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Interfacial magneto-hydrodynamic instabilities in astrophysical and laser plasmas

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Interfacial instabilities, such as Rayleigh-Taylor and Kelvin-Helmholtz instabilities, are of crucial importance in a variety of applications including astrophysical phenomena, inertial confinement fusion, and laboratory experiments. Driving engine of the unstable motions of the interface is vorticity. Richtmyer-Meshkov instability (RMI) is also categorized in the interfacial instabilities. The RMI occurs when an incident shock strikes a corrugated contact discontinuity separating two fluids with different densities. Because of the corrugation of the interface, the surface profiles of the transmitted and reflected shocks are also rippled. The RMI is driven by the vorticity left by these rippled shocks at the interface and in the fluids.

One of the urgent and curious questions related to the RMI is the interaction with a magnetic field. A strong shock wave traveling through the density inhomogeneity of magnetized interstellar medium is a promising site of the RMI. Recent laboratory experiments are designed to test the magnetic field amplification due to the RMI by the use of laser-induced shock waves. In inertial confinement fusion, the RMI excited at several capsule interfaces amplifies the perturbations that seed the Rayleigh-Taylor instability. For the fast ignition approach, the utilization of an external magnetic field to guide the fast electrons is discussed proactively and sheds light on the impact of MHD instabilities during the implosion.

The inclusion of a magnetic field brings two important consequences into the RMI, which are the amplification of an ambient field and the suppression of the unstable motions. The magnetic field can be amplified by the stretching motions at the interface associated with the RMI [1]. It has also shown that a strong magnetic field inhibits the nonlinear turbulent motions of the RMI. The vorticity generated by the interaction between a shock front and a corrugated contact discontinuity is the driving mechanism for the RMI. For the cases of MHD parallel shocks, the role of the magnetic field is to prevent the deposition of the vorticity on the interface, and stabilize the RMI [2,3]. It is found that these evolutions of the RMI is well characterized by the Alfven number, which is the ratio between the Alfven speed and the linear growth velocity of the instability.

We have performed laser experiments by using GEKKO laser in Osaka University to evaluate the growth of RMI in magnetized plasmas. The instability is triggered by laser-driven shock wave. An interface forms a CH foil with surface modulation and nitrogen gas. A permanent Neodymium magnet is installed near the target, which gives a weak seed magnetic field.

The growth of the interface perturbation is observed by optical radiography and the growth velocity is measured from the time evolution of the mixing layer. The strength of the seed field is much weaker than the critical value which is defined as the Alfven number is unity. The initial field is not enough to suppress the RMI and then can be amplified effectively due to the stretching of the interface. We could successfully measure the signal of the amplified field by B-dot probe, which shows the distinct difference between the RMI growing case and no turbulence case.

Characteristics of the magnetic evolutions of RMI are discussed in details based on our experimental results including the dependence on the laser intensity, modulation wavelength, and etc. We will also review the current status and future work of the researches of interfacial instabilities in high energy density [4].

References

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