

## Optimization of architecture and chemical composition of upconverting nanocrystals co-doped with lanthanide ions in respect of energy transfer to organic dyes.

### Project goal

The main goal of the project is to synthesize advanced nanocrystals containing lanthanide ions, attached them with organic dyes and to investigate Förster Resonance Energy Transfer (FRET) occurring between these molecules. The specific goals of the project are to check which amount of dopant ions will provide the most efficient FRET, how different distances between energy donor (D) and acceptor (A) molecules as well as kind and amount of the organic dye influence FRET efficiently.

### Description of research

The development of nanotechnology carries a number of innovative applications that allow for a better understanding of processes and phenomena occurring in nature. One of the processes that make a significant contribution to this is FRET. Thanks to this phenomenon, it has become possible to study DNA hybridization, antibody-antigen binding reactions, or protein conformational changes. To explain the FRET mechanism, it is useful to refer to the frequency of vibration of a tuning fork. If the two tuning forks are close enough to each other and their frequencies are the same, striking one of them will cause the other to vibrate. Otherwise, when the distances are too large or the frequencies of the tuning forks are found to be different, then the energy transfer will not take place. Analogous to the case of tuning forks, the FRET energy transfer between two molecules, i.e., from D to A on the principle of radiation-free energy transfer is possible, when the energy of excited D is equal to the energy, which can be absorbed by A (Fig.1). Moreover, these two molecules have to be close enough to each other. The distance between D and A should not exceed 10 nm. Nanocrystals doped with  $\text{Ln}^{3+}$  lanthanide ions showing energy up-conversion (UC) turned out to be suitable as D in FRET due to narrow absorption and emission bands, high photostability, and long luminescence decay times, what make the measurements of the materials comfortable. Moreover, the possibility of  $\text{Ln}^{3+}$  excitation in the NIR range is advantageous from the point of view of biological applications, because it fits into the so-called biological window of tissues, that is, the area showing a lower absorption coefficient and at the same time a greater depth of light penetration. The present project aims to study  $\text{NaYF}_4$  nanocrystals containing  $\text{Yb}^{3+}$  and  $\text{Tm}^{3+}$  ions in respect of FRET. The particles will be synthesized in a core and core-shell architecture in order to place the optically active lanthanide ions in different distance from A molecules. The particles will be synthesized by thermal decomposition method, which requires high 300°C temperature. A purity of the synthesized nanoparticles will be confirmed by X-ray powder diffraction (XRD) measurements. Thereafter, shape and size of the nanocrystals will be identified using advanced microscopy. Appropriate dyes, which will be able to absorb energy from D molecules will be attached in different amounts to the nanocrystals as an A. The luminescence intensity as well as luminescence lifetimes of D decrease in the presence of A. These two factors enable an estimate of FRET efficiency. Therefore, besides basic spectroscopic investigations, such as absorption spectra measurements aiming to confirm, that synthesized materials absorb the light at expected wavelengths, emission spectra as well as luminescence lifetimes of excited energy states of D molecules will be measured both, in presence and absence of an A molecules. The measurements will allow to calculate FRET efficiency.

### Reasons for attempting particular research topic

Until now, materials co-doped with Yb and Er ions have been systematically studied under FRET. However, also other ions, such as  $\text{Yb}^{3+}$  and  $\text{Tm}^{3+}$ ,  $\text{Yb}^{3+}$  and  $\text{Ho}^{3+}$  or  $\text{Yb}^{3+}$  and  $\text{Pr}^{3+}$  pairs, show efficient energy UC and can be used as donors in FRET, while there are few or no literature reports describing studies of such materials, especially systematic studies, in terms of the FRET phenomenon. Therefore the investigations conducted during the present project will contribute of new knowledge to the described scientific discipline, what will ensure better understanding of the phenomenon and will redound to broaden applications of FRET.

### Substantial results expected

FRET efficiency depends on ions dopant concentration. Nanocrystal architecture influence UC as well as FRET efficiency. Improved of UC luminescence efficiency does not mean improved of FRET performance.

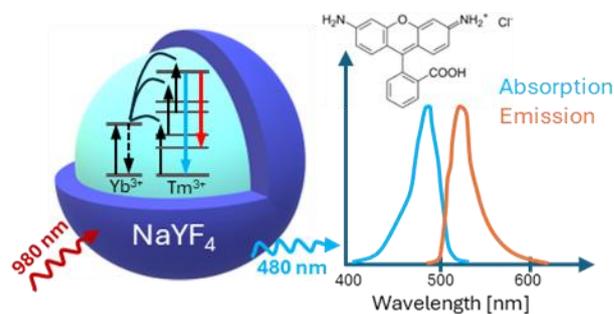


Figure.1: Schematic illustration of FRET from  $\text{Yb}^{3+}$ ,  $\text{Tm}^{3+}$  co-doped nanocrystal to organic dye.