EXPERIMENTAL STUDY OF PLASMA PHYSICSAnd particle acceleration at the PEARL LASER facility

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The investigations on high-power laser-plasma coupling have been stimulated by numerous applications such as the development of laser-based particle accelerators, the development of high-brilliance laser-based X-ray sources, as well as the production of high-energy-density matter of interest for astrophysics and inertial fusion. A review of the recent experimental investigations of laser-plasma interaction processes that have been conducted at the PEARL laser-plasma complex (IAP RAS) is reported. Main research fields described in the report are related to the laser-driven proton acceleration and to the laboratory astrophysics.

The experimental results on the laser-driven proton acceleration using a femtosecond laser pulse with the maximal power up to 170 TW (<8 J, 60 fs) focused in the focal spot of 6 um diameter on the surface of a thin aluminum target (whose thickness varied from 0.5 to 10 µm). The target has been oriented at 450 with respect to the laser axis. The intensity of the laser radiation in the focal spot reached up to 3 × 1020 W/cm2. TNSA (target normal sheath acceleration) was the main regime of proton acceleration in our experiments was. In this regime, protons are accelerated by the electrostatic field due to space charge separation caused by the heating of the target electrons by the laser radiation. During the experiments, energies of the accelerated proton achieved more than 43 MeV, which is a record value for the laser systems with output energy less than 20 J.

In the frame of the experiments on laboratory modeling of astrophysical problems, coupling of a high-amplitude and large-scale magnetic field to high-velocity plasma flows has been studied, to create conditions representative of magnetohydrodynamic processes in the vicinity of compact stars. In the course of this work we studied the physical processes in the boundary layer between the moving plasma with a magnetic field, which is a key factor for the development of physical models of different astrophysical objects, such as accretion disks, accretion columns, astrophysical jets etc. a young star objects (YSOs). YSOs are surrounded by an accretion disk and narrow bipolar jets, which are thought to play a key role in the evolution of these objects. Hence, understanding of physical mechanisms of the jet formation and of the matter accretion to an YSO is key to understanding the mass, energy, and angular momentum redistribution between the dense core and the parent cloud. The experimental results, modeling accretion on astrophysical objects with an intrinsic magnetic field are presented. It has been shown that at the inner edge of the accretion disk, i.e. in the area of magnetic/dynamic pressure balance is a subject of strong instabilities, which lead to efficient plasma penetration across the magnetic field lines. One may notice that this result could possibly cause reviewing and modifying significantly the model of the accretion disks.