DRF: Thesis SL-DRF-20-0967

RESEARCH FIELD

Plasma physics and laser-matter interactions / Corpuscular physics and outer space

TITLE

Development and benchmarking of novel AMR-PIC methods for the realistic 3D modelling of light-matter and light-vacuum interactions at extreme intensities

ABSTRACT

Nowadays, the major challenge of high-field physics or Ultra-High Intensity (UHI) physics is to design a very intense light source capable of exploring new regimes of Quantum Electrodynamics (QED) that are currently out of reach of conventional particle accelerators. In particular, above 10^29W/cm^2 also known as the Schwinger limit, vacuum breaks down and e-/e+ pairs can be produced out of vacuum. Such physical processes are only produced in the most extreme astrophysical events. Being able to reproduce and control them in the lab represents a huge fundamental interest.

Yet, the most intense light source on earth (presently, high-power PetaWatt -PW- lasers) only deliver intensities around 10^22W/cm^2. Reaching the Schwinger limit therefore requires a pradigm shift that we recently proposed in the Physics at High Intensity (PHI) group at CEA. Our solution consists in using a remarkable optical component, generated by a high-power laser itself when interacting with a solid target and known as an 'optically-curved relativistic plasma mirror'. Upon reflection on such a curved mirror, the reflected laser light is strongly intensified due to a temporal compression by Doppler effect and a spatial compression by focusing to tinier spots than the ones possible with the incident light. The PHI group recently proposed to use the plasma mirror optical deformation by the incident laser radiation pressure to tightly focus the reflected light. Preliminary 3D simulations show that intensities of 10^25W/cm^2 can be reached with this scheme at plasma mirror focus. At such intensities, yet unexplored non-perturbative QED processes would occur during the interaction of the reflected field with matter. This constitutes the first milestone towards the Schwinger limit.

Now, the major challenge to reach the Schwinger limit is to design novel realistic schemes to optically-curve the plasma mirror surface more strongly than with radiation pressure. In this context, the candidate will develop and validate numerically these novel schemes with Particle-In-Cell (PIC) codes. As the simulations envisaged are extremely costly in termes of computing time, the candidate will first have to develop and benchmark a new Adaptative Mesh Refinement (AMR) methode developed by the group of Dr. J-L Vay at Lawrence Berkeley National Lab (LBNL), in which the first phase of the PhD will start. During the second phase (at CEA);, the candidate will use the code to validate the new schemes and answer the following questions: what are the optimal laser-plasma conditions to reach the Schwinger limit? At which intensities does the reflected field start to produce e-/e+ pairs? Are these paires detectable? How to find clear signatures of the achieved intensities in experiments? The candidate will also support the interpretation of the very first QED experiments performed with plasma mirrors during his PhD.

LOCATION

Institut rayonnement et matière de Saclay
Service Laboratoire Interactions, Dynamique et Lasers
Physique à Haute Intensité
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