Generation of Laser-Driven, High-Mach-Number Magnetized Collisionless Shocks

D.B. Schaeffer[1], W. Fox[1,2], D. Haberberger[3], G. Fiksel[4], A. Bhattacharjee[1,2], D.H. Barnak[3], S.X. Hu[3], K. Germaschewski[5], and R.K. Follett[3]

[1] Dept. of Astrophysical Sciences, Princeton University, Princeton, USA
[2] Princeton Plasma Physics Laboratory, Princeton, USA
[3] Laboratory for Laser Energetics, University of Rochester, Rochester, USA
[4] Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, USA
[5] Space Science Center, University of New Hampshire, Durham, USA

Collisionless shocks are ubiquitous in space and astrophysical systems, and the class of supercritical shocks is of particular importance due to their role in accelerating particles to high energies. While these shocks have been traditionally studied by spacecraft and remote sensing observations, laboratory experiments can provide reproducible and multi-dimensional datasets that provide complementary understanding of the underlying microphysics. We present experiments undertaken on the OMEGA and OMEGA EP laser facilities that show the formation and evolution of high-Mach number collisionless shocks created through the interaction of a laser-driven magnetic piston and magnetized ambient plasma [1,2]. Through time-resolved, 2-D imaging we observe large density and magnetic compressions that propagate at an Alfvénic Mach number M_A~15 and that occur over ion kinetic length scales. Additional shock structure and electron and ion heating are observed with optical Thomson scattering, which is also used to characterize the initial ambient plasma. Particle-in-cell simulations constrained by experimental data further detail the shock formation and separate dynamics of the multi-ion-species ambient plasma. The results show that the shocks form on timescales as fast as one gyroperiod, aided by the efficient coupling of energy, and the generation of a magnetic barrier, between the piston and ambient ions. The development of this experimental platform opens the way for controlled laboratory investigations of high-Mach-number collisionless shocks, including mechanisms of shock heating and particle acceleration.

[1] Schaeffer *et al.*, Phys. Rev. Lett. **119**, 025001 (2017)
[2] Schaeffer *et al.*, Phys. Plasmas **24**, 122702 (2017)