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DISCLAIMER

EXPERIMENTAL INVESTIGATION OF THE CLASSICAL RAYLEIGH-TAYLOR INSTABILITY

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The evolution of the Rayleigh-Taylor (RT) instability in a compressible medium has been investigated at an accelerating embedded interface and at the ablation front in a series of experiments on the Nova laser. The x-ray drive generated in a gold hohlraum ablatively accelerated a planar target consisting of a doped plastic pusher backed by a higher density titanium payload with perturbations placed at the plastic-Ti interface. The targets were diagnosed by face-on and side-on radiography. In previous work focusing on single mode perturbations, wavelengths as short as 10 m have been observed to grow strongly at the embedded interface. Here multimode perturbations consisting of either 2, 10 or 20 modes superposed in phase have been investigated.

1 Introduction

One of the critical concerns for inertial confinement fusion is the Rayleigh-Taylor (RT) instability. At an ablation front, growth of short wavelength modes is stabilized. However, short wavelength modes have been shown to grow strongly at an embedded interface.[1] This work examines the growth of perturbations consisting of multiple modes superposed in phase at an embedded interface.

2 Experimental results

The experimental configuration is described in detail elsewhere [1,2] and consists of a planar experimental package mounted across a hole on a 3 mm long by 1.6 mm diameter gold hohlraum. Eight Nova beams at $\lambda = .351\ \mu$m are used to generate a 3.5 or 4.5 ns shaped x-ray drive. The accelerating target is back-illuminated with 6.7 keV He-α x-rays generated by the remaining two Nova beams at $\lambda = .528\ \mu$m, smoothed with 5 mm hexagonal element random phase plates, incident on an iron disk. Images are obtained with a gated x-ray framing camera, the flexible x-ray imager (FXI).[3] Each image is converted to $\ell n(\text{exposure}) \propto -\text{OD} = -\int \rho\kappa dz$, where ρ is density and κ is opacity, and analyzed by Fourier decomposition. The planar experimental packages consisted of a 40 μm thick brominated plastic ablator ($C_{50}H_{47}Br_3, \rho = 1.26$ g/cm^3)

backed by a 15 μm thick Ti payload ($\rho = 4.5$ g/cm^3).

Experimental data are presented for three perturbation profiles. The first profile consisted of a two-mode patttern corresponding to the superposition of $\lambda = 10$ μm and $\lambda = 15$ μm, each with an amplitude of $\eta_o = 1$ μm, superposed in phase. As the growth of these two modes proceeds into the nonlinear regime, defined as when the amplitude to wavelength ratio is no longer small ($k\eta \geq .1$), the two modes couple producing beat modes. The $k_+ = k_{10} + k_{15}$ mode corresponds to a wavelength of $\lambda_+ = 6$ μm which is below the experimental resolution (≈ 8 μm) but the $k_- = k_{10} - k_{15}$ corresponding to a wavelength of $\lambda_- = 30$ μm which is readily diagnosable. Figure 1 shows the amplitude (in ℓn(exposure)) for the 10, 15 and 30 μm modes.

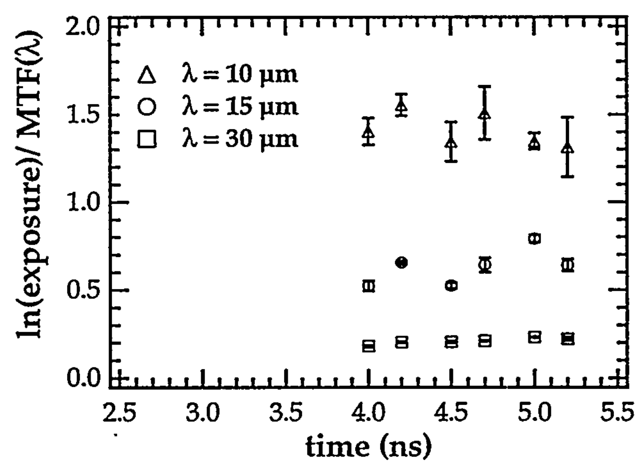

Figure 1: Experimental data and calculations for the growth of $\lambda = 10$ μm and $\lambda = 15$ μm superposed in phase. The growth of the $\lambda_- = 30$ μm beat mode is also shown.

Motivated by the experimental observation that growth of the shortest wavelengths was strongest,[1] the next profile studied was the superposition of two extremely short wavelengths ($\lambda = 4$ and 5 μm), each below the experimental resolution. In this case their growth is diagnosed solely by the appearance and subsequent growth of the $k_- = k_4 - k_5$, $\lambda_- = 20$ μm beat mode. The amplitude of this mode as a function of time is shown in Figure 2. Simulations predict linear growth factors of ≈ 22 and 40 for the 5 and 4 μm modes respectively at t = 4.5 ns, when the $\lambda = 20$ μm mode is first observed in the data.

One of the goals of this work is to demonstrate the onset of an *inverse*

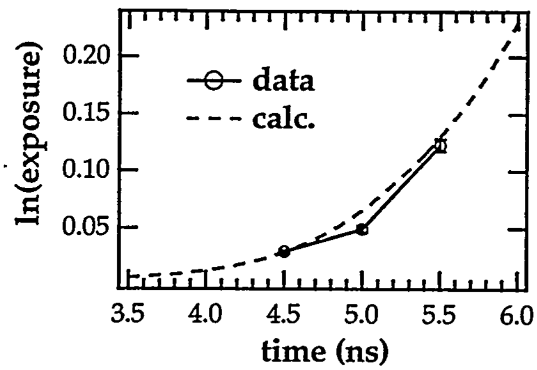

Figure 2: Experimental data and calculation for the growth of the $\lambda_{-} = 20\ \mu m$ beat mode.

cascade in the late nonlinear regime where the mode coupling has proceeded to fill in all mode space and longer wavelength structures are beginning to dominate the flow. A first attempt at an inverse cascade experiment was made by placing a large band of modes, modes 1 through 20 with a fundamental wavelength of $\lambda = 200\ \mu m$, at the embedded interface. The actual perturbation profile used and an image from the "raw" experimental data are shown in Figure 3.

In each case the solid curves represent calculations done using the 1-D radiation hydrodynamics code HYADES[4] to generate the gross foil motion and the time-dependent parameters generated were used in an analytic model to predict perturbation growth in the linear regime, with a correction for the finite layer thickness of the titanium. The nonlinear calculations utilized a model derived using third order perturbation theory.[5]

3 Summary

We have investigated the growth of multimode perturbations at an RT-unstable embedded interface. Two-mode initial perturbations showed the appearance of beat modes as their growth proceeded into the nonlinear regime. The growth of two modes which were both below the experimental resolution was diagnosed by the appearance and subsequent growth of the $\lambda_{-} = 20\ \mu m$ beat mode. Targets with a multimode perturbation will allow us to investigate the prediction of an *inverse cascade*, or trend toward longer and longer wavelength structures dominating the flow.

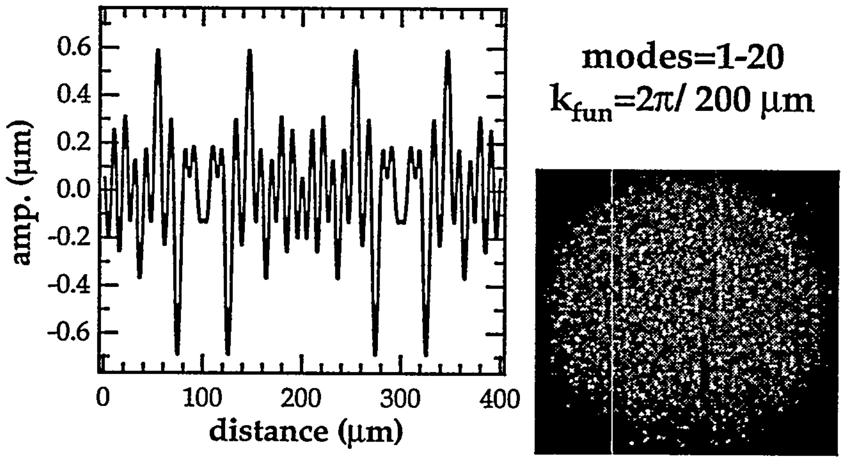

Figure 3: Multimode perturbation consisting of a band of 20 modes (modes 1-20, fundamental $\lambda = 200\ \mu$m) superposed in phase. The experimental image shown was obtained at t = 4.6 ns after the initiation of the laser drive.

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