

# TO GLOW AFTER OR NOT TO GLOW AFTER?

Danuta Dutczak, Cees Ronda, Andries Meijerink and Thomas Jüstel

University of Applied Sciences Muenster, Germany  
Debye Institute for NanoMaterials Science, Utrecht University, The Netherlands  
Philips Research Laboratories Eindhoven, The Netherlands

## Introduction

During last decade, afterglow phosphors have attracted considerable attention due to their potential applications in various fields, including emergency signs, light sources, luminous paints or optical data storage.

Till now, the most efficient afterglow materials are based on strontium aluminates e.g.  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+},\text{Dy}^{3+}$ ,  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+},\text{Dy}^{3+}$ . These materials yield strong luminescence due to the interconfigurational  $4f^7 - 4f^65d^1$  transition of  $\text{Eu}^{2+}$ . The afterglow can be prolonged by co-doping additional ions like  $\text{Dy}^{3+}$  or  $\text{Nd}^{3+}$ . Although extensive studies were conducted on afterglow phosphors, the mechanism underlying this phenomenon still remains unclear and existing theories are even contradictory.

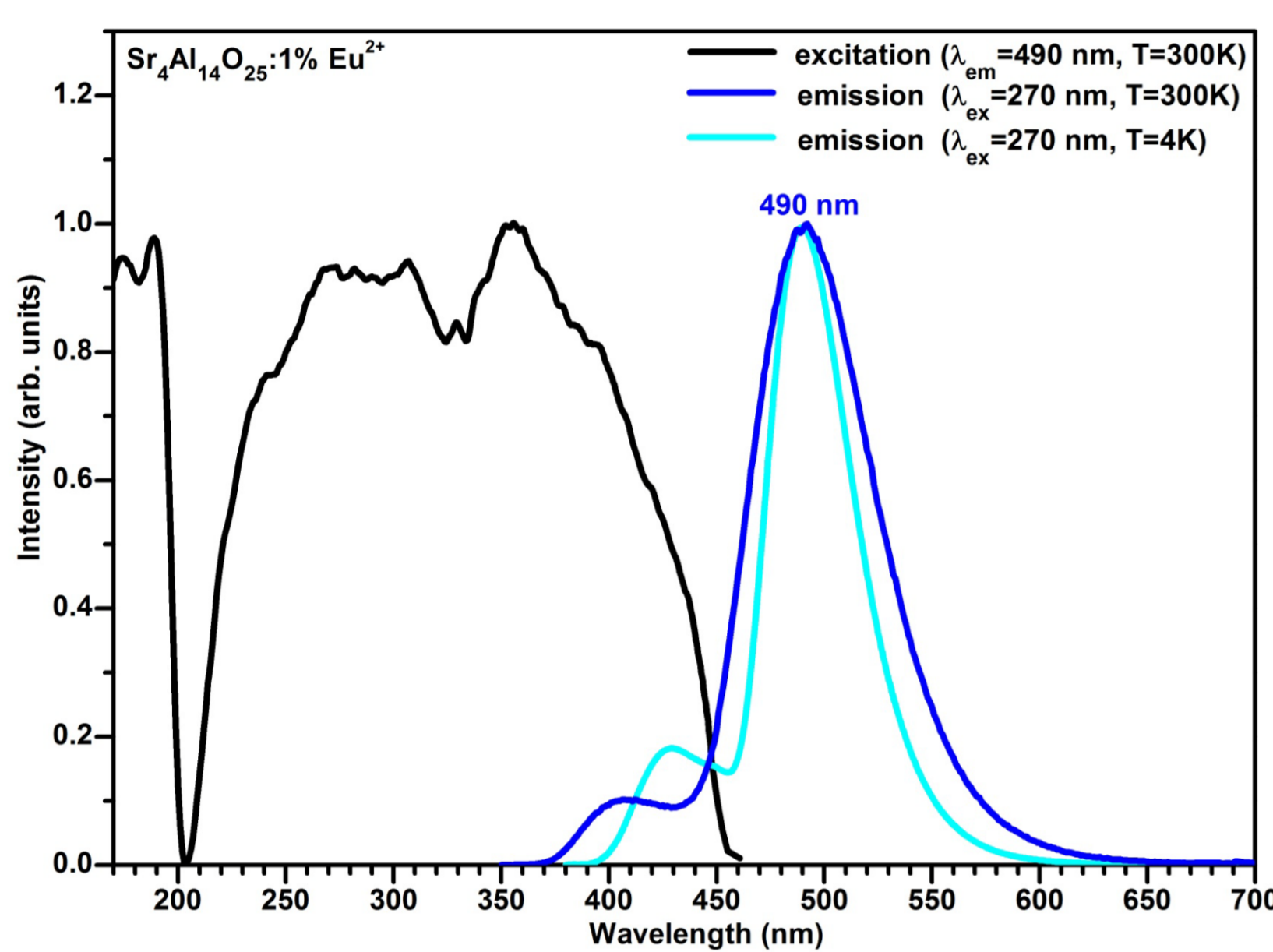
## Aim

This work deals with two afterglow materials based on strontium aluminates and aims at understanding the physics behind the persistent luminescence mechanism.

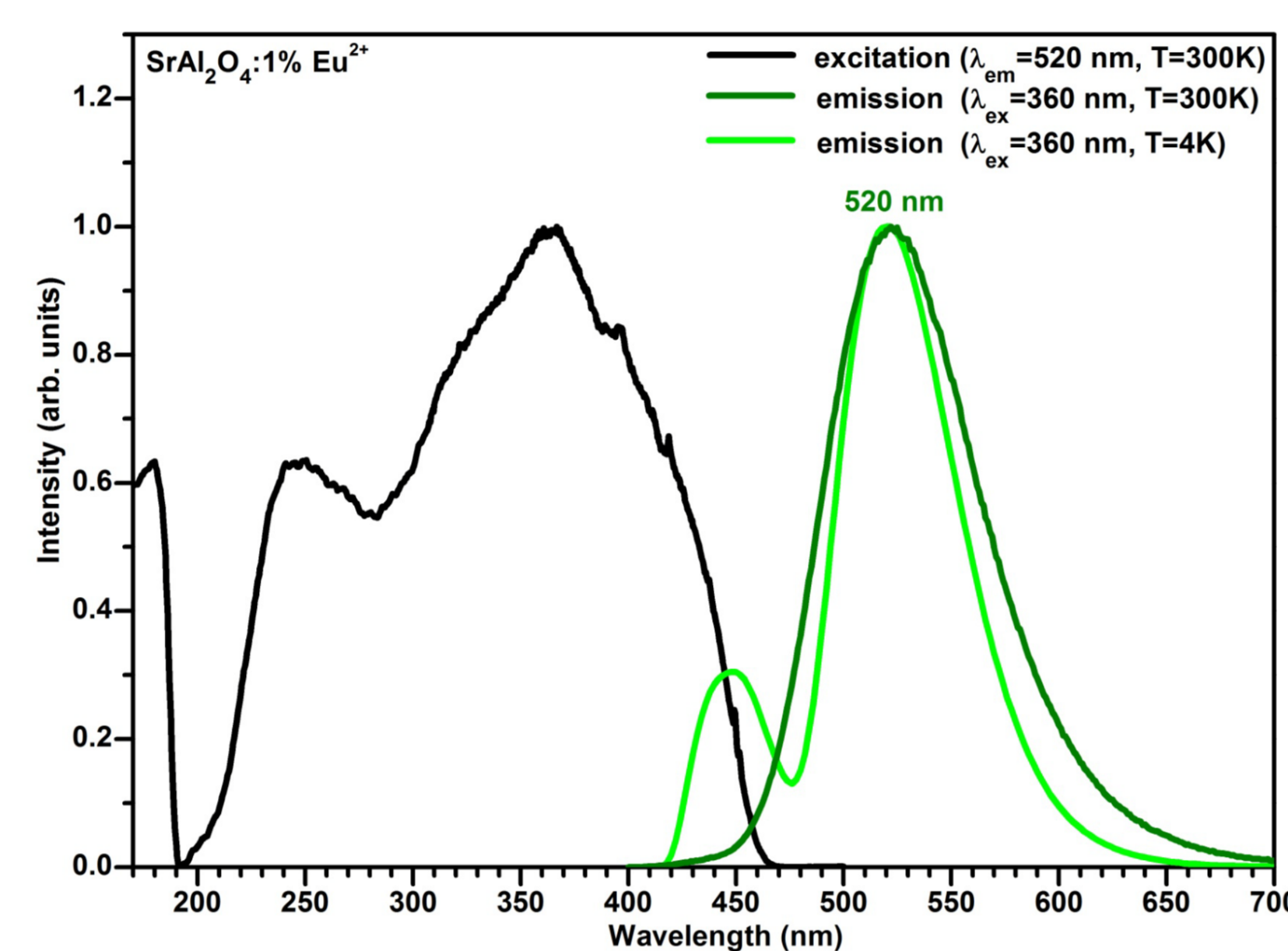
Strontium aluminates easily generate the multi-phases compounds according to molar ratio of  $\text{SrO}$  to  $\text{Al}_2\text{O}_3$ . Among all aluminates only  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  and  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  show persistent luminescence.

The aim is to understand why aluminates are the most suitable host lattices for persistent luminescence and why two of them show stronger afterglow.

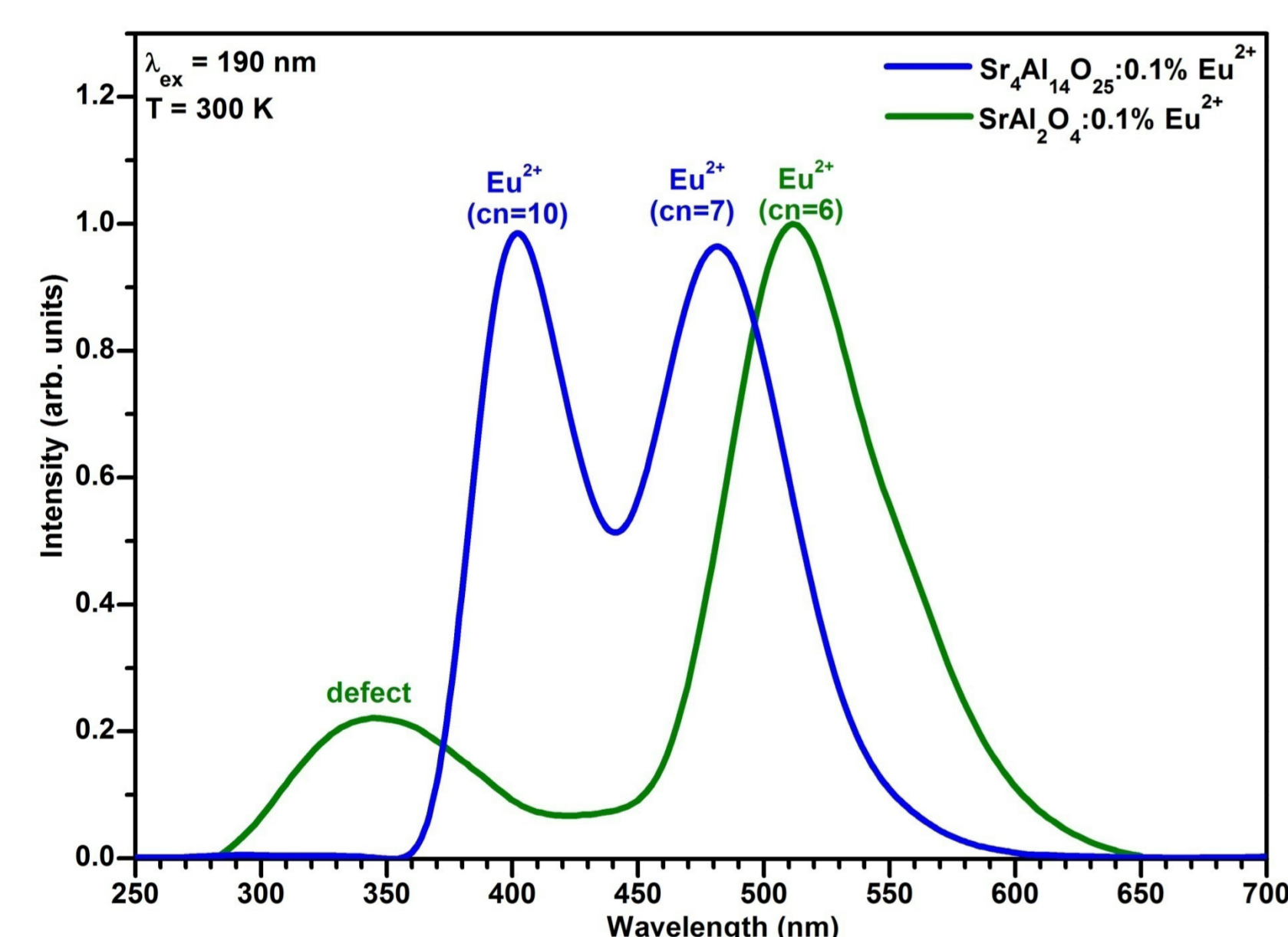
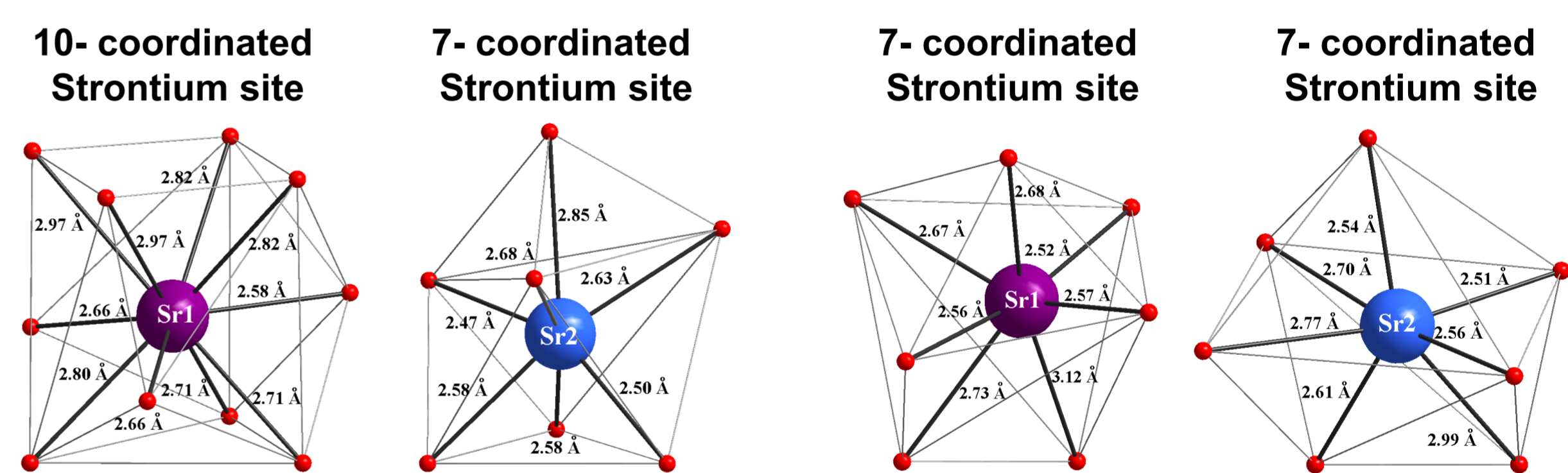
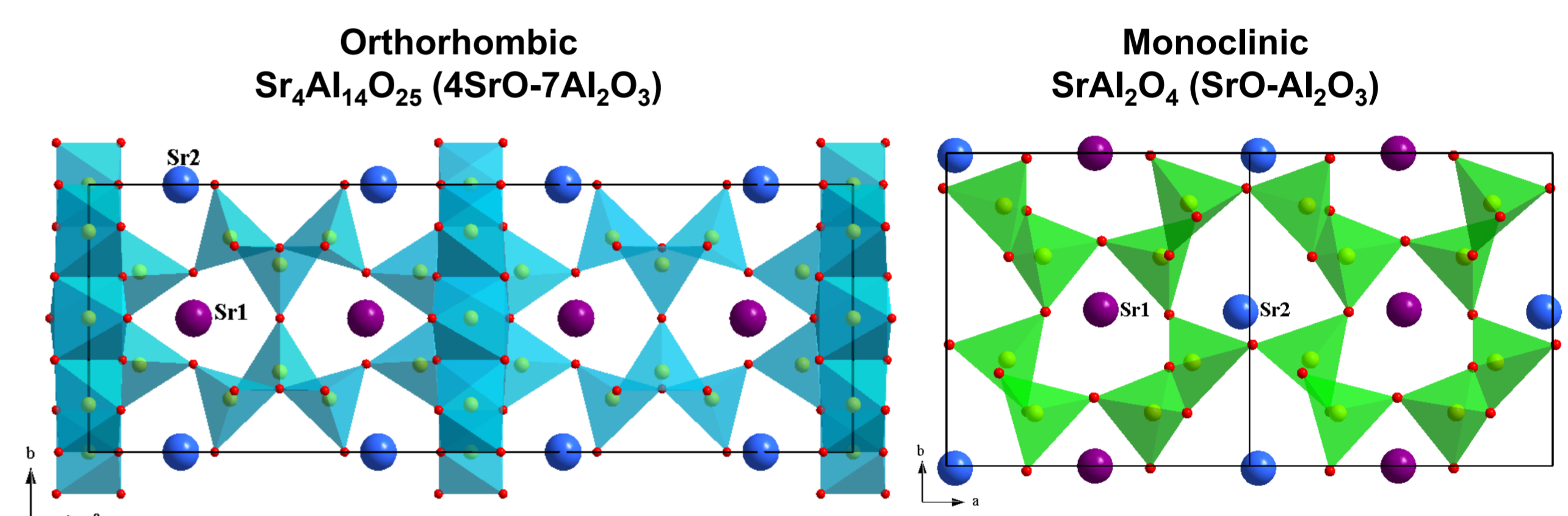
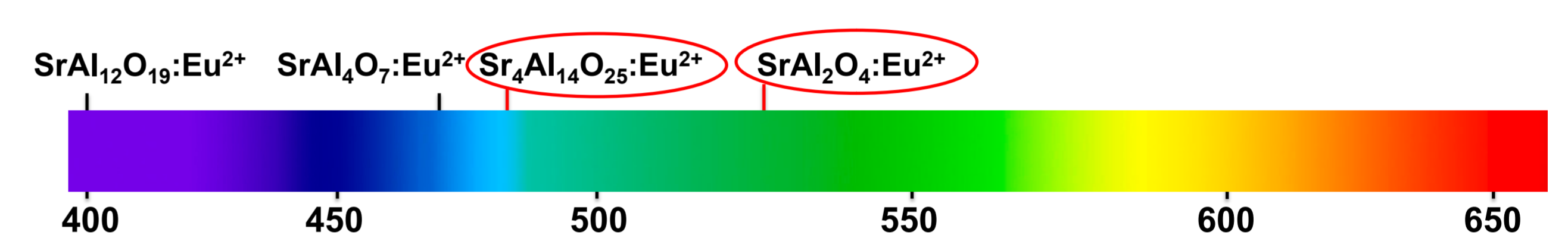
## Results



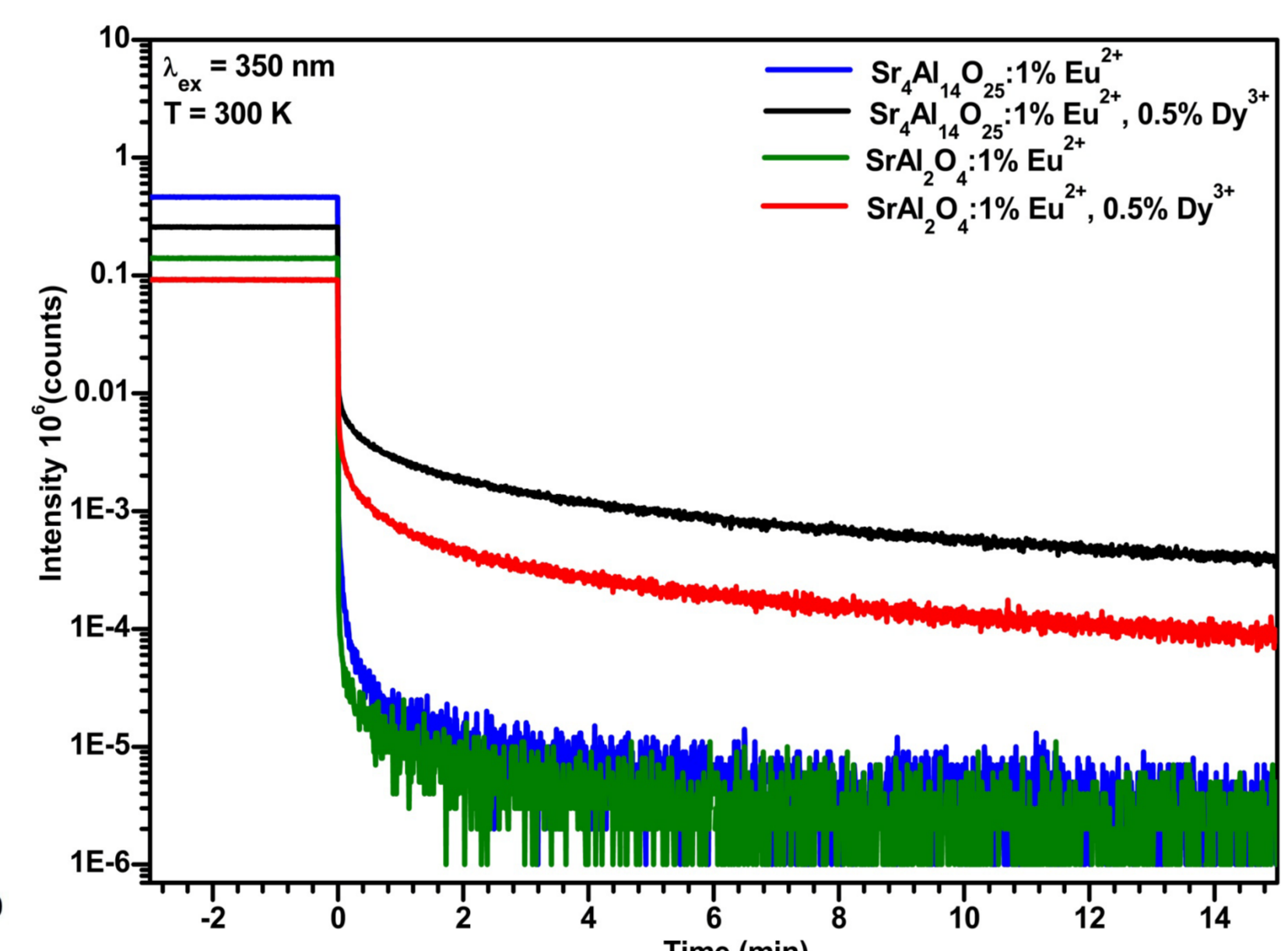
Emission and excitation spectra of  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$



Emission and excitation spectra of  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$

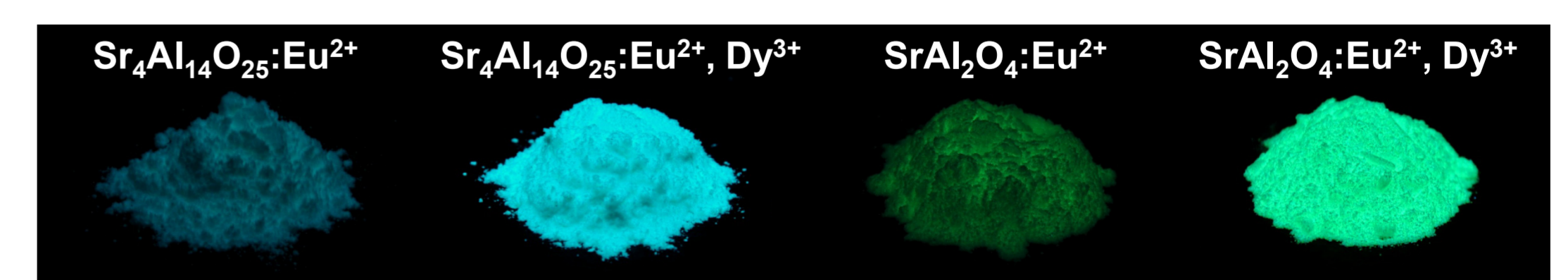
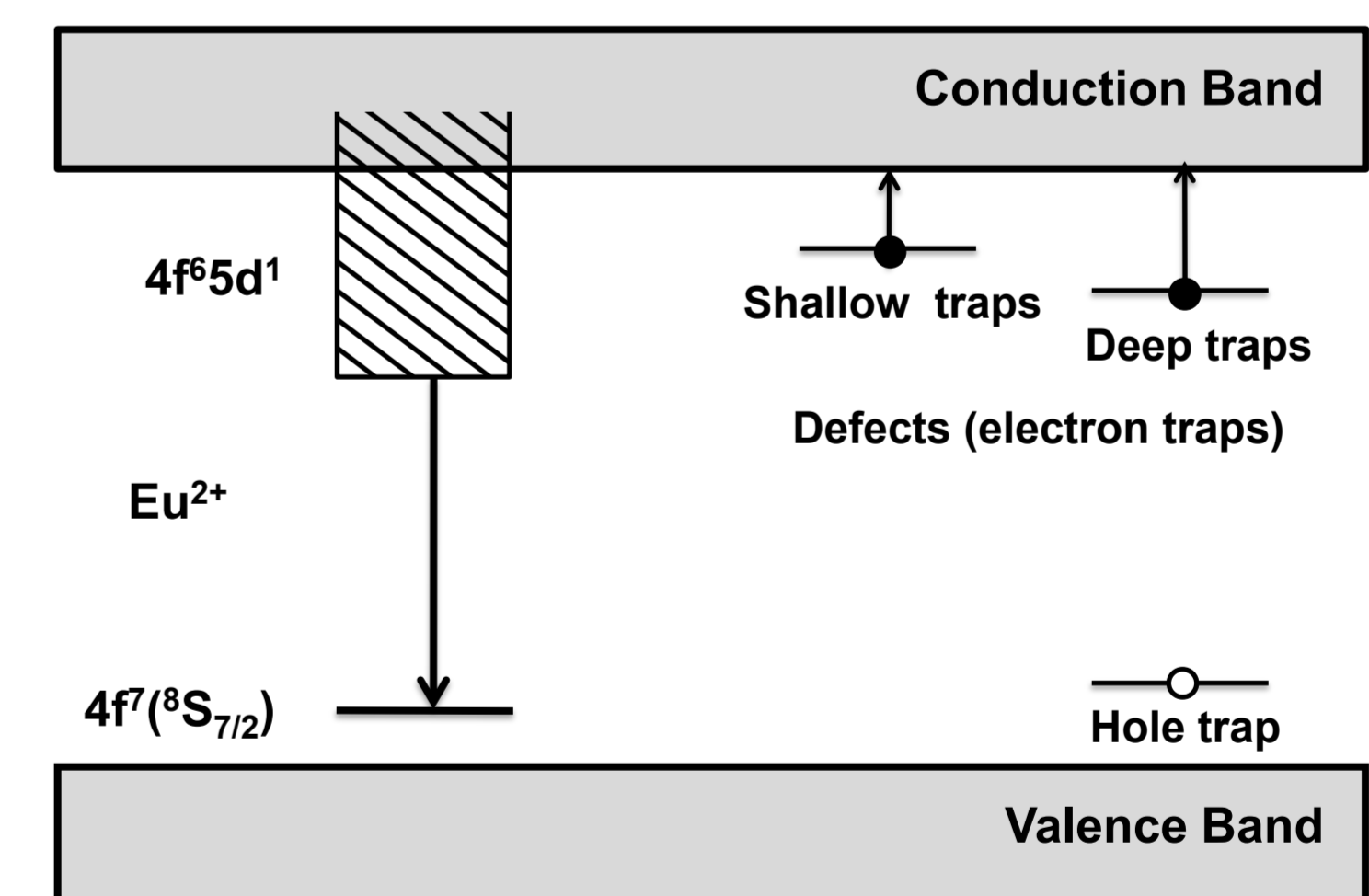


Emission spectra of  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  and  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  upon 190 nm excitation

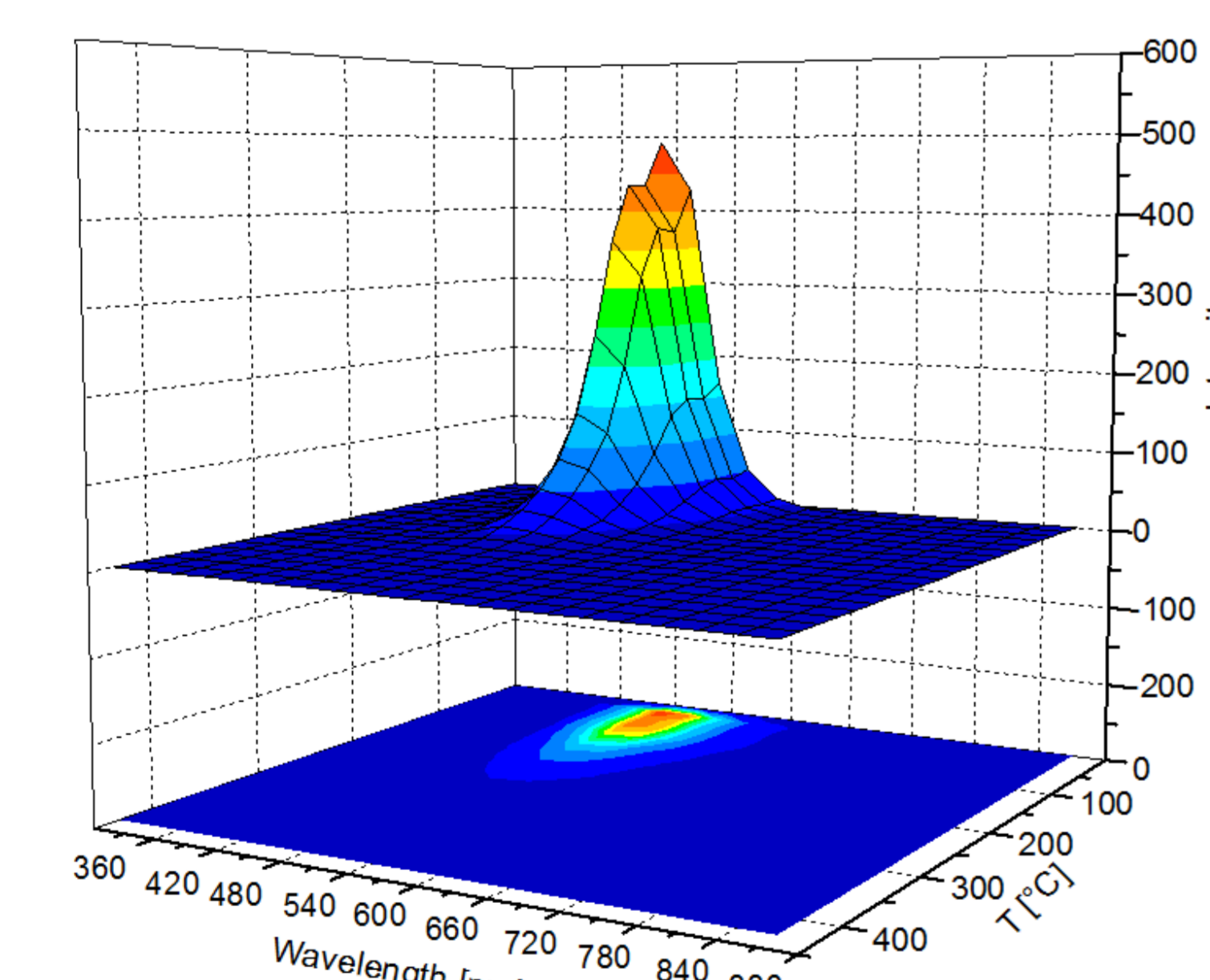


Decay curves of  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  and  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  after 3 min excitation

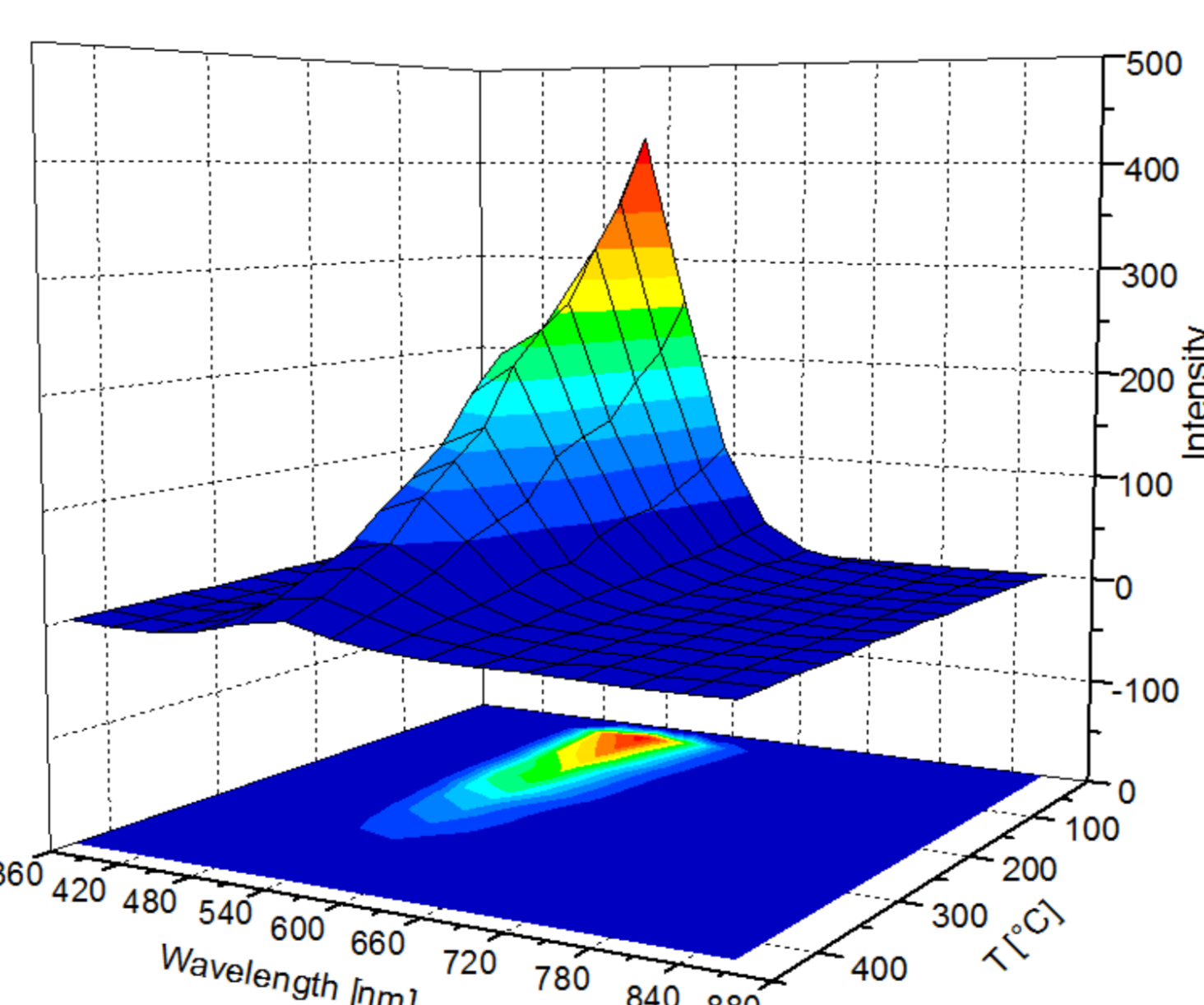
## Proposed Mechanism of Persistent Luminescence



Photographs of afterglow phosphors 1s after removal of excitation source



Thermoluminescence spectra of  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}, \text{Dy}^{3+}$



Thermoluminescence spectra of  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}, \text{Dy}^{3+}$

## Conclusions

In this work it is demonstrated, that long persistent luminescence in  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  and  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  phosphors can be amplified by co-doping with  $\text{Dy}^{3+}$  ions, which form additional electron traps. These two phosphors show afterglow even without co-doping. This phenomenon can be explained by the presence of defects in the host lattice. In case of  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  Self-Trapped Exciton (STE) emission was observed at 420 nm at low temperature. With increasing temperature thermally induced exciton diffusion occurs, resulting in energy transfer from the STE state to 5d levels of 10-coordinated  $\text{Eu}^{2+}$  which shows spectral overlap in this energy range. In case of  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  at a low doping level and excitation via the band edge defect luminescence was observed at 350 nm. Both,  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$  and  $\text{SrAl}_2\text{O}_4:\text{Eu}^{2+}$  phosphors have two strontium sites which increase the probability of the spectral overlap between the excited  $\text{Eu}^{2+}$  4f5d states and the trap states.