Particle acceleration in high energy density magnetic reconnection experiments

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Magnetic reconnection is a relaxation mechanism through which energy stored in magnetic flux is dissipated, leading to bulk plasma heating, plasma acceleration, and the generation of fast particles. Reconnection is important in astrophysical and space plasmas, from the strongly driven and collisionless interaction of planetary magnetospheres with the solar wind; to the more weakly driven and collisional flows found in the solar convective zone. In these plasmas, fast particles are a key signature of reconnection.

In this presentation, we describe experimental results from a novel reconnection platform [1, 2] which are consistent with the direct acceleration of electrons by the reconnecting electric field. The platform uses the MAGPIE pulsed power generator to produce plasma inflows ($u_{in} \sim 50$ kms^{-1}) that carry a strong azimuthal magnetic field ($B_{in} \sim 3$ T) and persist for many hydrodynamic timescales ($T_{total} \sim 500$ ns $\gg T_{hydro} \sim 10$ ns). These experiments are typically diagnosed using laser interferometry, Faraday rotation, and Thomson scattering.

For the results presented here thermal, magnetic, and ram pressure are all dynamically significant ($\beta_{dyn} \sim \beta_{therm} \sim 1$); the Lundquist number is $S \sim 120$; and the ratio of the ion skin depth to the layer width is $d_i/\delta \sim 1$. This regime is distinct and complimentary to laser driven and gas discharge reconnection experiments.

In this work we enhanced our diagnostic capability to study non-thermal electron acceleration by the reconnecting electric field. Metal foils were placed in the path of the accelerated electrons, which collisionally excited atomic transitions, producing characteristic X-Ray spectra. These were diagnosed using spherically bent crystal X-Ray spectroscopy and filtered pinhole imaging. Time resolved measurements were obtained using fast silicon diode detectors. We observed spectra consistent with a significant population of super thermal particles, exceeding the thermal velocity of the plasma by over an order of magnitude. By combining these fast particle diagnostics with our existing diagnostic suite, we can enhance our growing understanding of the link between astrophysical observations and laboratory experiments.

[1] L. G. Suttle et al. (2016) Phys. Rev. Lett. 116, 225001
[2] J. D. Hare et al. (2017) Phys. Rev. Lett. 118, 085001