POST-DOCTORAL POSITION AT C.E.L.I.A.

Starting between June & December 2023 for 2 years

Laser ion acceleration in gas jets: numerical simulation of nozzles damage mechanisms

Context :

Laser ion acceleration with gas jets has developed considerably in recent years. Compared to solid target ion acceleration, the gas jet acceleration scheme has many benefits. The first of these is that it is compatible with operation with high repetition rate lasers (>kHz). The development of this type of cadence laser is booming. They allow the production of thousands of shots in a single day. In the case of use with a secondary target, for applications such as neutron or radioisotope production, this leads to a strong increase in the dose of neutrons or radioelements. For a more classic experiment scheme with a single target (here the gas jet), the very large number of shots allows the achievement of large-scale parametric studies as well as an optimization of the different interaction parameters (laser and target). Another advantage of gas jets is that they do not produce debris that could damage the facility. Finally, the ion beam generated is pure and contaminant-free, which is very interesting from the point of view of the radiation protection of the facility, but also with regard to possible medical applications.

The main issue of these experiments on supersonic gas jets comes from the nozzles that generate these jets. These are damaged during the shots, which leads to a degradation of the plasma density profile at the center of the jet and to a degradation of the acceleration process. It is therefore necessary to replace the nozzle after few shots. The number of shots possible with a single nozzle varies according to the laser intensity. At the end, the cost of these experiments is high and the number of high repetition rate shots remains limited. Furthermore, the magnitude of the electromagnetic pulses (EMP) generated on this type of experiment remains high and of the same order of magnitude as the ones observed on solid targets. For high laser intensities, this phenomenon could lead to malfunctions, or even damages of the electronic equipment of the facility.

Goals :

The main goal of this post-doctorate focuses on the identification of the physical processes responsible for nozzle damage, as well as on the design of countermeasures adapted to mitigate this phenomenon. Today, several sources of damage are considered: the transverse ions flow, accelerated during the laser-plasma interaction, which hit the nozzle, the propagation of the electrical discharge current through the nozzle, or even the emission of intense X-rays. To quantify the impact of these different potential sources of damage, the post-doctoral student will use a multi-scale and multi-physics simulation chain based on the chaining of three simulation codes: a hydrodynamics code, a particle-in-cell (PIC) code for high-intensity laser-matter interaction, and finally a last PIC code for calculating the propagation of currents and electromagnetic fields on a larger scale. When the physics of this damage process will be well identified, the post-doctoral student will test numerically different solutions to mitigate this phenomenon. An experimental campaign on this topic, in which the post-doctoral student will be able to participate, is also planned on the ALLS laser facility at INRS in Montreal (Canada). The post-doctoral student will be in charge of the analysis. Thanks to the simulation chain that will have been implemented, the post-doctoral student will assess the intensity of the EMP produced on these experiments, and he or she will try to develop technological solutions to reduce it. Different materials and geometries of nozzles aimed to mitigate the discharge current will be tested as well as countermeasures aimed to short-circuit the latter. A first theoretical model for evaluating this EMP has been developed at CELIA. The results of these numerical simulations will also be compared with those obtained with this model.

Progress :

The first year of this post-doc will be devoted to the setting up of the calculation chain and the identification of the main sources of nozzle damage, as well as the evaluation of the EMP magnitude generated on gas jets. The analysis of the experiment carried out on the ALLS facility (INRS) will also be carried out during this first year. The second year of this post-doctorate will focus on the design of countermeasures to mitigate this damage as well as the intensity of the EMP generated on this type of experiment. Depending on the results, the post-doctoral student will then be able to define a new laser experiment in order to test the solutions designed by numerical simulations.

The post-doctoral student will be based at CELIA on the campus of the University of Bordeaux in Talence (France). He or she will be integrated into the IFCIA group and will have access to the calculation means of CELIA as well as those of the TGCC (CEA). He or she may also collaborate with teams from INRS (Canada) and CEA (France).

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