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Magnetically Driven Collisionless Reconnection at Low Plasma Beta Using Novel Laser-Powered Capacitor Coils

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Magnetic reconnection is a fundamental physical process occurring in nearly all magnetized plasmas in nature and in laboratory fusion experiments that rapidly converts magnetic energy to the form of plasma flow, thermal particles, and non-thermal energetic particles. The latter is often an observational signature of magnetic reconnection occurring remotely on the Sun and throughout the Universe. Theoretically, magnetic reconnection has been proposed as an efficient accelerator for charged particles to attain non-thermal energies than any previously proposed or known mechanisms, such as collisionless shocks and plasma turbulence. Over the past four years, our team has been dedicated to developing a robust new platform at sufficiently low plasma betas and measuring conspicuous particle acceleration from magnetically driven collisionless reconnection using strong coil currents powered by high power lasers at the Omega EP and Titan Laser Systems [1-2]. The main target is comprised of two parallel copper plates connected by two circular coils. As the high-power lasers irradiate the back plate an electric potential is built, driving strong currents in both coils and creating a quasi-axisymmetric reconnection geometry between them. This geometry allows better plasma confinement and long reconnection X-line and therefore efficient particle acceleration. Ultrafast proton radiography of the electromagnetic field structure showed a direct signature of reconnection and up to 60 kA of currents in the coils [2]. Plasma parameters were measured using an optical probe, confirming the low plasma beta in the reconnection region. Energetic electrons generated by magnetic reconnection were successfully measured with particle spectrometers. Our most recent work extends the coil current generation up to 100 kA by using the Omega EP IR lasers at a much higher laser intensity, opening up the possibility of studying turbulent reconnection at these laser facilities. This talk provides a comprehensive discussion of our experimental work, quantitative comparisons to Particle-In-Cell simulations, and interpretation in the context of astrophysical observations. This work was supported by the National Laser Users Facility under Grant No. NA0003608, the High-Energy-Density Laboratory Plasma Science under Grant No. DE-SC0020103, and the LaserNetUS initiative at the Jupiter Laser Facility. [1] L. Gao et al., PoP 23, 043106 (2016). [2] A. Chien, L. Gao, et al., PoP 26, 062113 (2019).