Magneto Rayleigh-Taylor Instability in Dense Plasmas

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Experiments, theory and simulations have been performed on the magneto-Rayleigh Taylor (MRT) instability in dense plasmas. Experiments are performed utilizing a 1-MA, 100 kV Linear Transformer Driver (LTD) at the University of Michigan. Peak currents of 0.6-0.7 MA are driven through 400 nm-thick Al foils with 150 ns risetime. Data show that at early times, the initial instability growth is due to short-wavelength electrothermal instability of the foil ablation. At later times, the wavelength increases and the magneto-Rayleigh-Taylor instability dominates. Exponential growth rates are compared with theory and MHD simulations of MRT instability. Seeding of MRT instability wavelengths is performed by laser micromachining of foils.

Introduction

The magneto-Rayleigh Taylor instability [1] is ubiquitous in nature, e.g., the Crab Nebula [2]. It also plays a role in plasma concepts, such as imploding liners to achieve magnetic field compression and heating of dense plasmas. The driving force for the instability is a light fluid (magnetic field pressure) that accelerates a heavy fluid (plasma). The magnetic pressure should therefore exceed the plasma pressure, requiring high magnetic fields and therefore high currents. In recent years, the development of compact Linear Transformer Drivers (LTDs) has made 1-MA, 100-kV generators within the reach of university laboratories.[3] By passing MA currents through thin metal foils, the magnetic pressure may be made to accelerate the plasma in such a way as to drive the Magneto-Rayleigh Taylor instability.

Experimental Configuration

The simplified experimental configuration is depicted in Figure 1. The current from the LTD generator is transmitted to the foil load by a magnetically-insulated transmission line. Some 0.6-0.7 MA of current is conducted through a 400 nm-thick Al foil (1-cm by 2-cm) with return current divided between two parallel anode plates. When the foil is centered between the anode plates there is zero net plasma acceleration. However, when the foil plasma is offset, there exists a net plasma acceleration towards the center that drives the magneto-Rayleigh Taylor instability. Shadowgraphy is performed with a sub-ns laser to investigate instability growth at the edges of the expanding plasma. A time sequence of shadowgrams is used to construct the Fourier spectrum and growth rate of instabilities.

Experimental Results

Figure 2 presents a sub-ns laser shadowgram of the magneto-Rayleigh Taylor instability of the expanded foil plasma at a late stage of development (~200 ns). Fourier analysis of the plasma edge verifies that there exist two dominant instability wavelengths: 1) a short wavelength component that arises from the electrothermal instability of the foil during vaporization, and 2) The longer wavelength component that develops later in the plasma evolution due to Magneto-Rayleigh-Taylor instability. Exponential growth rates of the longer wavelength instability have been found from a series of such shadowgrams that are consistent with the theory of magneto-Rayleigh Taylor Instability.

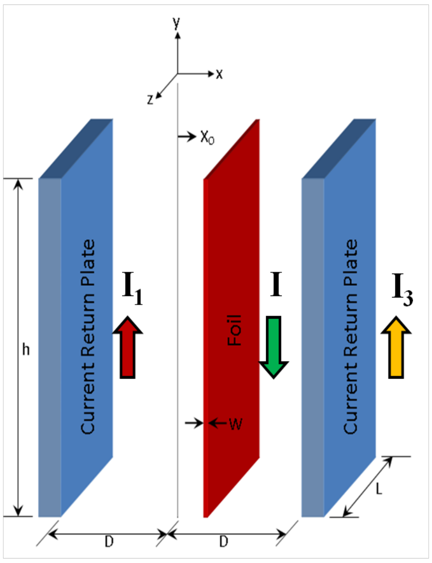

Figure 1.
Simplified experiment.

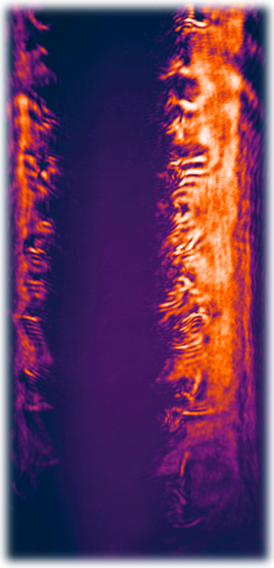

Figure 2. Laser shadowgram of MRT in ablated foil plasma (~200 ns).

<u>References</u>

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