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Observation of electromagnetic Weibel instabilities in laser-driven high Mach number counter-streaming plasma flow experiments[1]

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Astrophysical collisionless shocks are ubiquitous, occurring in supernova remnants, gamma ray bursts, and protostellar jets. They appear when the ion-ion collision mean free path is much larger than the system size. Here we present laboratory experiments using the high-power lasers and investigate the dynamics of high Mach number collisionless shock formation in two interpenetrating plasma streams. It is believed that in the astrophysical environment such shocks are the sites where seed magnetic fields are generated on a cosmologically fast timescale [1] via the Weibel [2] (or filamentation) instability. Particle-in-cell (PIC) numerical simulations have confirmed that the strength and scale of the generated magnetic field [3,4] are consistent with this concept. Our recent proton probe experiments on Omega show filamentary structures of Weibel instabilities, that are from electromagnetic nature and the inferred magnetization level could be as high as $\sim 1\%$ [5]. These results imply significance of electromagnetic instabilities in the plasma interactions in the ICF and astrophysical conditions. This paper will review the recent experimental results from various laser facilities as well as the simulation results and the theoretical understanding of these observations. The planned NIF experiments will be presented where it will be possible to observe the fully formed shocks.

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