Abstract

Plasma-magnetic field interactions are typically unstable. Under certain circumstances, the plasma can penetrate the magnetic field. In many situations such as the closure of magnetically insulated transmission lines, the structuring of nebular plasma in the Crab Nebula, and the penetration of solar wind plasma into the Earth's magnetic field, this effect is poorly understood or not widely agreed upon.

To study plasma penetration due to the presence of instabilities, experiments were performed by coupling together the Zebra pulsed power generator and an ablation laser. Zebra was employed to produce a magnetic field by passing a current pulse through an electrode. An ablation laser was employed to produce a plasma by heating a target. Using this experimental setup, several plasma penetration regimes were investigated by altering the electrode configuration to change the magnetic field topology and strength, and the parameters of the ablation laser to change the characteristics of the plasma flow.

Employing this setup, the interaction between a laser-produced plasma and a non-uniform applied magnetic field was investigated. Two effects were studied which allowed the plasma to penetrate the field. First, the growth of flutelike instabilities was investigated. Flutelike instabilities have the property $\vec{\mathbf{k}} \cdot \vec{\mathbf{B}} = 0$, where $\vec{\mathbf{k}}$ is the wavevector and $\vec{\mathbf{B}}$ is the magnetic field vector. The flutelike instabilities known as the large Larmor radius Rayleigh-Taylor instability, and the lower-hybrid drift instability, were observed to grow as the laser-produced plasma was decelerated by the magnetic field. In the nonlinear phase of growth, the plasma flow evolved into a directed flow that crossed the field at a constant velocity due to $\vec{\mathbf{E}} \times \vec{\mathbf{B}}$ drift. The second effect, not previously studied in the laboratory, investigated an explosive plasma flow that was converted into a directed flow by the external magnetic field. The directed flow penetrated the magnetic field due to $\vec{\mathbf{E}} \times \vec{\mathbf{B}}$ drift.

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