Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant ☐

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: Collaboration on proton acceleration by ultrashort intense pulses

Application Reference N°: 6404

1) Purpose of the visit

The goal of the visit was to establish co-operation between two groups working in the area of intense laser interactions with targets and especially in the area of laser–induced ion acceleration. The aim was the exchange of detailed information on proton acceleration in targets using different types of surface microstructures, comparison of experiment carried out by both groups and detailed comparison of physical mechanisms responsible for the proton acceleration enhancement.

2) Description of the work carried out during the visit

I have presented the results and capabilities of our group at the seminar in the High Intensity Laser Laboratory of the Racah Institute of Physics and we have discussed in detail the mechanisms of laser absorption and temperature enhancement of hot electrons. I have brought samples of targets that are produced and used by the Prague group for enhancement of ion acceleration by ultrashort laser pulses. These included thin foils with a monolayer of microspheres on the front side and ultra-thin silicon nitride foils. The experimental setup for testing of these targets was prepared and agreed.
I have been acquainted with the details of the experiments with microstructured snow targets that lead to surprisingly high proton energies up to 21 MeV at 5 TW (intensities <10^19 W/cm^2). We have discussed in detail the forms of microstructures at the target surface and the parameters of the short prepulse that precedes the main pulse by 10 ns. We have formulated the task for fluid simulation with our two-dimensional (2D) Arbitrary Lagrangian-Eulerian code PALE. We have started to study the heating and

ablation of one narrow whisker of 0.1 micron radius and of 2 microns length by the femtosecond prepulse of intensity 10^15 W/cm^2. The aim of this simulation is to find the plasma density distribution in the moment when the main pulse arrives at the target. The resulting density profile will be then used as the initial condition for 2D and 3D particle-in-cell (PIC) simulation of the interaction of the intense main laser pulse with the target. Both simple theoretical ideas and experience from experiment carried out in Max-Born Institute in Berlin, Germany substantiate the idea that a suitable prepulse is the key condition for reaching very high proton energies in the laser interactions with snow targets. The aim of two-dimensional PIC simulation is to assess the impact of the detailed parameters of simulations, e.g. initial temperature, the role of ionization processes. Then, a most suitable case will be chosen for 3D simulation that could attempt realistic description of the laser-interaction with a pre-expanded whisker. This is a very demanding task that has to assume constant ionization, collision will not be included and relatively low particle number per cell has to be used.

During the visit I could also get acquainted with other experiments performed by Professor Zigler's group, e.g. formation and control of laser filaments in air and studies of the ionization dynamics and the radiation hydrodynamics of high-Z plasmas. I was particularly interested in the experiment devoted to generation of collimated plasma jet by laser interaction with cratered target. That experiment is partially parallel to our experiments at the PALS laboratory where we have formed similar jets by using annular laser beam. The experiment at Hebrew University Jerusalem was treated by 1D fluid code and thus only very rough qualitative interpretation was possible. We have agreed that we shall try to model the experiment with cylindrical version of our 2D fluid code PALE.

3) Description of the main results obtained

Due to the short duration of the visit, the results can be only very preliminary. The main result is the detailed plan for the simulations aimed at interpretation of the experiments with snow targets performed at Hebrew University in Jerusalem. The detailed tasks have been formulated both for 2D fluid simulations of the interaction of the laser prepulse with the snow target and for the 2D and 3D PIC simulations of the interaction of the intense main pulse with a pre-expanded snow whisker.

4) Future collaboration with host institution (if applicable)

The plan for the future collaboration of both groups has been agreed. The Prague group will perform numerical simulations that can improve the understanding and interpretation of the experiments with microstructured snow targets performed by the Jerusalem group. The coordinated effort of both groups can lead to optimization of proton acceleration in snow targets. This can also substantiate the search for suitable regimes for proton acceleration in snow targets at substantially higher laser intensities where proton energies higher than 100 MeV are predicted.

5) **Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)***

If the simulations will be successful, a joint paper will be published in a prestigious international journal and ESF will be acknowledged. However, it is now too early to specify and guarantee the outcome.

6) Other comments (if any)

I am greatly indebted to Professor Arie Zigler and his team (dr. Z. Henis, dr. M. Botton-Dascal, Mr. E. Schleifer, Mr. J. Papeer) for their warm hospitality and fruitful discussions.