Luminescence properties of CsI:Eu single crystals: lattice structure and energy transfer

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Motivation

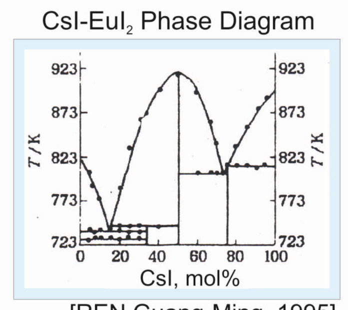
Search of new scintillator compounds directed to new host and/or modification of existed detectors with the efficient activator adding.

The well known CsI crystal doped by Europium is the potential candidate for new radiation detector.

Introduction

CsI-EuI$_2$ is non-isomorphic system. Previously it was shown that CsI:Eu contain different type of centers. The optical properties of such centers are different. The energy transfer mechanism in CsI:Eu crystals was not studied up to days.

CsI-EuI$_2$ Phase Diagram



[REN Guang-Ming, 1995]

Goldschmidt's rule

$$K = 1 - \frac{R_{Eu^{2+}}}{R_{Cs^+}} \qquad R_{Eu^{2+}} = 1.25\ \mathring{A} \qquad R_{Cs^+} = 1.74\ \mathring{A}$$

K = 28% > 15%

The goal is the study of luminescence properties and energy transfer in CsI:Eu crystals

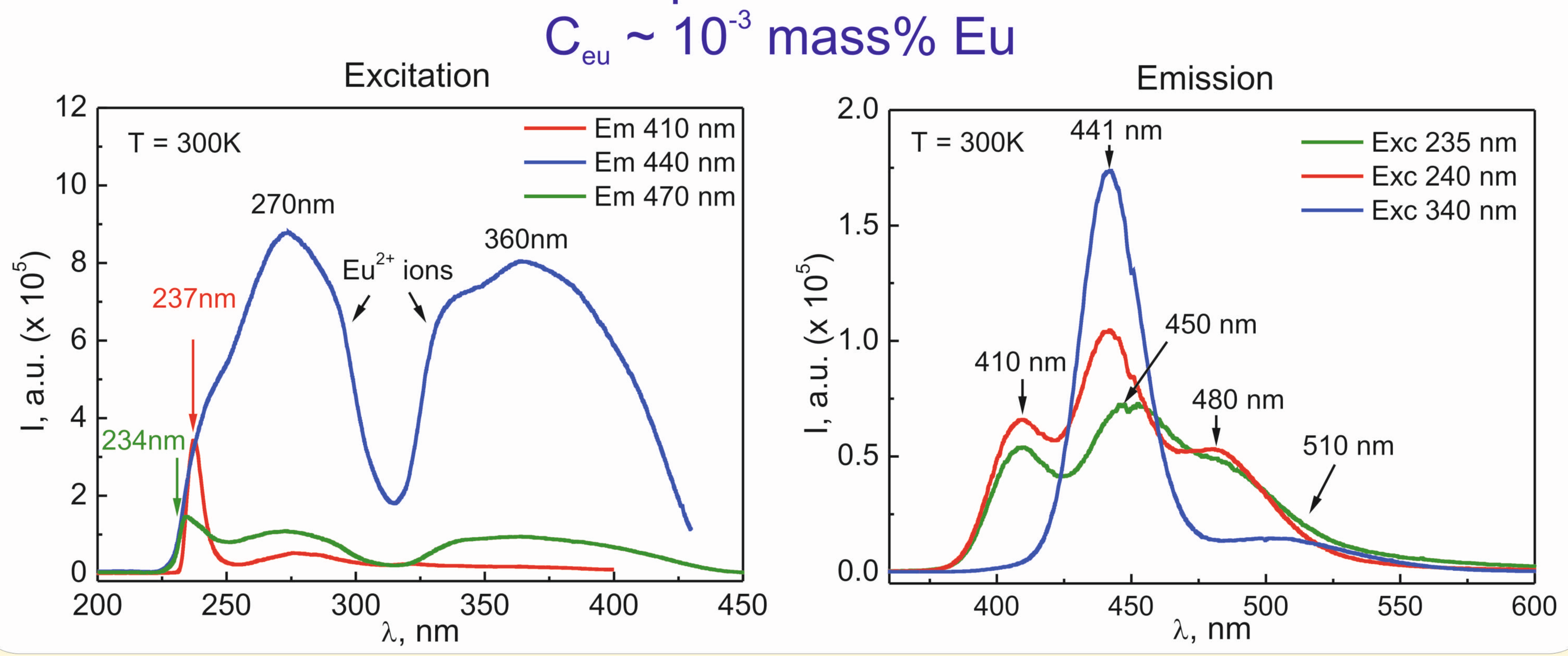
Material and methods

CsI:Eu crystals were grown by Czochralski method. Europium content was varied from 10^{-3} to 10^{-1} m.% Eu^{2+} in samples.

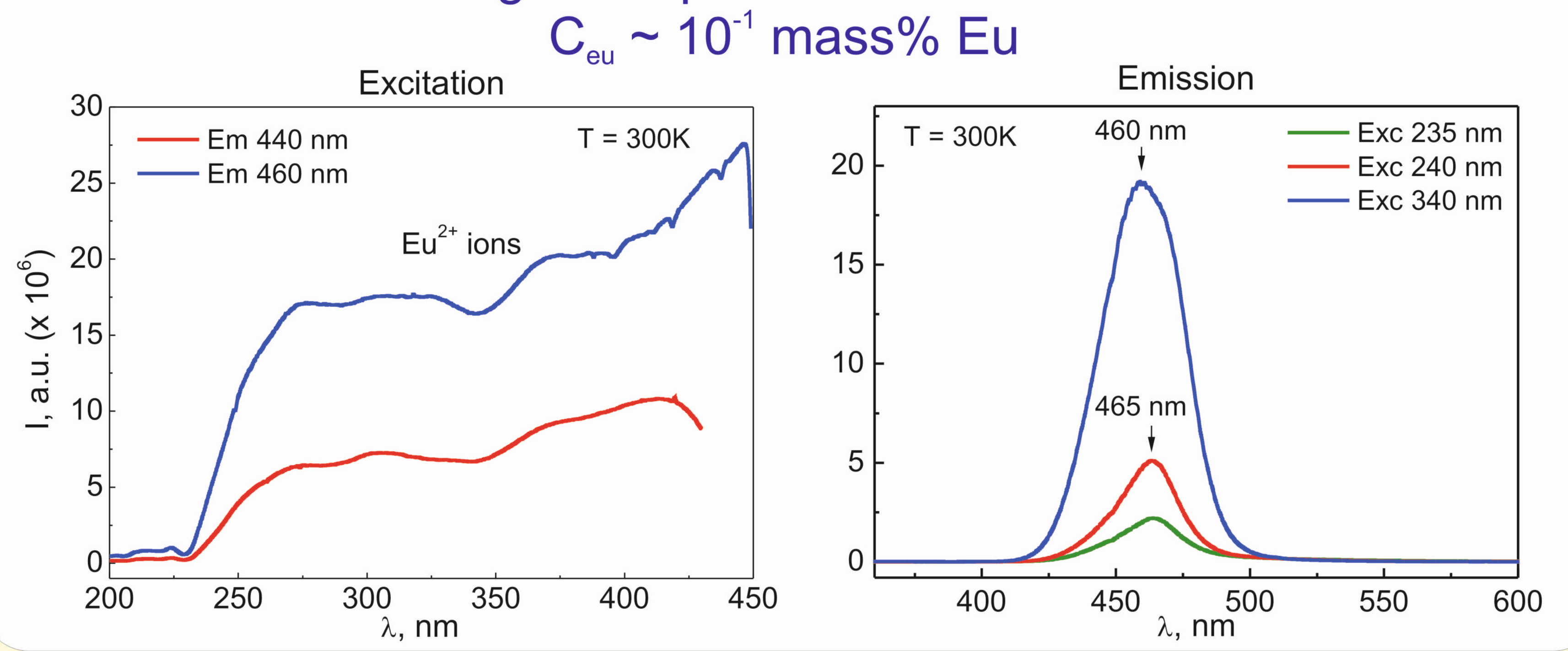
The absorption spectra were measured by means of SPECORD 40 spectrophotometer. Spectral and kinetic characteristics of photoemission were studied using FLS920 combined steady state and fluorescence lifetime spectrometer. Excitation and emission spectra were carried out in the HASYLAB at DESY (Hamburg, Germany) using synchrotron radiation stations SUPERLUMI. X-ray luminescence spectra were measurement in helium cryostat with X-ray tube (Tungsten anod, V = 30 kV, A = 30 mA).

Results

Low Europium concentration $C_{eu} \sim 10^{-3}$ mass% Eu

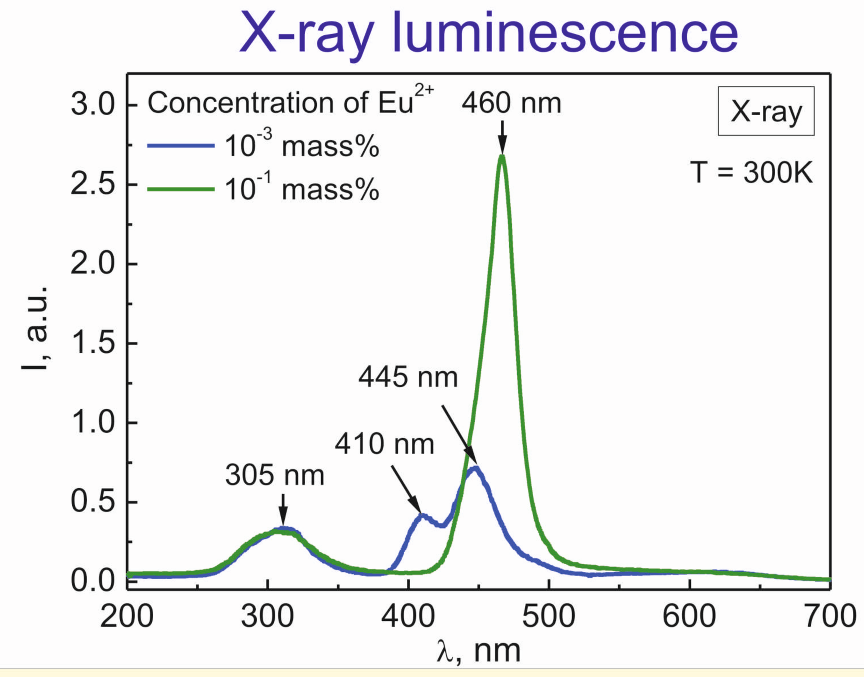


High Europium concentration $C_{eu} \sim 10^{-1}$ mass% Eu



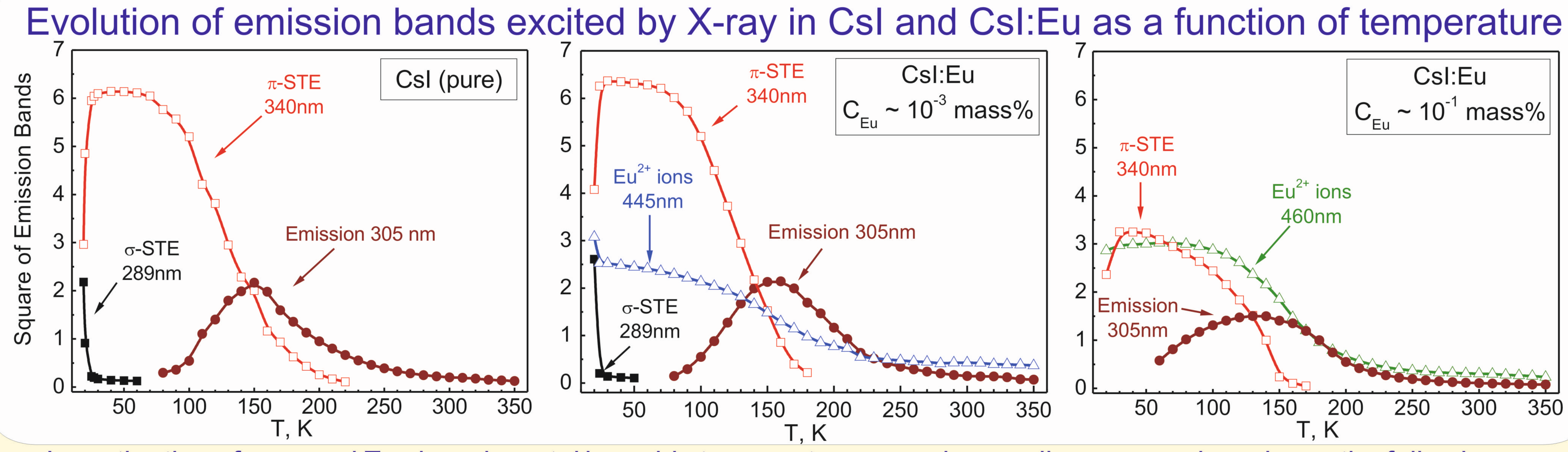
Several emission bands connected with different types of centers are found in CsI:Eu crystals excited in range of typical absorption bands at RT.
Intensity and spectra of luminescence depend on activator' concentration. The strong overlapping of absorption and emission spectra for high concentrated crystals are present, which leads to self-absorption.

X-ray luminescence



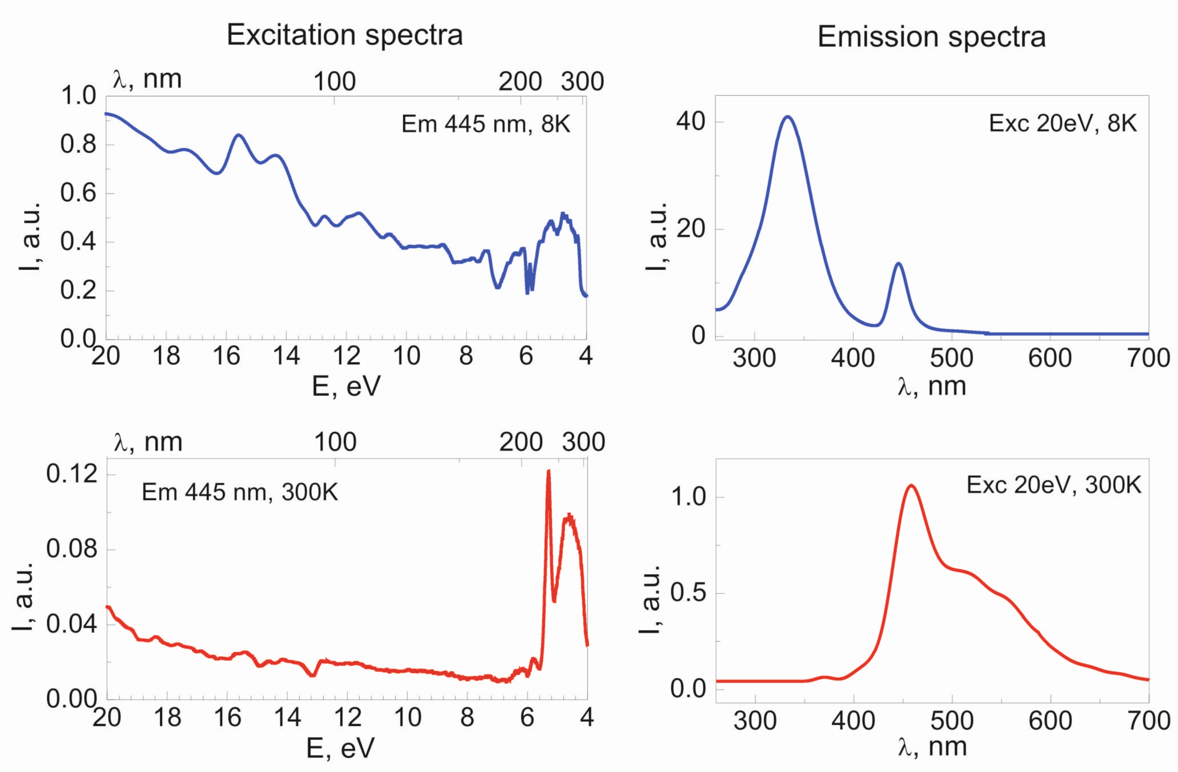
Excitation of CsI:Eu crystals by X-ray at RT leads to appearance of intrinsic band (305nm) and addition peaks at 410 and 445 nm in luminescence spectra of slightly doped crystal, whereas intense 460 nm band is found in highly doped sample.

Evolution of emission bands excited by X-ray in CsI and CsI:Eu as a function of temperature



Investigation of pure and Eu-doped crystal in a wide temperature range in a cooling process has shown the following:
1. Singlet and triplet STE-emission bands at 290 and 340 nm, accordingly, as well as intrinsic band at 305 nm, are revealed at low temperatures in pure CsI crystal.
2. In slightly doped sample the Eu^{2+} emission band 445 nm overlaps with bands at 340 and 305 nm. With the increasing of Eu-content the intensities of all mentioned bands are suppressed due to high overlapping with Eu^{2+} ion absorption bands.
Obtained data demonstrate the excitonic mechanism of energy transfer from based matrix to activator in CsI:Eu crystals.

CsI:Eu ($C_{Eu} \sim 10^{-3}$ mass%)



Spectral studies performed upon the synchrotron excitation within 4-20 eV range at 8-350K show that favorable conditions have been revealed for the transformation of VUV excitation quanta into Eu^{2+} emission at low temperatures (<150 K). In this region the main intense band is π-STE luminescence peak at 340 nm. An addition one at 456 nm corresponds to Eu^{2+} emission.

At higher temperatures (>150K), when the triplet exciton emission is quenched, intensity of Eu^{2+} luminescence became lower. So, the energy transfer in CsI:Eu corresponds to excitonic processes.

Acknowledgments

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Conclusions

The results obtained show that the main role in energy transfer between CsI lattice and Eu^{2+} ions plays the excitonic mechanism. This mechanism demonstrates high efficiency at low temperature and suppression at T> 150K. Presence of typical Eu^{2+} band in X-luminescence spectra at RT may be connected with the Eu- excitation bands overlapping with the intrinsic UV emission (305nm) of CsI lattice.