INTERNSHIP PROPOSAL

Laboratory name: Laboratoire d'Optique Appliquée (LOA), Institut Polytechnique de Paris
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Internship location: 181 chemin de la hunière, 91120 Palaiseau

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR g4QED, co-supervision between CEA and LOA, and CEA as employer

Modeling future strong-field QED experiments

State-of-the-art multi-PW lasers, such as APOLLON (France), and km-scale accelerators such as FACET-II at Stanford (USA) [1], allow to create on Earth the extreme conditions for fundamental interactions between particles and fields. Such interactions follow the laws of strong-field quantum electrodynamics (QED) that has emerged as a promising discovery science area with exciting opportunities. Strong-field QED effects appear when the electric field experienced by the electron in its rest frame approaches the Schwinger field $E_S=m^2c^3/(e\hbar)$, and their most spectacular manifestations include the production of electron-positron pairs through the inverse-Compton scattering and the nonlinear Breit-Wheeler processes. At multi-PW laser facilities such as APOLLON, strong-field QED experiments can be performed by colliding high-energy electrons produced by a novel type of particle accelerator, namely a laser-driven plasma accelerator, with a high-intensity counterpropagating laser pulse or another source of strong fields. Several avenues will be explored in the ANR g4QED project (Gamma photon sources as a path for strong-field QED experiments), specifically including two promising concepts: (i) the use of a plasma mirror to reflect the laser pulse and enable the collision between the high-energy electrons and the laser pulse [2], and (ii) the use of multiple foils to focus the electron beam to very small size, and use the focused electron beam itself as the source of strong fields [3,4].

The internship and the PhD will aim to model, theoretically and numerically, these two concepts and to provide the best strategies to implement them experimentally on APOLLON and FACET-II. The work will involve a rich variety of physics: the interaction between laser pulses and plasmas, between particle beams and plasma, as well as the strong-field QED physics that we aim to unveil experimentally. The development of advanced numerical modeling for this project will also be key to provide accurate physical interpretation for the experiments. During the internship, the student will work more specifically on the first concept with the modeling of the plasma channel formation, the laser focusing and compression in the plasma, the laser-driven plasma acceleration, the generation of the plasma mirror for the laser reflection, and finally the strong-field QED collision. The goal is to understand its potential for strong-field QED experiments, as well as possible limitations or paths for further improvements.

[1] V. Yakimenko et al., Phys. Rev. Accel. Beams 22, 101301 (2019).
[2] K. Ta Phuoc et al., Nature Photonics 6, 308 (2012).
[3] A. Sampath et al., Phys. Rev. Lett. 126, 064801 (2021).
[4] A. Matheron et al., Comm. Phys. 6, 141 (2023).

Condensed Matter Physics: YES Soft Matter and Biological Physics: YES
Quantum Physics: YES Theoretical Physics: YES