*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, D-5.002 (2007)*

Investigation on Laser-driven RT Instability Using Soft X-ray Laser

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Abstract:

The experiment of laser-driven Rayleigh-Taylor (RT) instability on Shenguang II (SG-II) facility has been presented. A Ni-like silver soft x-ray laser at 13.9nm has been used as a probe to take radiography of the modulation target RT instability first time. The modulation target is irradiated by a laser beam at 527nm of wavelength, 1500J of energy and 2.4ns of pulse width (FWHM), which is focused to intensity of 4×10^{14}Wcm^{-2} on the target by a lens array. The evolvement of RT instability has been observed clearly. The results obtained by numerical simulation agree with that given by experiments.

1. Introduction

In inertial confinement fusion (ICF), the study of the Rayleigh-Taylor (RT) instability is an important issue[1],[2]. It can induce the ablation front (the “pusher”) material mix into the DT nuclear fuel, degrading performance[3-6]. Experiments to measure mix directly in implosions are difficult, typically relying on spectroscopy of secondary neutrons[6] and x-ray tracer layers[7] to signal the onset of mix. For single-layer targets, the RT instability is diagnosed usually by x-ray radiography. The result is not ideal on the aspects of special distinguish and clarity.

Since the x-ray laser (XRL) have the characteristics of short pulse, high flux and coherent, it is suitable for single shot imaging of transient phenomena[8],[9]. In this paper, we reported a new method of measuring the RT instability. Using the Ni-like XRL at 13.9nm wavelength as a probe, the temporal evolution of RT instability has been observed clearly.

2. Experimental setup

The experiment was performed at Shenguang II (SG-II) laser system. The experiment setup is show in Fig.1. Two laser beams (No.1 and No.7 laser beam) were line-focused by cylinder lens array (LA) system, radiated on coupled double silver-coated glass targets. It created the saturated Ni-like 13.9nm XRL[10]. Each beam was at 1053nm wavelength, delivered 100J energy onto target. There was a pre-pulse with a contrast ratio of about 5% 3ns before the main pulse. The main pulse duration was 90ps. The duration of the XRL was about 30ps. It contained 450 μJ energy. In this experiment, the XRL was the probe beam.

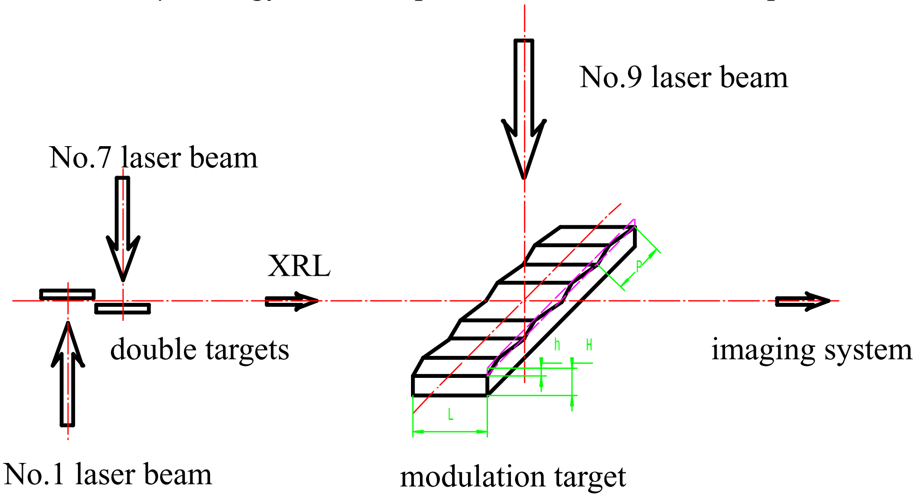

Figure 1. Experimental setup. Two laser beams (No.1 and No.7 laser beam) were employed to create the XRL. The RT instability plasma was produced by irradiating the No.9 laser beam onto a modulation target.

The nanosecond laser beam (No.9 laser beam) was employed to create the RT instability plasma by irradiating onto a modulation target. The frequency doubled nanosecond laser has a central wavelength of 527nm. The pulse duration was 2.4ns. Using lens array, it irradiated uniformly on a field with a diameter of 350μm. The modulation target was made in CH. A H-thickness, L-width CH film was eroded cosine periodically. The period was P, amplitude (peak to valley) was h. Typically, L~200μm H~20μm P~50μm h~4μm.

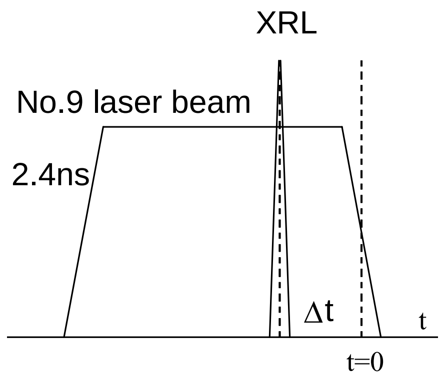

Figure 2. Time relationship. The No.9 laser beam has a duration of 2.4ns. Setting the middle of the decline time zero, the time that the XRL reaching the modulation target was Δt.

The XRL passed through along the modulation groove. The radiograph was gathered by a soft x-ray CCD. The time relationship of the XRL reaching the modulation target and the nanosecond laser beam radiating on the modulation target was shown in figure 2. Adjusting the time delay Δt, different evolution status images of RT instability have been gotten.

3. Experimental results and simulation

A series experiment results has been acquired (Fig.3.), which indicate the information of RT instability evolution. The experiments used the typical parameter modulation targets, the close drive conditions (the pulse duration was 2.4ns, the energy contained was about 1500J, the pulse shape like that showed in Fig.2, the laser beam irradiated from the left side of the target). The difference was the time delay Δt (see Fig.2). Figure 3 shows the results with Δt equal -1050ps, -650ps, -250ps, 0ps, 150ps, respectively. When Δt=-1050ps, the distance of acceleration was short. It was just 65μm. So the spikes and bubbles didn't developed sufficiently. As Δt=-650ps, 250ps and 0ps, the accelerating distance became bigger, so the spikes and bubbles increased. Finally (Δt=150ps) the spikes and bubbles mixed. The temporal evolution process that the bubbles and spikes produced, grow, and disappeared was clear.

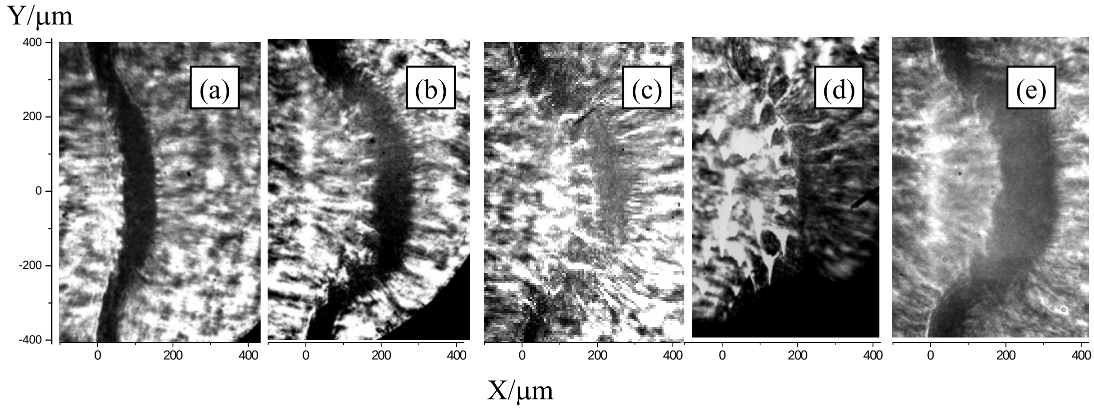

Figure 3. Temporal evolution of the RT instability. (a) Δt=-1050ps, the spikes and bubbles were not clear. (b) Δt=-650, (c) Δt=-250ps, (d) Δt=0ps, they developed. (e) Δt=150ps, the spikes and bubbles mixed.

Figure 4 revealed an RT instability radiograph and the simulation result. The radiograph was taken at Δt=0, 1030J driven energy. The simulation was carried out on LARED-S, which was a two-dimensional code. The simulation conditions which were close to the experiments were shown as below. The laser energy was 1030J. The wavelength was 527nm. The pulse duration was 2.4ns. The focus was 275μm diameter, guass shaped. The simulation results agreed well with the experiments. Because the laser focus modulation period was longer than the target, they would couple nonlinearly. It was clear on the edge of the laser focus, the spikes and bubbles were lean, namely, the modulation period become bigger.

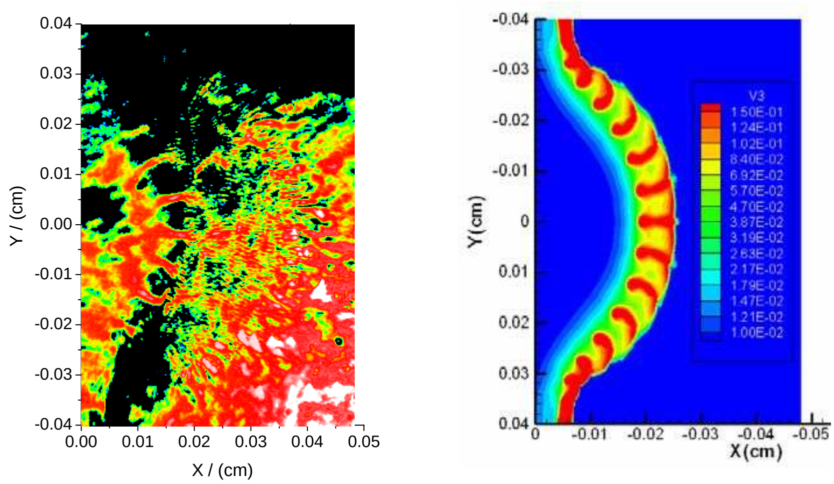

Figure 4. Contrast of a radiograph taken at $\Delta t=0$ and a simulation result.

4. Summary

We have presented a new method of measuring the laser-driven RT instability. By the XRL radiograph, we have measured the evolution of the laser-driven RT instability. The development of the spikes and bubbles was seen clearly. The simulations taken on LARED-S agree well with the experiments.

5. Acknowledgements

The authors would like to thank all the members of SG-II operation group, whose excellent works made the experiments go on wheels. We also thank Tongji physics for providing the targets and filters.

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