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Astrophysical Weibel instability in counter-streaming laser-produced plasmas

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Astrophysical shock waves play diverse roles, including energizing cosmic rays in the blast waves of astrophysical explosions, and generating primordial magnetic fields during the formation of galaxies and clusters. These shocks are typically collisionless and require collective electromagnetic fields to couple the upstream and downstream plasmas. The Weibel instability has been proposed to provide the requisite interaction mechanism for shock formation in weakly-magnetized shocks by generating turbulent electric and magnetic fields in the shock front. This work presents the first laboratory identification of this Weibel instability between counterstreaming supersonic plasma flows and confirms its basic features, a significant step towards understanding these shocks. In the experiments, conducted on the OMEGA EP laser facility at the University of Rochester, a pair of plasmas plumes are generated by irradiating of a pair of opposing parallel plastic (CH) targets. The ion-ion interaction between the two plumes is collisionless, so as the plumes interpenetrate, supersonic, counterstreaming ion flow conditions are obtained. Electromagnetic fields formed in the interaction of the two plumes were probed with an ultrafast laser-driven proton beam, and we observed the growth of a highly striated, transverse instability with extended filaments parallel to the flows. The instability is identified as an ion-driven Weibel instability through agreement with analytic theory and fully kinetic particle-in-cell simulations of colliding ablation flows, which include a collision operator. The experimental proton-radiography results are compared with synthetic ray-tracing through 3-D simulations.

[1] W. Fox, G. Fiksel, A. Bhattacharjee, et al, *Phys. Rev. Lett.* **111**, 225002 (2013).