

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR8502
Internship director's surname: Mathieu Kociak
e-mail: Mathieu.kociak@universite-paris-saclay.fr Phone number: 0675345317
Web page: <https://equipes.lps.u-psud.fr/stem/>
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

Probing quantum coherence in artificial atoms with relativistic electrons

Can a fast electron probe the quantum coherence of an artificial atom? Quantum coherence is central to quantum physics and underpins quantum information processing. Measuring it in individual systems such as quantum dots with nanometer spatial resolution would open new possibilities for exploring light-matter interactions and developing approaches to quantum-state readout.

Our team has pioneered the study of quantum optical systems with fast electrons, demonstrating single-photon emission and its characterization in a scanning transmission electron microscope [Tizei, L. H. G. & Kociak, M. *Phys. Rev. Lett.* 110, 153604 (2013)]. More recently, we have developed electron energy-gain spectroscopy (EEGS), bringing laser-defined spectral resolution to electron microscopy [Aua, Y. et al. *Nat. Commun.* 14, 4442 (2023)]. We now seek to cross a new frontier in quantum science and technology: accessing the quantum coherence of an individual artificial atom with a relativistic electron. The central question is whether, and how, this coherence can be encoded in the electron's state and experimentally read out. Establishing such a capability would introduce a new way to interrogate quantum systems with nanoscale spatial resolution.

This M2 internship, with the prospect of continuing into a PhD, will contribute to this effort within the ERC Advanced Grant FreeQCC. The project combines a state-of-the-art monochromated transmission electron microscope, a laser system, and engineered samples designed to enhance electron-light-matter interactions. During the internship, the student will help develop the optical setup, participate in experiments, and analyze the resulting data.

The broader project will require theoretical developments to describe the interaction and identify measurable signatures of coherence. These will be pursued in collaboration with theoretical partners, with opportunities for the student to contribute according to their interests.

We seek a curious and motivated student interested in quantum physics, nano-optics, and experimental research. The project offers the opportunity to explore an emerging research frontier with implications for both fundamental physics and future quantum technologies, through a combination of advanced instrumentation, experiments, and theory.

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