Title : Towards extreme beams and strong-field quantum electrodynamics experiments

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Research Area : Laser and Plasma Physics, Optics, High Energy Physics

Methods: high-power lasers, high-energy accelerators, plasmas

PhD track subject :

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 are explored in our group to enable strong-field QED experiments, 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 latter concept is completely novel, leveraging the very high fields generated at the surface when a beam enters a conductor or a plasma, and provides a new mean for focusing beams to extreme densities, approaching that of a solid (see Figure). Besides strong-field QED experiments, these concepts also open new opportunities to generate bright gamma rays and electron-positron pair plasmas.

We are looking for motivated students interested to follow a 5-year PhD track, with the opportunity to contribute to the project from the modelling of these concepts to their experimental realisation at APOLLON and Stanford. The project 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 in the years to come.

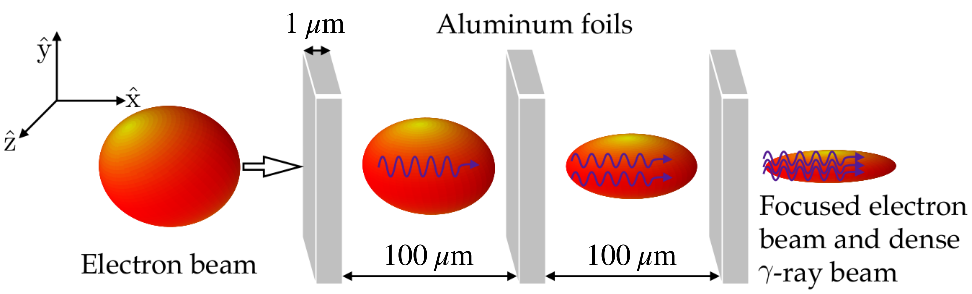

Figure: Schematic of the concept of self-focusing and generation of gamma rays in the collision of a high-energy electron beam with multiple foils.

References :
[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).