2025-2026

Master thesis proposal

Title: Ultrafast Dynamics and Charge Carrier Localization in Metal Halide Perovskites

Keywords: Ultrafast spectroscopy, Exciton recombination, Charge trapping, Metal halide perovskites

Scientific description: Metal halide perovskites (MHPs) have emerged as a class of semiconductors with exceptional optoelectronic properties**,** reaching performances comparable to crystalline silicon in photovoltaics while offering simple and low-cost fabrication. Beyond solar cells, these materials show great promise for light-emitting devices, spintronics, and quantum photonics**,** thanks to their tunable bandgap, large spin–orbit coupling, and long carrier diffusion lengths. A key question remains, however: **how do the structural and dielectric properties of the perovskite lattice influence the motion and recombination of photo-generated carriers**?

After optical excitation in halide perovskites, photons with energy higher than the band gap create electron–hole pairs with excess kinetic energy, known as hot carriers. These carriers first undergo rapid thermalization through carrier–carrier scattering, reaching a quasi-equilibrium distribution characterized by a hot-carrier temperature higher than that of the lattice. Subsequently, hot carrier relaxation occurs as carriers lose energy to the lattice via carrier–phonon interactions, mainly through optical phonon emission. This cooling process typically happens on the picosecond timescale. In halide perovskites, however, carrier cooling can be unusually slow due to strong electron–phonon coupling and possible phonon bottleneck effects, where emitted phonons are reabsorbed before dissipating.

This internship offers an opportunity to explore the ultrafast dynamics of charge carriers and excitons in cutting-edge MHP materials. This internship is part of an ongoing research project- ANR SPOIR. The main objectives are to characterize hot and cold carrier recombination dynamics over timescales ranging from femtoseconds to nanoseconds, identify the nature and influence of trapping states that affect carrier lifetimes and efficiency, and establish correlations between structural quality and optoelectronic performance**.** The project will combine fundamental physics with experimental innovation, providing a strong foundation for future research or a PhD project in the group.

Techniques/methods in use: The project involves advanced **time-resolved spectroscopic techniques**, including: **Femtosecond transient absorption spectroscopy (TA)** to monitor carrier relaxation and non-emissive states. **Time-resolved photoluminescence (TRPL)** to determine excitonic lifetimes and radiative processes. **Photo-induced Faraday rotation (PFR)** to probe spin dynamics and carrier localization.

Applicant skills: Background in **solid-state physics**, **optics**, or **semiconductor physics**. Strong interest in experimental research and optical spectroscopy.

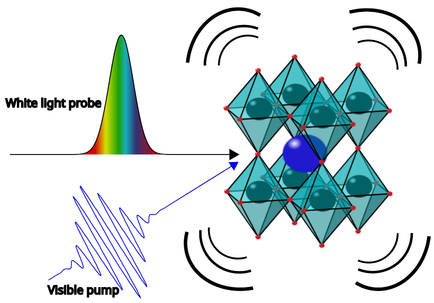

Figure 1: Schematic of the femtosecond pump, white light probe experiment

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Internship location: Campus Pierre et Marie Curie (Mto Jussieu)

Possibility for a Doctoral thesis: Y, financial support ANR or doctoral school.