INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR8502
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Internship location: Laboratoire de Physique des Solides, bâtiment 510, université Paris-Saclay, Orsay

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

Coherent control of artificial atoms with relativistic electrons

Nano-optics is the science of optical phenomena that occur well below the diffraction limit of light. To overcome this fundamental limit, a wide range of new techniques and concepts have been developed over the past two decades. Among them, the use of fast electrons, traveling at about half the speed of light, has proven particularly powerful for probing the optical properties of nanomaterials. Our team has been pioneering in this field, employing electron energy-loss spectroscopy (EELS) and cathodoluminescence spectroscopy (CL) to investigate a wide variety of excitations in solids, ranging from phonons [Li, X. et al. Three-dimensional vectorial imaging of surface phonon polaritons. Science 371, 1364–1367 (2021).] to excitons [Hou, J. et al. Liquid-phase sintering of lead halide perovskites and metal-organic framework glasses. Science 374, 621–625 (2021)], with levels of spatial and spectral resolution that were previously unattainable. More recently, we have developed energy-gain spectroscopy (EEGS), a technique that combines the exceptional spatial resolution enabled by the extremely short wavelength of electrons (a few picometers) with the sub-μeV spectral resolution provided by a laser [Auad, Y. et al. μeV electron spectromicroscopy using free-space light. Nat. Commun. 14, 4442 (2023).]. This unique capability has made it possible to study systems of major interest for quantum optics, such as ultra-high finesse optical cavities.

Despite these advances, a central question remains unanswered. While the coherent study and manipulation of excitations in sub-micrometer systems such as photonic and plasmonic cavities is now well established, the situation is still completely open, both theoretically and experimentally, when it comes to atomic or quasi-atomic systems such as quantum dots. The aim of this internship, which is expected to evolve into a PhD project, is to explore the entirely new domain of coherent manipulation of optical states in artificial atoms with relativistic electrons.

The project will take place on a unique experimental platform combining a state-of-the-art monochromated transmission electron microscope (TEM) with a laser system, along with specifically engineered lithographic samples designed to optimize electron–photon interactions. Such unique combination opens new perspectives in the nano-optics field that could not be considered before. The project will be performed in the framework of the ERC advanced grant FreeQCC. During the internship, the student will contribute to the development of the laser optical setup, take part in the experiments, and analyze the resulting data. This work requires a motivated and curious candidate with a strong interest in physics and a genuine desire to explore a research field that is only beginning to be charted, at the frontier of nano-optics, quantum science, and advanced instrumentation.

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