Master 2: ***International Centre for Fundamental Physics***

<u>INTERNSHIP PROPOSAL</u>

Laboratory name: Laboratoire d'Optique Appliquée (Institut Polytechnique de Paris)
CNRS identification code: UMR 7639
Internship director'surname: Adrien Leblanc, CNRS
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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: IP Paris graduate school application

High density plasma injection for laser-plasma electron acceleration

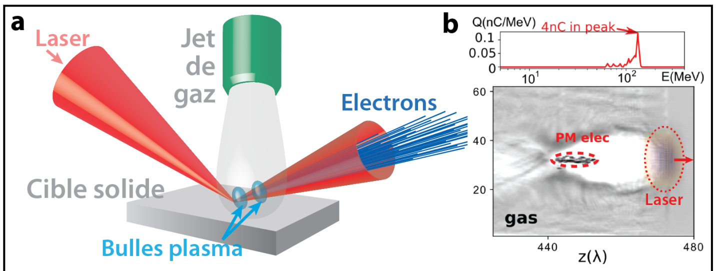
➢Relativistic electron beams have many potential societal applications, particularly in medicine. Today two types of electron accelerators are used: either linear accelerators, which are very expensive, or using laser acceleration in a plasma, which is more compact and less expensive but not yet directly applicable to societal applications. This has been a very active field of research for two decades with several challenges such as (i) increasing the charge (number of electrons), and (ii) improving the mono-energetic aspect of the beams.

➢Using a very high power femtosecond laser (a few 100TW) focused at ultrahigh intensity, two types of acceleration have been demonstrated:

1) by laser reflection on a solid target: thanks to the high density, a high charge of a few tens of nano-coulombs (nC) is accelerated but only weakly, a few MeV, because on a small acceleration distance (a few 10-100µm);

2) by propagation of the laser in a gas, a plasma bubble is formed in the wake of the pulse. It traps and accelerates electrons over several centimeters to reach very high energies, a few 100MeV, but with less charge on the order of ~1nC (low density gas). Shock gas cells have been developed to inject the electrons into the bubble in a localized manner in order to make the beam almost mono-energetic.

➢**<u>Internship subject:</u>** the idea is to create a relativistic electron source that associates a gas cell with a with a solid target in order to combine the strengths from both, see figure, panel a. <u>Step 1, injection:</u> the laser reflects off a solid target to extract a large charge from the high density in a very localized way, just at the surface of the target. <u>Step 2, acceleration:</u> then the laser propagates 1-2cm in the gas to accelerate the electrons at high energies and mono-energeticly. A preliminary numerical simulation of the laser-plasma interaction, see panel b, shows a beam of 4nC at 100MeV with an energy dispersion of a few percent. Experimental proof of such a source would be unprecedented in the field.



a- Hybrid target principle: solid + gas target.
b- Numerical simulation of laser reflection onto such a target: laser highlighted in red dash line on the right, plasma bubble in white, trapped electrons in black. Top curve: electron beam spectrum.

➢ **<u>Objectives:</u>** 50% theoretical/simulations, 50% experimental. (i) Carry out numerical simulations of the interaction to understand the physics of the injection of electrons from the solid target and to determine which configuration optimizes the acceleration conditions. (ii) Develop a hybrid target with hydrodynamic simulations. (iii) Performing the experiment. These objectives are very ambitious in 6 months: the internship will focus on theory and simulations (80%) and the thesis will be 50/50. If only theory or experiment is prefered, it can be discussed.

➢ **<u>Environment:</u>** The theoretical and numerical part (i) will be in collaboration with CEA Saclay (co-supervisor H. Vincenti) and the University of Berkeley in California. The development of the hybrid target (ii) and the experiment (iii) will be carried out at the LOA's Ultra-fast Particle and X-ray Sources (UPX) team. A dynamic team that is at the world's forefront of laser electron acceleration.

Condensed Matter Physics: YES	Soft Matter and Biological Physics: NO
Quantum Physics: YES	Theoretical Physics: YES