Perpendicular subcritical shock structure in a collisional plasma experiment

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Shock waves are ubiquitous in astrophysical, space and laboratory plasmas and often include an embedded, dynamically significant magnetic field. These magnetic fields allow dissipation mechanisms specific to magneto-hydrodynamics, such as resistive Ohmic heating, to contribute to shock shaping. Low Mach number shocks can in fact be shaped exclusively by resistive heating. Such shocks are referred to as subcritical, having a magnetosinic Mach number in the range $M_{MS} = 1 - 2.76$. Subcritical shocks have been studied experimentally in collisionless plasmas [1, 2] but have not previously been measured in the collisional regime. We present new results from an experimental investigation of perpendicular subcritical shock structure in a highly collisional plasma. A supersonic ($M_S \sim 2.5$), super-Alfvénic ($M_A \sim 3$) plasma flow is produced by the current driven ablation of an inverse wire array z-pinch at the MAGPIE pulsed power facility. Shocks are studied by placing stationary obstacles into the flow. Laser probing diagnostics including interferometry, Faraday rotation imaging and optical Thomson scattering allow detailed measurement of the shock structure. We demonstrate that the downstream flow is supersonic, a defining feature of subcritical shocks. We find that hydrodynamic variables are continuous across the shock, as predicted by theory, and that the shock width is equal to the classical (Spitzer) resistive diffusion length. Temperature measurements at the shock are consistent with a balance between adiabatic and resistive heating and radiative cooling, indicating that viscous dissipation is not present. This work was supported by First Light Fusion Ltd. and by the US Department of Energy (DoE) including awards no. DE-NA0003764 and DE-SC0020434.

References

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