Particle-in-cell simulations of laser-driven, ion-scale magnetospheres in laboratory plasmas

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Ion-scale "mini-magnetospheres" provide a unique environment for studying kinetic-scale plasma physics, and have been observed around comets [1], weakly-magnetized asteroids [2], and localized regions of the moon [3]. In this work, we present collisionless particle-in-cell (PIC) simulations of ion-scale magnetospheres that reproduce recent laboratory experiments performed on the Large Plasma Device (LAPD) at UCLA [4]. In our PIC simulations, a super-Alfvénic driver plasma flows against a dipolar magnetic field that is embedded in a uniform magnetized background plasma. The simulations replicate the main magnetospheric structures observed in the experiments, namely the kinetic-scale magnetopause and the plasma current distributions. The properties of mini-magnetospheres created in this interaction are studied for different dipole and plasma parameters, and PIC simulations are utilized to extract key observables for the experiments and the conditions in which they form [5].

Additionally, we develop a semi-analytical model of the parameters that characterize the coupling between the driver and the magnetized background plasmas. The semi-analytical model is compared with the simulations, showing good agreement. The model is also used to provide bounds for the experimental parameters, such as the density and flow velocity of the driver plasma.

References

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