Ph.D offer

Quantification and imaging of energy transfers in organic solids - upconverting nanoparticles hybrid systems

UNIVERSITY: University of Lille, Faculty of Sciences and Technologies

Laboratory: LASIRE (UMR 8516, DyNaChem team)

Supervisors: Aude BOUCHET, Assistant professor, aude.bouchet@univ-lille.fr
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Related research project (international/national/regional): IRP CNRS NANOSYNERGETICS / KAKENHI – Promotion of Joint International Research (MEXT, Japan)

Expected/obtained funding: Doctoral school SMRE

Keywords – Energy transfer; π-conjugated organic dyes; up-converting nanoparticles; exciton propagation; super-resolution microscopy; localization methods

Background – Energy transfer is essential for sun light harvesting in natural and synthetic materials such as organisms using photosynthesis and solar cells. Assemblies of π-conjugated compounds such as photosynthetic antenna and conjugated polymers exhibit very fast (picosecond) and long-range energy transfer (exciton diffusion, few tens of nanometers). The averaged energy transfer rate is usually determined through time-resolved spectroscopic measurements for macroscopic samples (solution, film), providing the corresponding averaged energy transfer length but do not allow to image the diffusion of single excitons.[1] The direct visualization of energy transfer dynamics at the nanometric level needs to use super-resolved techniques that can overcome the intrinsic optical limit diffraction, i.e about 200 nm for visible light. Imaging of these nanometric properties would be a major help for designing efficient organic systems that transports excitation energy to a precise target location at ultra-high speed.

Goal – The determination of energy transfer length requires a nanoscopic localization of both excitation and emissive sites. Among super-resolved imaging techniques, localization methods are the best ones as they can easily determine the position of a single emitter within few nanometers,[2] the resolution being dependent on the amount of collected photons and signal-to-noise ratio. To distinguish excitation and emission localizations, the strategy will consist in using dual color experiments to precisely localize the generated exciton and its release after diffusion. To this aim, up-converting nanoparticles (UCNP) will be used as nanometric excitation sources which will trigger the process. UCNP are lanthanide-doped nanoparticles which present the unique feature of being able to emit light up to the blue region of the visible spectrum while being excited in the near infrared (NIR).[3] The energy provided by the excited UCNP is transferred to π-conjugated fluorescent compounds which release visible light after propagation of an exciton along their backbone. In this project, the PhD work will consist in understanding, quantifying and optimizing the energy transfers from UCNP to different 2D-fluorescent organic dyes film, especially with the goal of being able to localize UCNP and dyes emission at the nanometric level.

Job description – To this aim, the Ph.D student will prepare films containing π-conjugated organic dyes and UCNP and will perform ultrafast time-resolved imaging of the energy transfers by using the hyperspectral confocal microscope available in LASIRE. The setup is equipped with UV-to-NIR excitation sources and detection via a ps-resolution time-gated intensified CCD-camera. Super-resolved imaging of energy transfer will be performed in Lille and in Japan to localize the emissive site positions with spatial resolutions down to 10 nm. The hyperspectral super-resolved data will be analyzed in collaboration with chemometrics specialists of the DyNaChem team.[4]

Environment – This project is grounded on a recent funded international project between LASIRE (DyNaChem team) from Univ. Lille and Professor Syoji Ito team from Osaka University (KAKENHI – Promotion of Joint International Research, MEXT "Super-resolved nanometer-scale imaging of energy transfer in organic solids using upconversion nanoparticles as nanometric excitation sources"). It will be run within the frame of the CNRS French-Japanese International Research Project Nanosynergetics2 (http://www.nanosynergetics.cnrs.fr/). The Ph.D. thesis will be supervised by Dr. Aude Bouchet and Dr. Michel Sliwa (LASIRE, DyNaChem team, http://lasir.cnrs.fr/dynachem/), and in close collaboration with the Japanese partner (Prof. Syoji Ito). The PhD student will spend several months in Osaka.

Candidate profile - Candidates should have a Master in physics or chemistry. He / She should be highly motivated to work in an international and interdisciplinary project. Skills in optical spectroscopy, microscopy or photochemistry would be particularly appreciated.

References - [1] G. G. Rozenman, K. Akulov, A. Golombek, T. Schwartz, *ACS Photonics* **2018**, 5, 105-110

[2] L. von Diezmann, Y. Shechtman, W. E. Moerner, Three-Dimensional Localization of Single Molecules for Super-Resolution Imaging and Single-Particle Tracking, *Chem. Rev.* **2017**, 117, 7244-7275

[3] B. Amouroux, C. Roux, J.-D. Marty, M. Pasturel, A. Bouchet, M. Sliwa, O. Leroux, F. Gauffre, C. Coudret, Importance of the mixing and high-temperature heating steps in the controlled thermal coprecipitation synthesis of sub-5-nm $Na(Gd\text{-}Yb)F_4$:Tm, *Inorg. Chem.* **2019**, 58, 5082

[4] D. Cevoli, S. Hugelier, R. Van den Eynde, O. Devos, P. Dedecker, C. Ruckebusch, Multilinear Slicing for curve resolution of fluorescence imaging with sequential illumination, *Talanta* **2022**, 241, 123231

Planned recruitment date: October 1st, 2022

How to apply: Send a CV, motivation letter and transcripts (first and second year of Master) to aude.bouchet@univ-lille.fr and michel.sliwa@univ-lille.fr.