CONF. 9606 229--1

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JUN 24 1996

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This paper was prepared for submittal to the
24th European Conference on Laser Interaction with Matter
Madrid, Spain
June 3-7, 1996

May 30, 1996

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MEASUREMENTS OF LASER IMPRINT BY XUV RADIOGRAPHY USING AN X-RAY LASER

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We have developed a technique for studying the imprint of a laser beam on a thin foil using an x-ray laser as an XUV backlighter and XUV multilayer optics. This technique allows us to measure small fractional variations in the foil thickness due to hydrodynamics imprinted by direct laser irradiation. We present results of imprinted modulation and growth due to a low intensity $0.53\text{ }\mu\text{m}$ drive beam incident on a $2\text{ }\mu\text{m}$ Al foil using a germanium x-ray laser at the Vulcan facility. We present measurements of the modulation due to static RPP, SSD smoothed, and ISI smoothed speckle patterns at $0.53\text{ }\mu\text{m}$ irradiation.

1 Introduction

In direct drive Inertial Confinement Fusion, high intensity laser beams directly irradiate the outside of a hollow spherical capsule that contains a layer of solid fusible D-T in its inner surface. For ignition scale targets, the laser pulse starts at low intensity 'foot' at 10^{13} W/cm^2 for several nanoseconds before it builds up to more than 10^{15} W/cm^2 during the main drive portion of the pulse. Laser heating of the capsule surface results in an ablation pressure that accelerates the capsule shell radially inward in a spherical implosion. During this acceleration, perturbations due to surface roughness and due to imprint from spatial non-uniformities in the laser irradiation undergo Rayleigh-Taylor growth, potentially severely degrading performance.

We have used an x-ray laser for XUV radiography to characterize the modulations in optical depth of a thin foil due to laser imprint and subsequent Rayleigh-Taylor growth. Preliminary experiments were done using an yttrium x-ray laser backlighter on Nova to characterize the imprint due to $0.35\text{ }\mu\text{m}$ laser irradiation of a $3\text{ }\mu\text{m}$ Si foil^{1,2,3}. We have extended these experiments using a Ge x-ray laser backlighter on the Vulcan laser. We characterized the imprint and subsequent Rayleigh-Taylor growth of modulations due to $0.53\text{ }\mu\text{m}$ laser irradiation of a $2\text{ }\mu\text{m}$ thick Al foil at $2\text{-}8 \times 10^{12}\text{ W/cm}^2$. In this paper we describe some results from the experiments conducted at the Vulcan laser facility.

2 XUV Radiography of laser imprint

We generated a Ge J=0-1 x-ray laser at 19.6 nm using six beams of the Vulcan laser. We placed a thin ($2\text{ }\mu\text{m}$) Al foil about 3 cm from the output of the Ge x-ray laser. We then used two multilayer mirrors to image the Al foil in the x-ray laser wavelength onto an XUV sensitive CCD; a 1 m spherical mirror at near normal incidence, and a flat mirror at 45° incidence, as shown in Figure 1. The spherical mirror was placed 53 cm from the Al foil, providing a 16X magnified image of the foil on the CCD, and the 45° angle of incidence planar mirror was used to relay the image onto the CCD and spectrally isolate the image from the thermal background noise.

Figure 1: Geometry for the x-ray laser target and XUV imaging system used to measure the modulation in optical depth of a thin Al foil due to direct drive laser imprint.

We used a single Vulcan laser beam with a static random phase plate speckle pattern, SSD smoothed speckle pattern, and ISI smoothed speckle pattern to imprint on the Al foil. We characterized the imprinted modulation as a function of time with the different smoothing schemes.

3. Results and Discussion

In Figure 2, we show optical far field images of the single beam laser focal spot used in these experiments. This figure shows intensity modulation of a) a static RPP speckle pattern, b) a 1-D SSD smoothed speckle pattern, and c) for an ISI smoothed RPP speckle pattern.

Figure 2: Far field images of the laser focal spot. The scale is in microns at the target.

We irradiated the $2\text{ }\mu\text{m}$ thick Al foils directly by an intensity of $3\text{--}8 \times 10^{12}\text{ W/cm}^2$ of $0.53\text{ }\mu\text{m}$ laser light using the three speckle patterns, and we recorded the modulation in optical depth in the foil due to laser imprint and subsequent Rayleigh-Taylor growth using the Ge x-ray laser backlighter. We show XUV radiographs of the modulation in optical depth in the Al foil in Figure 3, recorded at 0.2 ns into the laser pulse.

Figure 3: Modulation in optical depth of an Al foil irradiated by a) a static RPP speckle pattern, b) a 1-D SSD smoothed speckle pattern, and c) an ISI smoothed speckle pattern, all at $0.53\text{ }\mu\text{m}$.

Power spectra for the imprinted modulation measured in these images are shown in Figure 4. The integrated RMS modulations in optical depth we measured from these XUV radiographs were 0.37, 0.17, and 0.20. The RMS measured from undriven Al foil targets was about 0.13. This corresponds to a surface roughness of about 60 nm on the Al foil.

We show the RMS modulation in optical depth as a function of time recorded by XUV radiography in Figure 5. This figure shows that the modulation imprinted due to a static speckle pattern grows faster than for a smoothed speckle pattern. The SSD smoothed case shows a strong reduction in the modulation, but it still grows late in time. The ISI smoothed beam, however, does not show significant growth at any time up to 0.8 ns.

Figure 4: Power per mode calculated from the XUV optical depth modulation measured from the radiograph images shown in Figure 3.

Figure 5: RMS modulation in optical depth of the Al foil measured as a function of time for the static, SSD smoothed, and ISI smoothed drive beams.

4 Summary

We demonstrated measurements of the modulation imprinted by low intensity $0.53 \mu\text{m}$ irradiation of a thin Al foil using the Ge x-ray laser at the Vulcan laser facility. We measured the imprinted modulation and subsequent Rayleigh-Taylor growth in the foil as a function of time with various laser smoothing schemes.

5 Acknowledgements

This work was partially supported by the Lawrence Livermore National Laboratory under the auspices of the U.S. DOE under Contract No. W-7405-ENG-48. EW was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung under Project No. P10844 NAW.

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