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Electromagnetic Ion/Ion Beam Instabilities in the Laboratory, the Magnetosphere, and Simulation[1]

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Collisionless electromagnetic ion/ion beam instabilities play an important role in the formation of quasi-parallel bow shocks in planetary magnetospheres. One particular instability, the Right-Hand Resonant Instability (RHI), is responsible for generating large-amplitude ($\delta B/B_0 > 1$) ultra-low frequency (ULF) electromagnetic waves in the quasi-parallel foreshock, which interact nonlinearly to create structures such as shocklets and current filaments. Demonstrating the detailed microphysics of these processes through experiment or observation remains an open challenge.

Spacecraft observations of these features are well complemented by dimensionless-parameter scaled laboratory experiments. A recent series of experiments at the University of California, Los Angeles has made volumetric measurements of waves produced by the RHI that are directly comparable to those observed in the terrestrial magnetosphere. In the experiment, a high-energy laser ablates a super-Alfvénic ($M_A = 5$) laser-produced plasma (LPP) from a plastic (HDPE) target embedded in the highly repeatable magnetized ambient plasma of the Large Plasma Device (LAPD). The LPP, which consists primarily of several carbon charge states, expands quasi-parallel to the background magnetic field and is unstable to the RHI. As the instability grows it generates waves which are measured by an array of 3-axis magnetic flux probes. Moving the probes between shots allows the collection of volumetric data sets comprising thousands of shots.

Waves generated in the experiment exhibit spectral properties and circular polarization consistent with linear theory for the RHI. 2D planes transverse to the background magnetic field far from the growth region reveal spiraling current filaments, followed in time by an alternating axial current structure. Mutual comparison with linear theory and 2D hybrid simulations shows that the observed waves closely match spacecraft measurements from the terrestrial quasi-parallel foreshock, although waves in the experiment reach much lower amplitude ($\delta B/B_0 < 0.01$). This result demonstrates that parameter-scaled laboratory experiments can reproduce magnetospheric waves previously only observed *in situ*.

[1] In collaboration with M.S. Weidl, R.S. Dorst, D.B. Schaeffer, C.G. Constantin, S. Vincena, S. Tripathi, and C. Niemann (University of California, Los Angeles), D. Winske (Los Alamos National Laboratory), L.B. Wilson III (NASA Goddard Space Flight Center) and D. Larson (Lawrence Livermore National Laboratory).