3-year funded PhD thesis

Ultrafast multiphotonic processes in plasmonic nanoparticles

- **Context.** The interaction of metal nanoparticles and ultrashort laser pulses results in a series of transient phenomena which can be exploited for biomedical means. We have recently demonstrated the ejection of electrons from isolated gold nanorods under infrared pulsed laser irradiation tuned to their longitudinal localized plasmon mode. This induces the generation of a nanoscale plasma and further reactive oxygen species (ROS) over a large spatial range[1]. The latter are known as sources of oxidizing stress for cells, which is the basic mechanism of photodynamic therapy against cancer[2,3]. In addition, the nanoparticles exhibit an ultrafast photo-luminescence covering the whole visible spectral domain. All these processes are of multiphotonic origin through the production of a hot electron gas within the nano-objects. However, several challenges are still to be tackled to understand the fundamental mechanisms and, later, optimize the biomedical application. The team leads a multidisciplinary project, grouping 5 partners, which has recently be awarded a funding by the "Plan Cancer" of INSERM (French Health and Medicine research agency) and by the Labex *NanoSaclay* of University Paris-Saclay which supports the 3-year PhD fellowship.

- **Objective.** The main goal of the PhD is to study through experiments and modelling the fundamental physical and physico-chemical multiphotonic processes induced in and around gold nanoparticles by ultrashort laser pulses, as well as the role played by the plasmon mode in these processes.

- **Work to achieve.** The PhD student will carry out optical microscopy approaches (ultrafast transient absorption spectroscopy experiments[4] to reveal the dynamics of electron ejection, fluorescence imaging to monitor the production of ROS[1]). The student will also participate in part of photoelectron emission microscopy experiments in CEA/SPEC and in the numerical simulation of the processes. For this, models will be developed to catch the physics of the series of phenomena involved[5] as well as their dependence on the plasmonic near field topography. Beyond, the seek for an efficient ROS generation from direct ionization of water molecules will be carried out, as this is still a very challenging issue in treatments of resistant hypoxic cancer tumors. A partnership with a biomedical laboratory in St-Louis hospital (Paris) will allow us to determine *in vivo* the efficiency of our irradiated nanoparticles and to optimize a protocol for further therapies.

- **Student's profile.** The student may be specialized in nanophysics, with a solid background in solid-state and optical physics. She/he likes multidisciplinary scientific challenges.

- **References**

1. T. Labouret *et al., Small* **11**, 4475 (2015).
2. L. Gao *et al.*, *ACS Nano* **8** (7), 7260–7271 (2014).
3. L. Minai *et al.*, *Nano Lett.* **16** (7), 4601–4607 (2016).
4. X. Wang *et al.*, *J. Phys. Chem. C* **119**, 7416 (2015) ; L. Di Mario *et al.*, *Phys. Rev. B* **97**, 115448 (2018).
5. T. Labouret and B. Palpant, *Phys. Rev. B* **94**, 245426 (2016).

Laboratory: Laboratoire de Photonique Quantique et Moléculaire (LPQM) (CentraleSupélec – ENS Paris-Saclay – Université Paris Saclay - CNRS) in Institut d'Alembert. Experiments will also be performed in PPSM (R. Pansu team).

Supervisor: Prof. Bruno Palpant (LPQM), *bruno.palpant@centralesupelec.fr*