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

INTERNSHIP PROPOSAL

Laboratory name: **Laboratoire de Physique des Solides**
CNRS identification code: **UMR 8502**
Internship director'surname: **Kociak**
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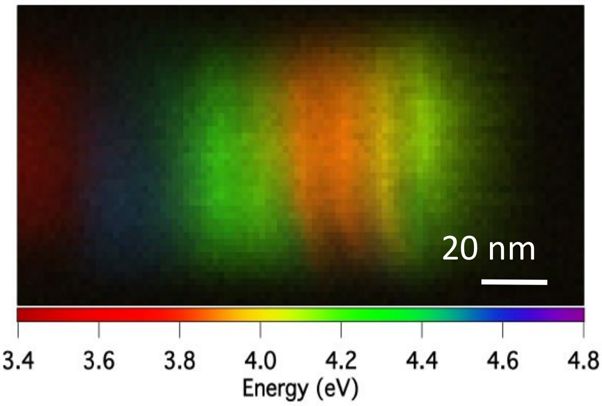
Internship location: **Laboratoire de Physique des Solides**

Thesis possibility after internship: **YES** Funding: **YES** (ANR -in progress-, EDOM)

Quantum Free Electron for Nanooptics

Nanoptics, the study of the electromagnetic properties of nano-objects at the nanoscale is a fascinating subject. Indeed, when the size of a nano-object becomes smaller than a typical length scale - the *de Broglie* wavelength for excitons in semiconductors or the wavelength of the visible light for plasmons in metal nanoparticles - optical excitations in nanomaterials become confined. Thus, the basic optical properties of nanomaterials now critically depend on their morphology and structure at the nanometer scale or even at the individual atom scale. However, the combined study of the structure and optical properties of a nanomaterial cannot be done with photonic microscopies, which are generally limited by diffraction to sizes greater than one hundred of nanometre.



An alternative, largely pioneered in our group, is to use electron-based microscopies and spectroscopies. Indeed, electron energy loss spectroscopy (EELS) and cathodoluminescence have been very successful for the deep sub-wavelength investigation of several nanooptical objects and excitations, such as plasmons, quantum wells and single photon emitters. Despite these successes (see figure showing the mapping of optical properties of stacks of GaN quantum wells few angstroms thick), large parts of the nanooptical realm, such as quantum nanooptics or super-chirality, can hardly be addressed with EELS and CL. Beyond the technical problems, the main reason is conceptual: in most of the studies, the quantum character of the probe electrons is totally neglected. Now, we have recently [G. Guzzinatti et al., *Nature Communications*, 8, 14999 (2017)] shown theoretically and experimentally that taking the quantum aspects of the electron used to probe the objects of interests into account lift most of the above-mentioned bottlenecks.

The aim of this internship is to explore the virgin domain of the use of quantum relativistic electron properties for the study of classical and quantum nanooptics.

The trainee will have the opportunity to use a world-wide unique spectromicroscope, learn about state-of-the-art electron lithography and developments in modern theories of electron-matter interaction.

This topic is for fitted for a curious student, with a taste for experiment and theory, and attracted by new concepts in electron-matter interaction and nanooptics.

If you are interested, please feel free to contact us for a visit and discussion.

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

Condensed Matter Physics & Quantum Physics