Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: CEMES-CNRS
CNRS identification code: UPR8011
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Internship location: CEMES-CNRS, Toulouse, France

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Nano-optics with Femtosecond Electron Pulses in an Ultrafast Electron Microscope

Nanosized systems have optical properties that can differ significantly from their bulk counterpart due to the existence of optical resonances such as surface plasmons in metallic nanoparticles or Mie modes in high refractive index nanostructures. These excitations have extremely short lifetimes (fs-ns) and pattern the optical near-field on subwavelength scales. Their properties depend very sensitively on the size, shape and environment of the nano-object. Understanding these effects is essential both from a fundamental point of view and for applications in photodetection, sensing and photovoltaics.

Ultrafast Transmission Electron Microscopes (UTEM) combining sub-picosecond temporal resolution and nanometer spatial resolution have emerged as unique tools for investigations at ultimate spatio-temporal resolution [1,2]. In particular, Electron Energy Gain Spectroscopy experiments performed in a UTEM have been a game-changer in nano-optics as they allow mapping the optical near-field at the nanometer scale. EEGS experiments are pump-probe experiments. They involve two femtosecond pulses: a first laser pulse (pump) which excites the nano-object and a delayed electron pulse (probe) which is used to study the sample. The interaction of the electron with the optically excited sample results in absorption or emission of photons by the particle with a probability that depends sensitively on the optical near-field.

The internship will be devoted to the study of the optical excitations of plasmonic nanostructures by electron energy gain spectroscopy (EEGS) and non-linear electron energy loss spectroscopy. We will perform EEGS experiments to map the optical near-field with subwavelength resolution on plasmonic nanostructures. More complex experiments involving two pump pulses instead of one will be performed to investigate the influence of mechanical or electronic excitations on the response of the nano-objects. This internship is a unique opportunity to work on a demanding project at the cross-roads of ultrafast optics, TEM and nano-optics. This project is mainly experimental but modeling of the interaction between the fast electron and optical excited nanostructure will also be an exciting challenge for candidates with a solid background in solid state physics and optics.

[1] Ultrafast Transmission Electron Microscopy : fundamentals, instrumentation and applications - Arnaud Arbouet et al - AIEP, 207, 2018, 1076-5670, 2018
[2] High brightness ultrafast transmission electron microscope based on a laser-driven cold-field emission source: principle and applications - G.M. Caruso et al - Ultramicroscopy, 186, 128-138, 2018

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO