Excellent activities of the Computational Physics Group at the Department of Physical Electronics of FNSPE CTU in Prague

Our research group is engaged in investigation of ion accelerating in the interaction of short intense laser pulses with targets. In this field of research, we concentrate our effort to maximize the efficiency of the acceleration process and our theoretical research is carried out with the help of plasma particle simulations. Recently, we also participate in the preparation and coordination of experiments that run on the laser systems at CEA Saclay and APRI-GIST in South Korea.

Our most important results concerning the acceleration of ions include the work dealing with very efficient acceleration of quasi-monoenergetic ion beams using intense laser pulses with circular polarization [1]. We demonstrated a new regime of the ion acceleration process, based on the radiation pressure of the laser pulse. Due to high efficiency it is attractive for prospective applications, especially when the target is very thin with a thickness in the order of several to tens of nanometers (depending on the parameters of the laser pulse). Such targets are now available and the first experiments on high-power laser systems are beginning to confirm predictions of our article. The significance of our work is confirmed by the fact that it is the second most cited papers in the history of the journal, in which it was published.

In collaboration with Prof. Kawata from the Utsunomiya University, Japan we have also suggested the use of microscopic structures on the target surface to enhance the absorption of intense laser radiation, which results in an increased efficiency of ion acceleration in very thin targets. Very simply, we can say that it is the application of some of the principles of stealth technology to reduce reflection and maximize absorption of electromagnetic radiation on the target surface. This research was at first carried out theoretically by using computer simulations [2]. Colleagues in my department subsequently suggested the possibility of the production of suitable targets for the first "proof-of-principle" experiments. The target is composed of a thin plastic film the surface of which is coated by a uniform layer of microscopic polystyrene spheres of various sizes. The first joint experiments with our collaboration confirmed the conclusions of our theoretical studies [3].

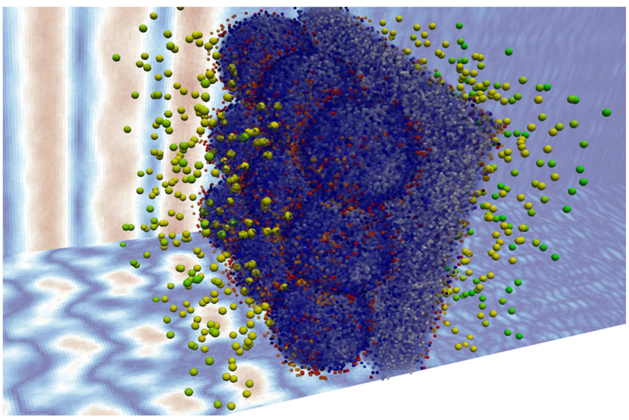

Figure 1: Results of 3D simulation of ion acceleration from the target with surface microstructure after the interaction with a short intense laser pulse. The microstructure on the surface of the target enhances laser absorption and ion acceleration efficiency significantly.

[1] O. Klimo, J. Psikal, J. Limpouch, V. T. Tikhonchuk, Physical Review Special Topics-Accelerators&Beams **11**, Art. No. 031301 (2008).

[2] O. Klimo, J. Psikal, J. Limpouch, J. Proska, et al., New Journal of Physics **13**, Art. No. 053028 (2011).

[3] D. Margarone, O. Klimo, I. J. Kim, J. Prokupek, J. Limpouch *et al.*, Physical Review Letters **109** (23), Art. No. 234801 (2012).

For hydrodynamic simulations of laser-plasma interactions, the Arbitrary Lagrangian-Eulerian (ALE) approach is the state-of-the-art method, keeping the strengths of the Lagrangian methods, while significantly improving its robustness by a mesh smoothing technique and high-order conservative interpolation approach for transferring all fluid quantities to the smoothed mesh. The group members investigate all aspects of the ALE approach, improve existing and develop new numerical methods to improve its robustness, stability, and accuracy. The group members develop and use in-house PALE (Prague ALE) code, allowing to perform hydrodynamic simulations of laser-plasma interactions. They collaborate with several teams of experimental physicists at the PALS laser facility and model processes during experiments to help them predict or explain various phenomena.

As an example, let us mention the work related to the ignition of the inertial confinement fusion. A novel channel target configuration have been designed and tested experimentally. This experiment can be modeled numerically in two phases: modeling of laser absorption and ablative acceleration of the flyer target and modeling of high-velocity impact of the accelerated plasma on the massive target, shock wave evolution and crater formation. To reach the parameters necessary for the ignition, various target configurations have been modeled numerically and the shock wave structure, profiles of various plasma quantities, or the predicted crater size have been investigated [4]. In Figure 2, the density and temperature profiles in a later stage of the crater formation are shown, demonstrating complex fluid structures below the channel. The measured crater sizes correspond well to the ones obtained from the numerical simulations.

In a different series of experiments, the possibility of enhancing the boron fusion reaction was studied theoretically, experimentally and numerically [5]. Our group contributed by a series on numerical experiments, mainly modeling evolution of the boron concentration evolution in time for various target configurations. The numerical data support the experimental results and correspond well to the expected behavior. This important achievement has been recently published in prestigious journal PHYSICAL REVIEW X.

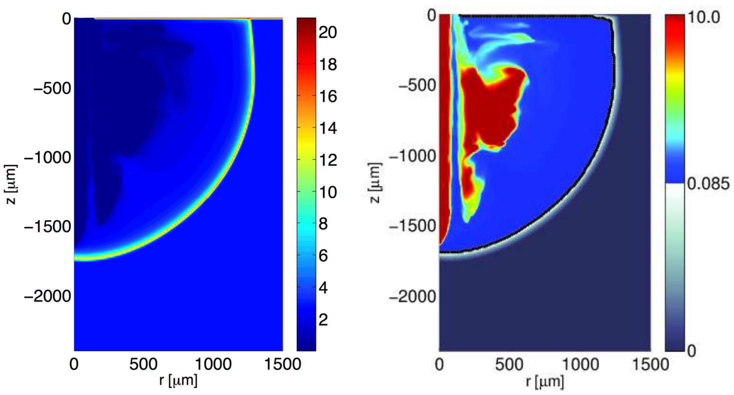

Figure 2 Density in g/cm^3 (a) and temperature in eV (b) of the plasma inside the crater 1 μs after laser pulse. Propagating shock wave melts and evaporates the massive target material, solid material is shown in a gray colormap.

[4] J. Badziak, S. Jablonski, T. Pisarczyk, P. Raczka, E. Krousky, R. Liska, M. Kucharik *et al.* Physics of Plasmas **19**, Art. No. 053105 (2012).

[5] A. Picciotto, D. Margarone, A. Velyhan, P. Bellutti, J. Krasa, A. Szydlowsky, G. Bertuccio, Y. Shi, A. Mangione, J. Prokupek, M. Kucharik, G. Korn, Physical Review X **4**, art. no. 031030 (2014).