LuAG:Pr^{3+}-porphyrin based nanohybrid system for singlet oxygen production: toward the next generation of PDTX drugs

Kseniya Popovich

Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Břehová 7, 115 19 Prague, Czech Republic

PDTX for cancer treatment

- **Conventional methods:**
  - **- surgery**
  - **- radiation therapy**
  - **- chemotherapy**

  systemic side effects

  high radiation doses

- **Photodynamic therapy (PDT):**

  non-invasive method

  no systemic side effects

  temporary photosensitization

  low penetration

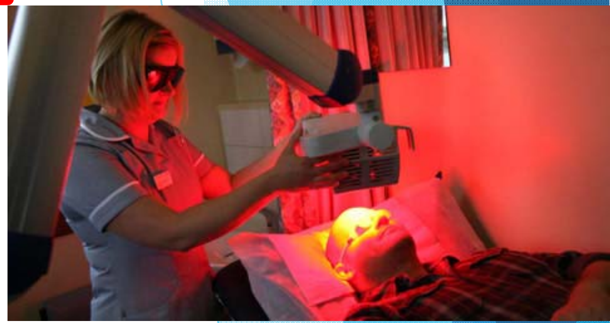


Fig. 1: Photodynamic therapy.

X-Ray induced photodynamic therapy (PDTX)

- ✓ lower radiation doses
- ✓ *ex vivo* activation enabled (no X-ray exposure to the patient)
- ✓ higher efficiency

How does it work?

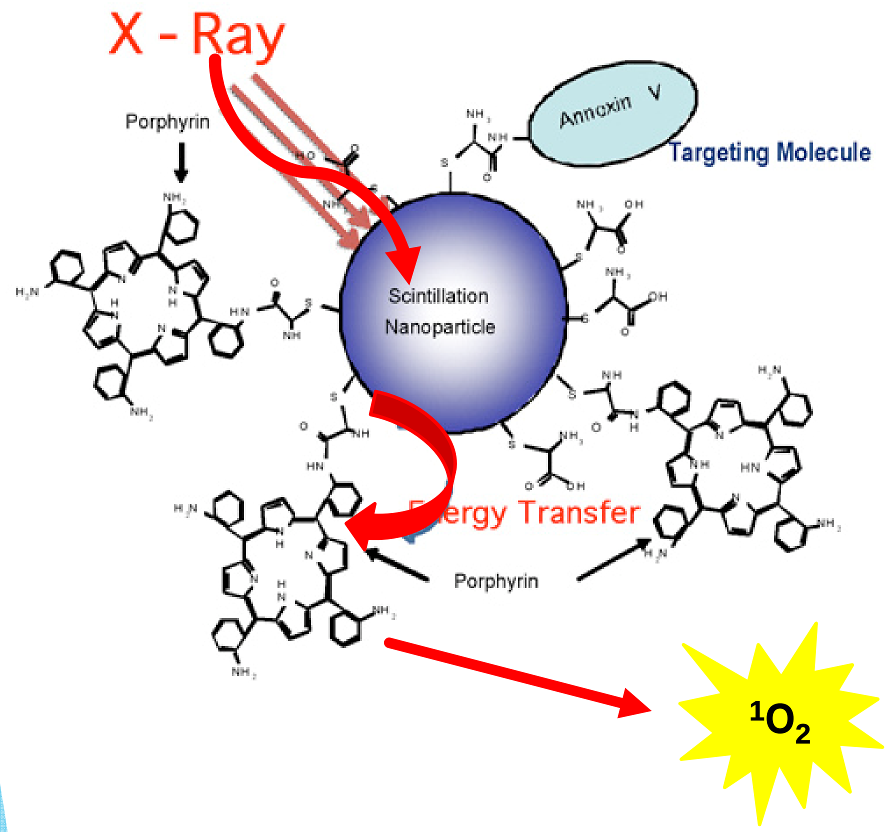


Fig. 2: Principle of the PDTX.

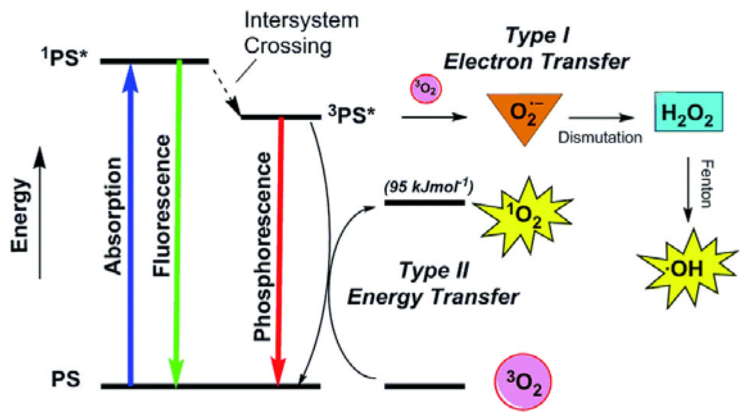
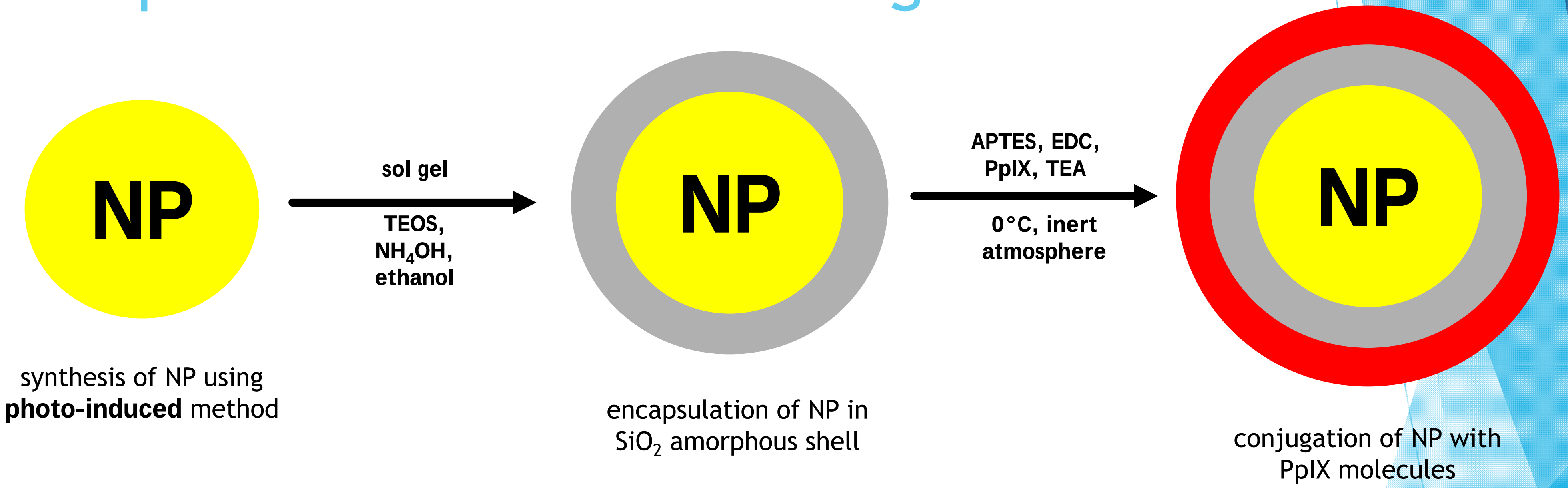


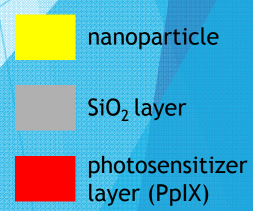
Fig. 3: Jablonski diagram illustrating a photosensitized production of the reactive oxygen species in the PDTX.

Preparation of the PDTX drug



Why LuAG:Pr^{3+}?

- ✓ chemically stable and non-toxic;
- ✓ cubic structure, high density and Z_{eff};
- ✓ suitable average size to promote EPR effect;
- ✓ radiation stability and high luminescence intensity;
- ✓ Pr^{3+} ensures spectrum overlapping with the absorption band of PpIX.



Material Characterization

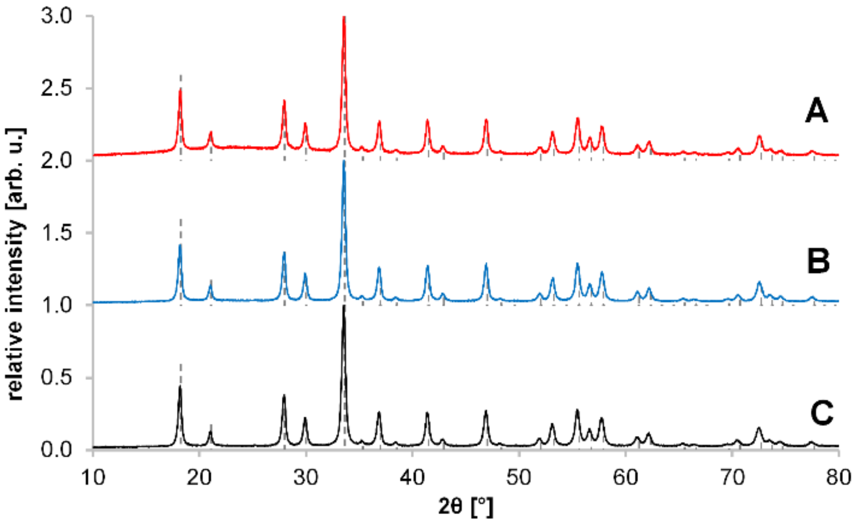


Fig. 4: Diffractograms of LuAG:Pr^{3+}@SiO_2-PpIX (A), LuAG:Pr^{3+}@SiO_2 (B) and LuAG:Pr^{3+} (C) compared with standard data of LuAG from ICDD PDF-2 database (card No. 01-073-1368, dashed lines). Data are offset for clarity.

Specific surface area:

LuAG:Pr^{3+}	LuAG:Pr^{3+}@SiO_2
(29.6±0.4) m^2/g	(32.0±0.2) m^2/g

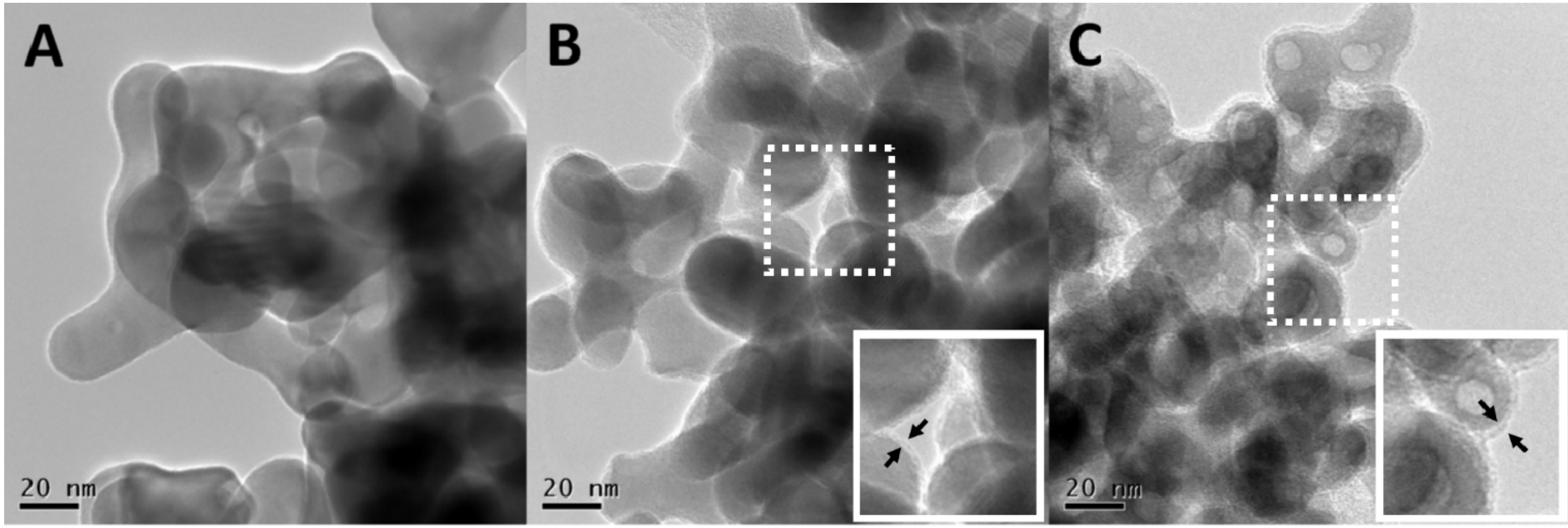


Fig. 5: TEM images of the as-prepared LuAG:Pr^{3+} (A), LuAG:Pr^{3+}@SiO_2 (B) and LuAG:Pr^{3+}@SiO_2-PpIX (C).

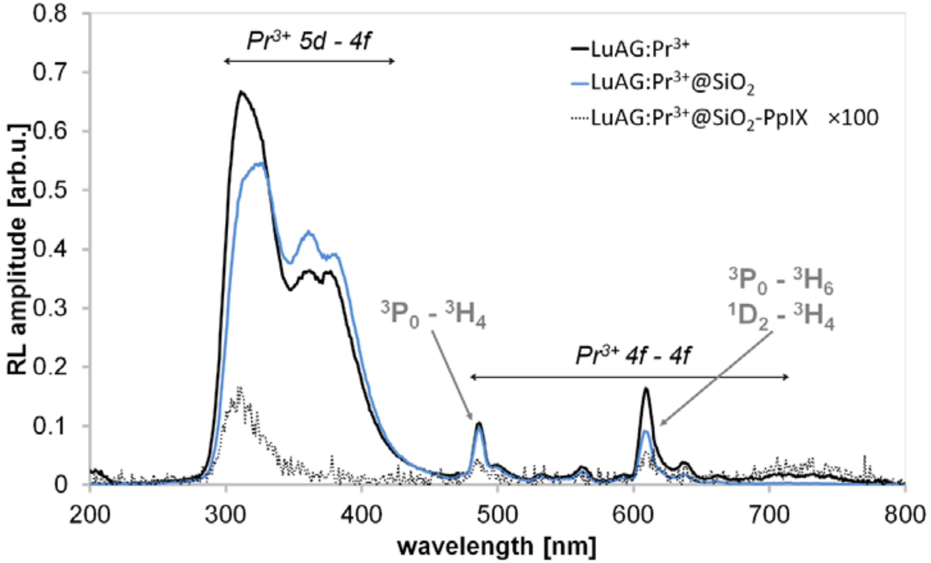


Fig. 6: X-ray excited room temperature (RT) RL spectra of LuAG:Pr^{3+}, LuAG:Pr^{3+}@SiO_2 and LuAG:Pr^{3+}@SiO_2-PpIX samples.

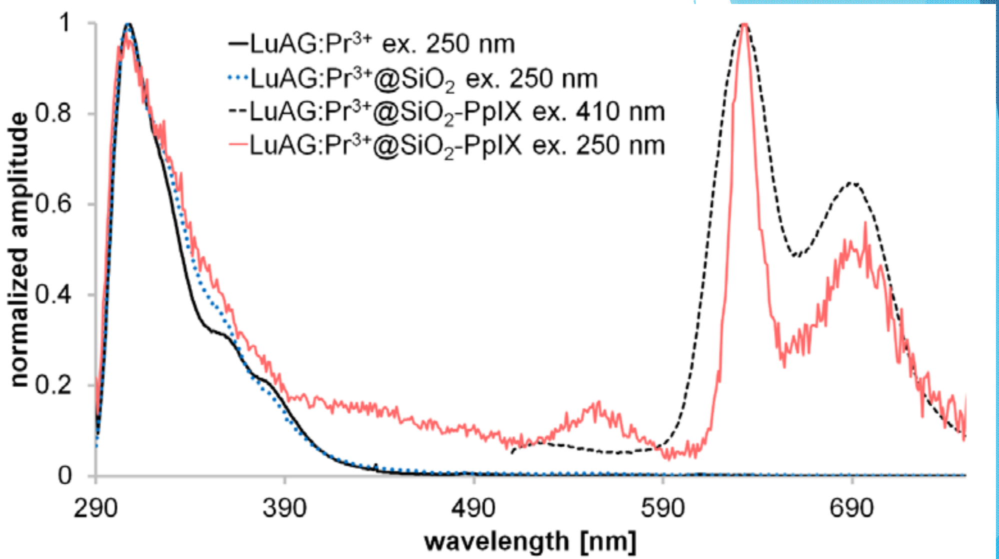


Fig. 7: Normalized (to a maximum) RT PL emission spectra under excitation $\lambda_{ex.}$ = 250 nm (LuAG:Pr^{3+}, LuAG:Pr^{3+}@SiO_2 and LuAG:Pr^{3+}@SiO_2-PpIX samples) and $\lambda_{ex.}$ = 410 nm (LuAG:Pr^{3+}@SiO_2-PpIX sample).

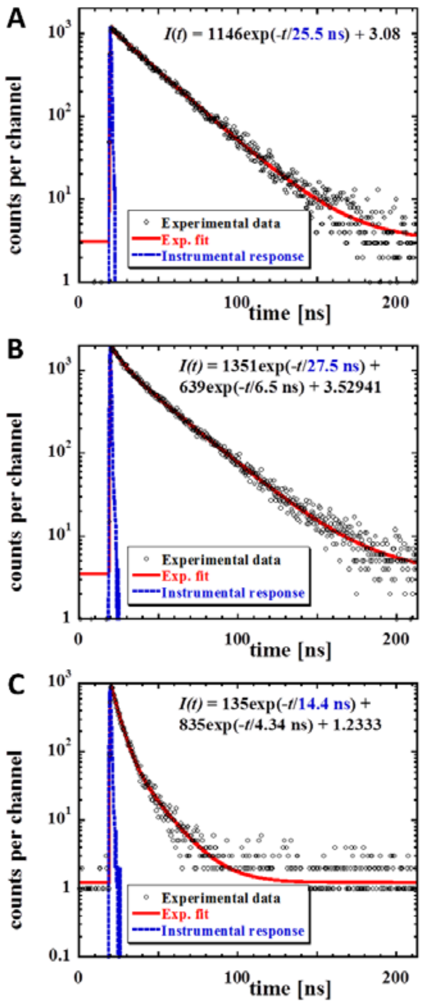


Fig. 8: RT PL decays of the 320 nm emission excited at 281 nm (4f – 5d absorption band of Pr^{3+}). In (A) LuAG:Pr^{3+}, in (B) LuAG:Pr^{3+}@SiO_2 and in (C) LuAG:Pr^{3+}@SiO_2-PpIX. Experimental data are approximated by a function I(t) displayed in the figures. Red line is a convolution of I(t) and instrumental response (blue line in the figures).

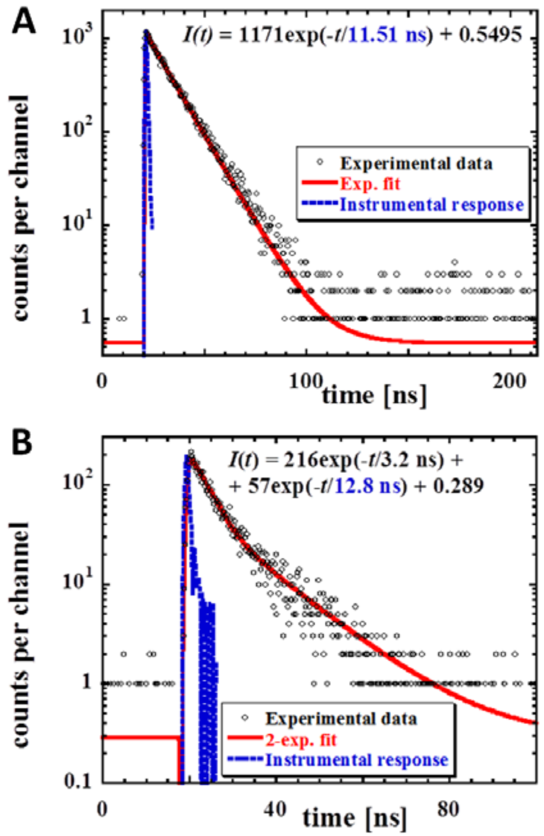


Fig. 9: RT PL decays of the 630 nm emission in LuAG:Pr^{3+}@SiO_2-PpIX. In (A) excitation at 281 nm, in (B) excitation at 389 nm. Experimental data are approximated by a function I(t) in the figure. Red line is a convolution of I(t) and instrumental response (blue line in the figure).

Singlet oxygen detection

- APF (aminophenyl fluorescein) commercial probe;
- NaN_3 as a $^1O_2$-quencher.

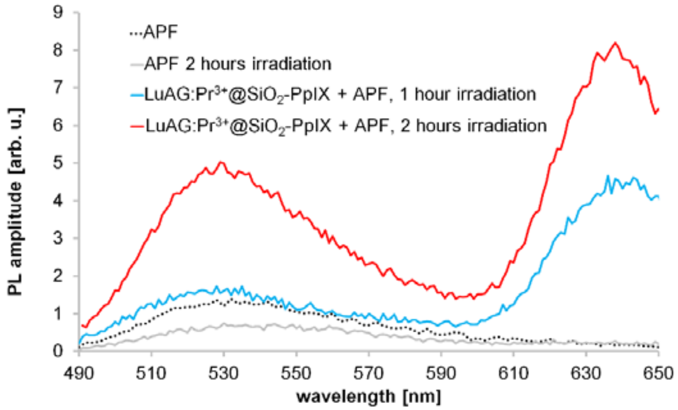


Fig. 10: RT PL emission spectra (λ_{ex} = 450 nm) of pure APF (before and after X-ray irradiation) and LuAG:Pr^{3+}@SiO_2-PpIX + APF after X-ray irradiation.

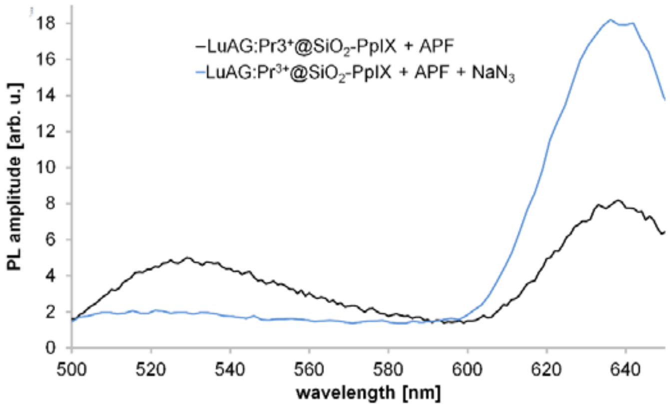


Fig. 11: RT PL emission spectra (λ_{ex} = 450 nm) of LuAG:Pr^{3+}@SiO_2-PpIX + APF and LuAG:Pr^{3+}@SiO_2-PpIX + APF + NaN_3 samples.

Conclusions

- LuAG:Pr^{3+}@SiO_2-PpIX nanocomposite material was prepared;
- RT RL and PL spectra suggest the energy transfer from Pr^{3+} ions to PpIX outer layer;
- The decay time measurements indicate the non-radiative energy transfer from the LuAG:Pr^{3+} core to photosensitizer molecules;
- Singlet oxygen production using the prepared nanocomposite was demonstrated using APF chemical probe.

Popovich, K., Tomanová, K., Čuba, V., Procházková, L., Pelikánová, I.T., Jakubec, I., Mihóková, E., Nikl, M.: *„LuAG:Pr^{3+}-porphyrin based nanohybrid system for singlet oxygen production: toward the next generation of PDTX drugs"*. Journal of Photochemistry & Photobiology, B: Biology 179 (2018) 149 – 155.