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The ions counterclockwise motion near the diamagnetic cavity edge

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The plasma expansion into an ambient environment containing magnetic field and background is applicable to many processes in cosmic plasma and astrophysics, such as supernova explosions, coronal mass ejections, formation of comet coma, ion releases in the Earth's magnetosphere, etc. The active experiments in the Earth's magnetosphere (AMPTE, CRRES) have shown that the magnetic field is expelled by the cloud plasma, the diamagnetic cavity is formated and even in the case of a simple configuration of spherically symmetric plasma expansion demonstrate complex dynamics and effects that require more detailed investigation and explanation. These problems actualize experiments with laboratory plasma, which make it possible to reproduce and observe these objects with detailed diagnostics and under specified conditions. For example, such experiments are carried out at the KI-1 facility (Institute of Laser Physics SB RAS, Novosibirsk) and Large Plasma Device (UCLA, USA).

Recent experiments at the KI-1 facility, where a plasma cloud is created by the action of a laser pulse on a polyethylene target, are aimed at studying the features of a diamagnetic cavity in the presence of a weak magnetized background. As a result, a counterclockwise rotation region of hydrogen ions was discovered using spectral diagnostics. A laboratory experiment is accompanied by numerical simulations to interpret observations and to investigate the physics of this effect.

We present the results of a diamagnetic cavity simulation using the parallel semi-implicit kinetic code iPIC3D. The plasma cloud explosion, similar in parameters to the experiments at the KI-1 (the case of sub-Alfven expansion and non-magnetized ions), occurs into an ambient magnetic field and a background plasma. The azimuthal velocities of different ions species (background hydrogen, plasma cloud protons and carbon ions) were investigated at the cavity boundary (in an equatorial plane). The protons counterclockwise motion is shown, which does not coincide with the direction of their gyromotion, in contrast to heavier carbon ions. The time-integrated velocity distributions along the observation line (virtual optical axis) were constructed to compare the kinetic simulation results and the spectral data in laboratory experiments. In addition, the cases of a high and low background plasma density are considered and the dependence on a background plasma level is demonstrated. The work was supported by The Russian Science Foundation 23-22-00386 grant.