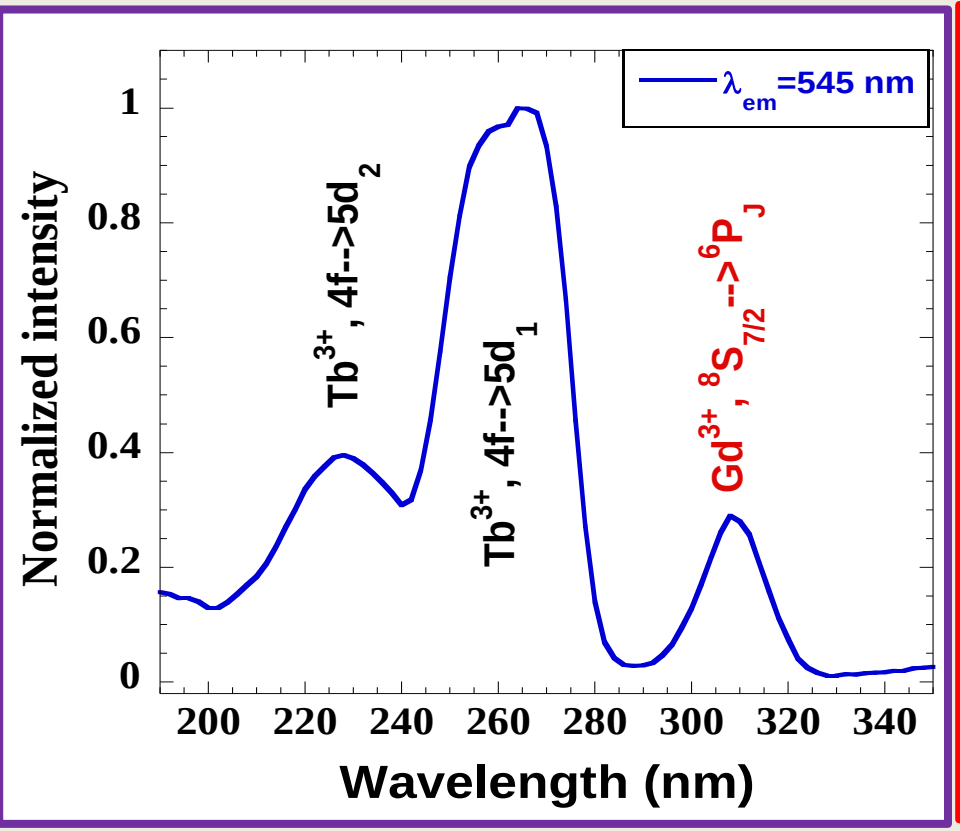
the decay times of Sm^{3+} emission at 614 nm and the integrals of Sm^{3+} luminescence between 530 and 680 nm as a function of temperature. In both cases the Sm^{3+} luminescence was excited directly into Sm^{3+} ions at 372 nm

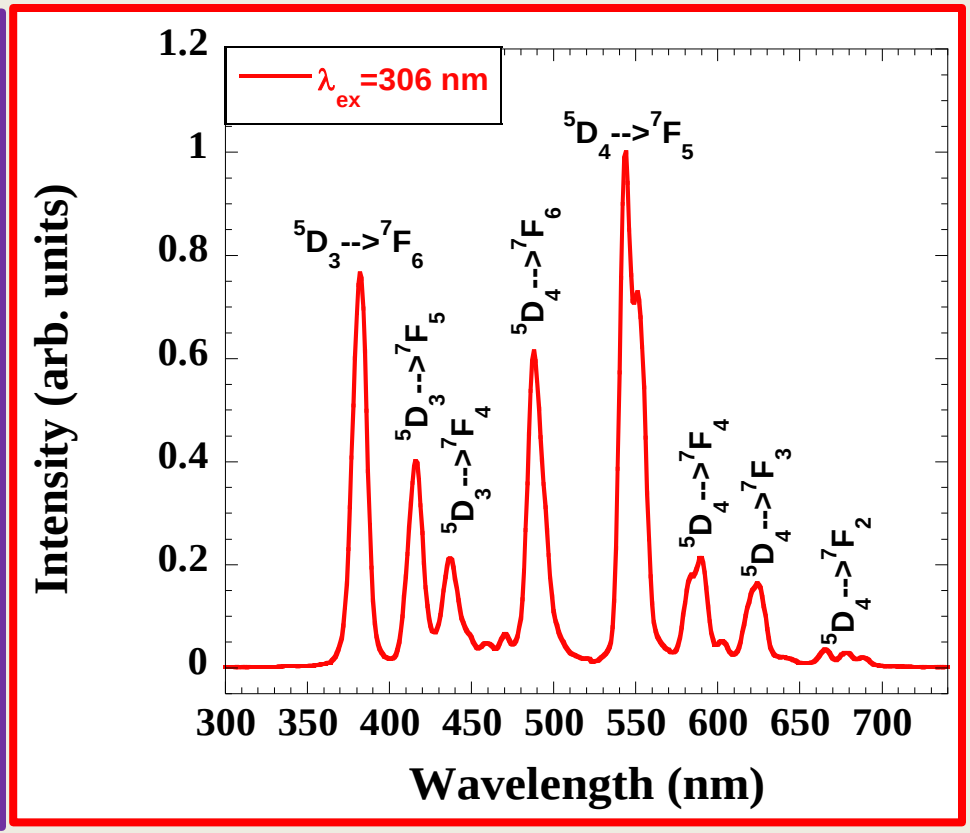
$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$ 1%



absorption spectrum of the Tb^{3+} activated $Gd_3Ga_3Al_2O_{12}$ single crystal. Tb^{3+} concentration in the sample is 1 mol %.

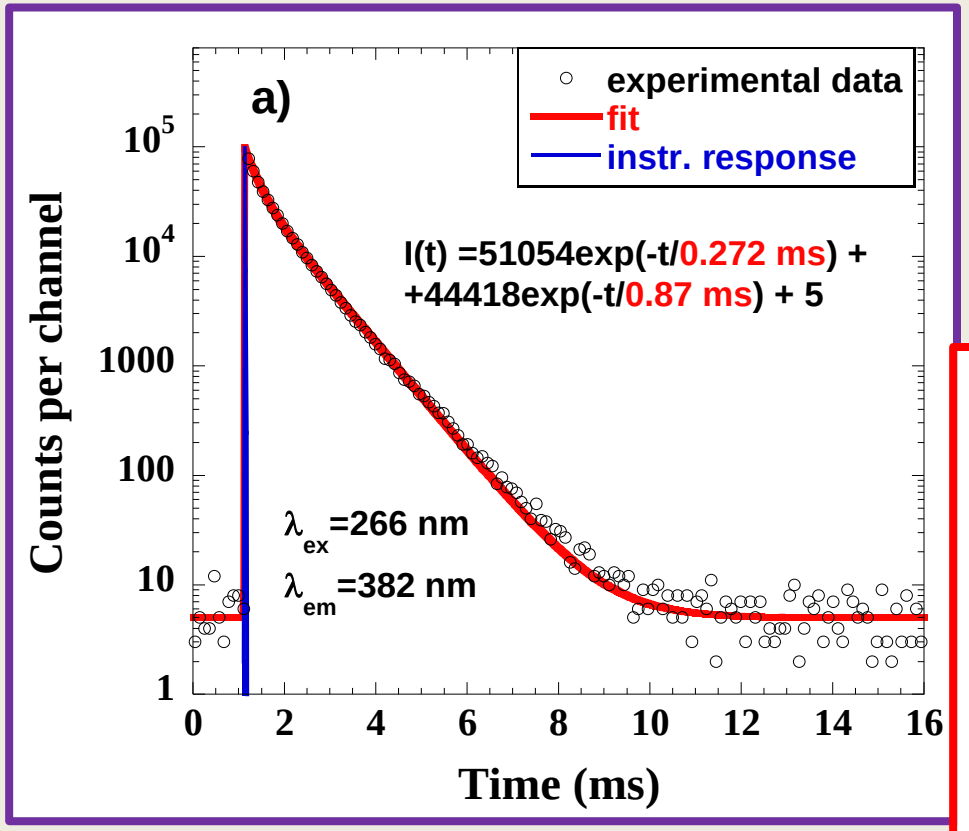
$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$ 1%



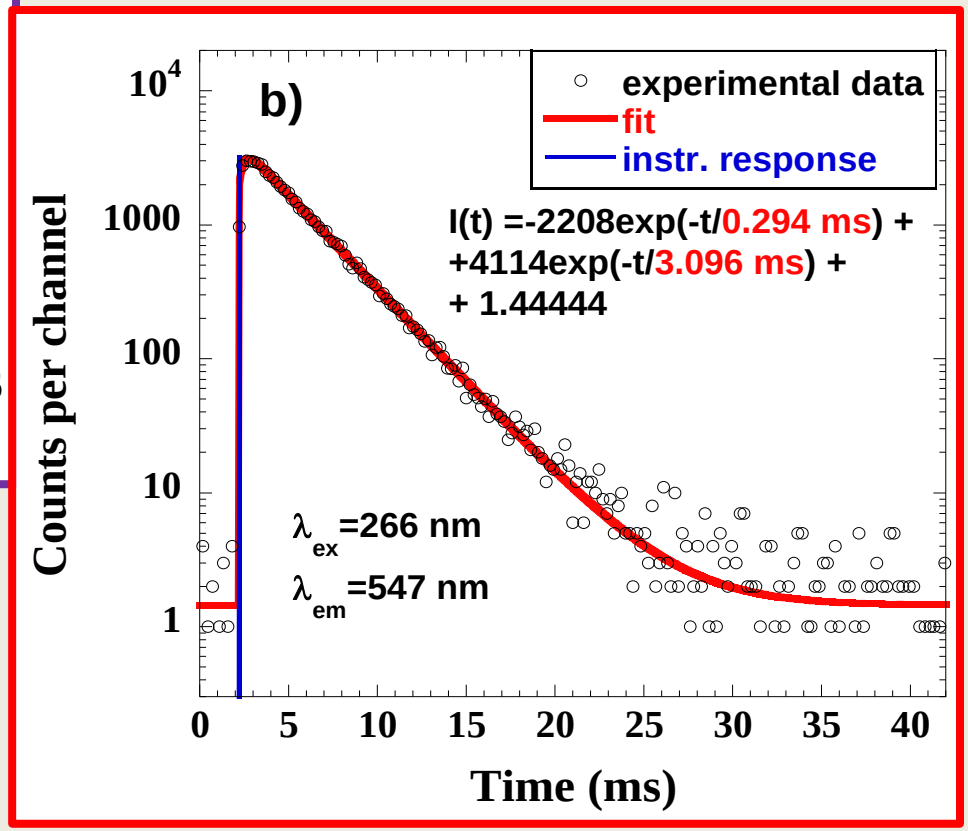


RT excitation (λ_{em}=545 nm) and emission (λ_{ex}=306 nm) spectra of GGAG:Tb^{3+}

$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$ 1%

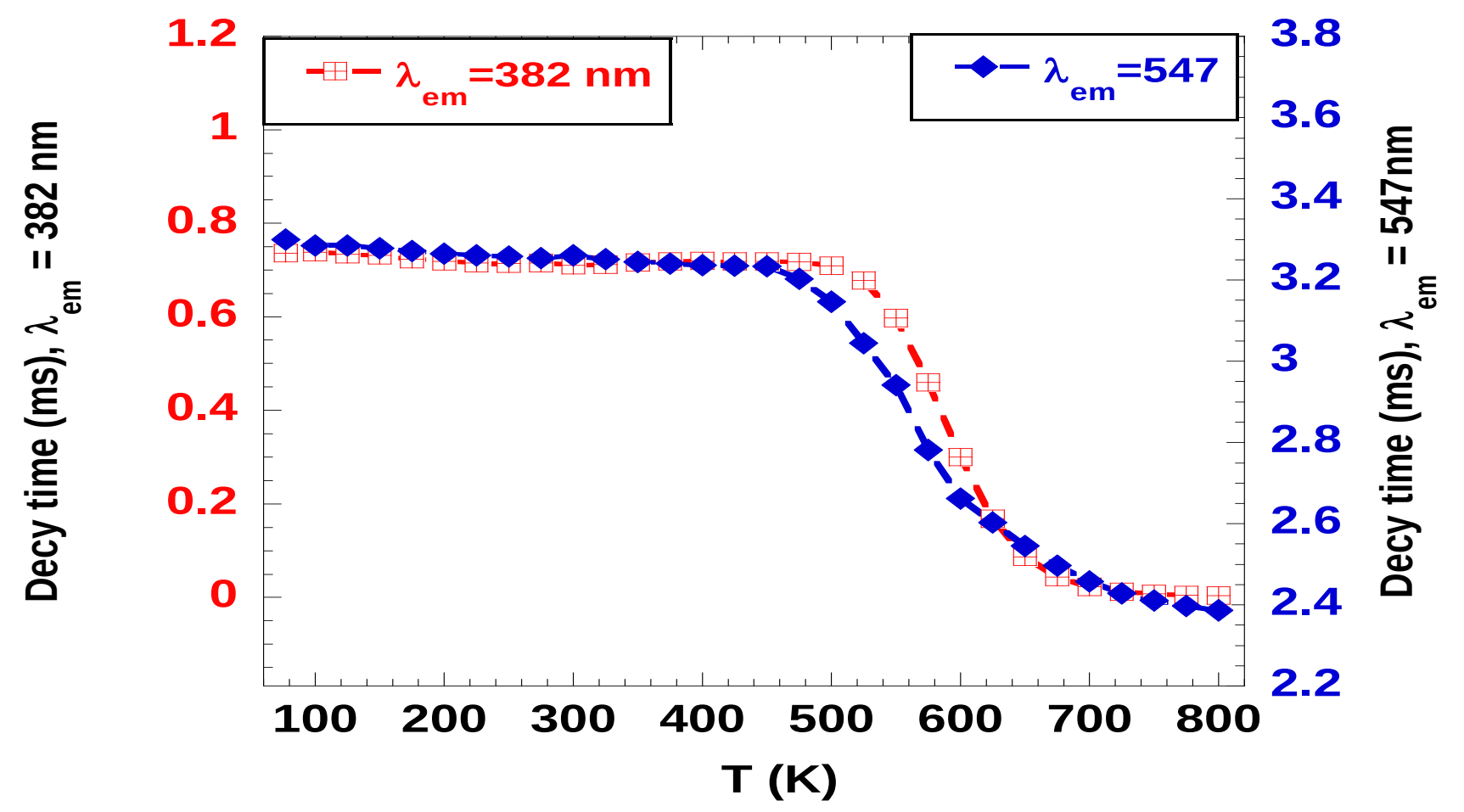


decay curve of the Tb^{3+} emission at 547 nm under excitation into Tb^{3+} at 266 nm



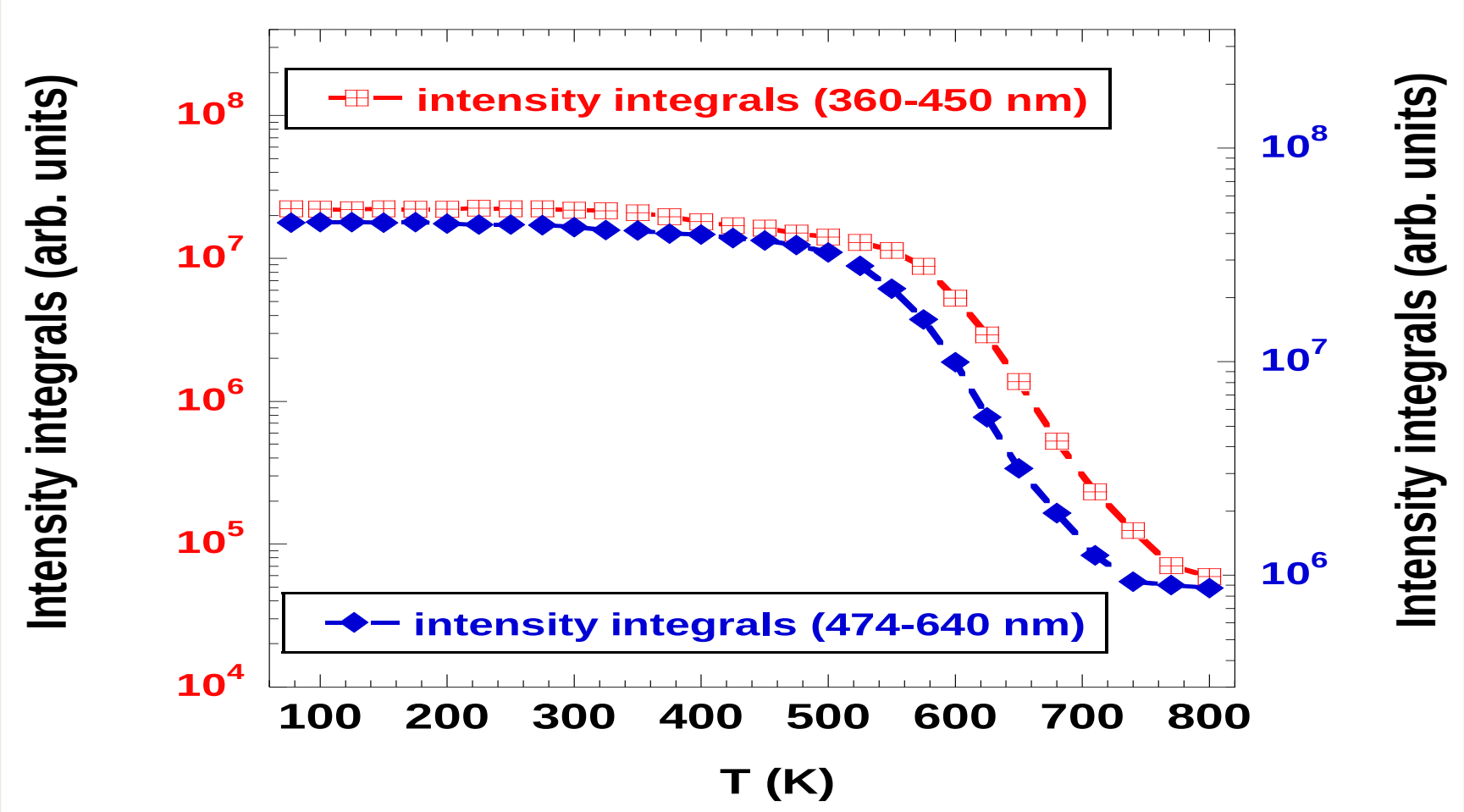
decay curve of Tb^{3+} emission at 382 nm under excitation into Tb^{3+} at 266 nm

$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$ 1%



temperature dependence of the photoluminescence decay times of Tb^{3+} $^5D_3 \rightarrow {}^7F_6$ **(blue curve)** and $^5D_4 \rightarrow {}^7F_5$ **(red curve)** emission at **382** and **547 nm**, respectively, under excitation into $4f \rightarrow 5_1$ absorption transition at 266 nm

$Gd_3Ga_3Al_2O_{12}:Tb^{3+}$ 1%



temperature dependence of the PL intensity integrals of Tb^{3+} emission related to **$^5D_3 \rightarrow {}^7F_J$ (red curve)** and **$^5D_4 \rightarrow {}^7F_J$ (blue curve)** transitions under excitation into $4f \rightarrow 5d_1$ band at 266 nm.

Conclusions

✓ Non-radiative energy transfer from Gd^{3+} towards Dy^{3+}, Sm^{3+} and Tb^{3+} was observed

✓Gd^{3+} ions very effectively sensitize the Dy^{3+}, Sm^{3+} and Tb^{3+} luminescence

✓ Photoluminescence features of Dy^{3+}, Sm^{3+} and Tb^{3+} in GGAG single crystal confirmed a high homogeneity of the host lattice

✓ GGAG:Dy^{3+} shown the stable luminescence up to 800 K

✓Thermal quenching of the Sm^{3+} luminescence sets in at 600 K (most probably due to multiphonon relaxation)

✓ Thermal quenching of the Tb^{3+} luminescence sets in at 500 K (most probably due to induced photoionization process)

Acknowledgment

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and to you for your attention!