Scientific Report of the visit of Andrea Sgattoni at Centre of Plasma Physics of the Queen's University of Belfast

Important Note

The grant for the short visit has been awarded for 15 days from 1^{st} November 2010. For personal reason I had to come few days earlier and leave on 13^{th} December. This is the reason for my tickets not to match 1 Nov, 16 Nov.

Purpose of the visit

The purpose of my visit has been the interpretation and the investigation via numerical PIC (Particle In Cell) simulations of some laser-plasma ion acceleration experiment conducted by the group of Prof. Marco Borghesi. In particular, I focused my attention on an experimental campaign conducted at the RAL (Rutherford Appleton Laboratory) with the laser GEMINI on thin target (50-1000 nm). The results show a weak dependency of the maximum proton energy with respect to the thickness of the target and to the polarization of the laser pulse. The aim is to try to investigate with some PIC simulation the mechanisms of the acceleration in the parameter range of the experiments.

Work carried out

The work has been devoted to the preparation of some 2D PIC simulation introducing a multilayer target. The target in the simulation is composed by three layers: a main target of Aluminium Al^{9+} and two thin layers of protons contaminants on either side of the main target. The target is considered already ionised and the electron density is 10 time overcritical for the two contaminants layer and 100 time overcritical for the main target. The laser pulse simulated has a time duration $\tau = 50$fs, focal spot $FWHM = 2.5\ \mu$m and a peak intensity of $I = 6\ 10^{20}$ W/cm^2. Both P and S linear polarization and CP circular polarization have been considered with normal incidence on the target.

Description of the main results obtained

The first results of the simulation carried out, showed an important acceleration of the protons present on the front layer of the target, illuminated by the laser. This fact was one of the aspect that drove the idea of using a contaminant layer on the front surface as well as on the back of the target. The proton layer present on the front surface is accelerated both forward, in the direction of the propagation of the laser, and backwards. The backward acceleration is due to the TNSA (Target Norma Sheat Acceleration) and was not considered by the experiment diagnostic, while the forward acceleration can be attributed to the RPA (Radiation Pressure Acceleration) mechanism. The mixing of the two mechanisms in the diagnostic of the experiment, namely the proton accelerated by the illuminated surface plus the TNSA-proton accelerated forward from the non-illuminated surface, was an aspect that lead our investigation. Being the

target thin, if a TNSA-driven accelerating fields arises, it is highly possible for the RPA-accelerated protons to find themselves interacting with these fields. The simulations show exactly this and how the proton bunches coming from the illuminated layer get readily accelerated via RPA and then find themselves on the other side of the target mixing with protons from the back contaminants layers. The simulation performed are rather preliminary and certainly need further investigation, to span on a wider range of main target and layer thicknesses, together with some more complex chemical compositions, but do lead us to the conclusion that indeed the proton from the illuminated surface are promptly accelerated, and constitute part of the detected bunches. Moreover, the simulation conducted in circular polarization does show a significant deformation of the target that leads to a non-normal local incidence of the laser pulse on the target, driving a non negligible electron heating and consequent TNSA acceleration.

Another interesting feature of the result obtained, is the strong dependency of the result with respect to the polarization used for the laser pulse. In an experiment conducted with normal incidence, there is, obviously, no difference between P and S polarization, namely laser's transverse electric field lying, for example, on the horizontal or vertical plane respectively. In a 2D simulation considering an horizontal plane, P polarized laser pulses have the transverse electric field lying on the plane while S is orthogonal. This fact introduce a known difference in the simulation. What has been observed in our simulation is how big is the difference revealed to be in the parameter set we have chosen. A few hypothesis have been made and further consideration are under scrutiny, but very laminar motion of the electron density in the S polarization case is very evident and strongly in contrast with P polarization case.

Future collaboration with host institution

I do and will work intensively in collaboration with Andrea Macchi (Pisa Italy) who has been collaborating with the group of Marco Borghesi at Queen's University Belfast. I am involved in the ISCRA project named TOFUSEX at CINECA (Italian consortium for high performance computing) headed by Andrea Macchi, this project aims to investigate laser induced ion acceleration via numerical simulation and the work conducted at the Queen's University will be further developed within this project and will be done in collaboration with the Belfast group. Another project, SULDIS already approved by the Italian Ministry of education, will is starting this months and will involve the group of Andrea Macchi (Pisa), the group of Matteo Passoni (Milano) and Andrea Sgattoni. SULDIS is aimed to study ion acceleration from a theoretical and numerical point of view, and to propose experiment to be conducted in collaboration with experimental groups and the group of Marco Borghesi at the Queen's University Belfast will surely be part of the main project's collaborators.

Projected publications/articles resulting or to result from your grant

With a further refinement and analyses of the result obtained a possible publication could cover the interpretation of the results of the experiments previously conducted by Marco Borghesi and collaborators.