HIGH Z INTERACTION PHYSICS ON NOVA*

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ABSTRACT

A detailed understanding of the interaction of laser light with high Z materials is important for the development of indirect drive inertial confinement fusion. To improve our understanding of the interaction of 0.35 μm light at intensities between 10^{14} and 10^{15} W/cm^2 with high Z materials, we have performed a variety of experiments to address important physics issues. Hydrodynamics and ablation, transport processes, and x-ray conversion have been studied with thin Au dot targets and Au and Be mixture targets.

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INTRODUCTION

The conversion of laser light to x rays is a critical step in indirect drive laser fusion. We have completed several experiments on the Nova laser at LLNL to address important physical issues in this process. A simple view of the interaction of laser light and high Z materials can be described in terms on the energy flow from the laser light absorption region near the critical surface. Much of the laser light absorbed is transported into the target to higher density, lower temperature material where some of this energy is radiated as soft or thermal x rays and some is lost into heating the target material. The heated material ablates and moves towards the lower density and higher temperature region away from the target surface (corona). The high temperature causes significant emission of multikilovolt x rays (e.g. M-band emission in Au). The thermal x rays are important for driving indirect drive fusion targets. An important parameter is the x-ray conversion efficiency, the fraction of absorbed laser radiation converted into thermal x rays.¹ The multikilovolt x rays may also contribute to the drive, but they may also be a source of target preheat and degrade the performance of a target, depending on the target design.

It is obvious that in high Z interaction experiments the interplay between atomic physics, radiation transport, thermal transport, hydrodynamics and laser absorption is complicated.¹ We have attempted to design experiments to address several aspects of this problem and increase our understanding of the conversion of absorbed laser light into x rays in high Z materials. In this paper we will discuss the preliminary results of two experiments: thin dot experiments and Au:Be mixtures on dilution experiments.

THIN DOT EXPERIMENTS

A thin dot target consists of a 500 Å thick 300 μm diameter dot of gold surrounded by plastic in the shape of a flat disk (Fig. 1). The large differences in x-ray emission (thermal and M-band) between the plastic and the gold allows us to follow the heating, ablation, and expansion of the gold dot with x-ray measurements. The 2 μm of plastic in front of the gold serves to erode the rising edge of the flat topped laser pulse. From our measurements of the gold x-ray emission, we can measure the mass ablation rate of this material. A decrease in the thermal emission of the gold should occur when the laser burns through the dot and this yields a measure of the ablation rate of this material.

In addition to the ablation rate measurements, imaging the gold x-ray emission allows us to follow the expansion of the gold down the density gradient, a direct measure of the hydrodynamics of the expansion of an inner, as opposed to a surface zone, of material. All of these experiments were performed on the Nova laser with 1500 J of 0.35 μm light in a 2 ns square pulse at 4×10^{14} W/cm².

A Wolter x-ray microscope (22 times magnification) was used to image the 2-3 keV emission from the thin dot targets. Viewing the target from the side and streaking the emission (Fig. 2), we can see a distinct change in the slope of the emission ~840 ps after the start of the laser pulse. This corresponds to the ablation of the gold and a burn through of the plastic and is in good agreement with calculations of the mass ablation rate of the plastic. The expansion velocity of the gold was measured to be 1.6×10^7 cm/s. A transmission grating streaked spectrograph also viewed a dot target. The M-band emission was delayed from the start of

the laser pulse and the low energy x-ray emission which was consistent with the streaked x-ray microscope data. Null experiments were performed on pure CH and Au targets to demonstrate that this effect was due to the presence of the dot.

DILUTION TARGETS

By varying the relative concentration of Au in Be materials can be created that have constant atomic constituents but dramatically different transport properties, e.g., radiative opacity. For Au and Be mixtures in these experiments the Be disk targets made of the material were produced using co-sputtering. Pure Be, 1/500, 1/100, 1/20 (atomic fraction of Au in Be), and pure Au targets were used. Beryllium is a very simple material which fully ionizes easily and radiates weakly, therefore, it acts to dilute the more complex gold which produces a very complex spectrum. Disk targets were irradiated with 1600 J of 0.35 μm laser light in 1 ns pulses. The experiments were diagnosed in details to study the total energy balance in the experiment as summarized in Fig. 3. The present discussion will be limited to our preliminary results of the soft x-ray spectrum and gold M-band emission.

The Dante soft x-ray spectrometer is a multichannel filtered x-ray diode array.² The data from this instrument can be unfolded to give a time averaged thermal x-ray spectrum. Figure 4 shows the change in the soft x-ray spectrum as a function gold concentration in the target. The area under these curves is proportional to the x-ray conversion. From this data we can see that the x-ray conversion efficiency falls off more

slowly that the gold concentration, clearly demonstrating the importance of opacity effects. Detailed comparisons to calculations are in progress.

Significant changes in the gold M-band emission occur as the gold concentration of the target is varied for otherwise identical experiments (Fig. 5). The gold emission for a 1/100 mixture shows much better defined edge features and indications of a different ionization state distribution than a pure gold target. Because of the low gold concentration in the target, the M-band x rays can penetrate the target. This spectrum (Fig. 5) is a convolution of the laser generated x rays and absorption of the target material.

CONCLUSIONS

We have recently completed two experiments that address the basic physics issues important to understanding the conversion of absorbed laser light into x rays. Thin gold dot experiments have measured mass ablation rates and the subsequent hydrodynamic expansion of gold. Dilution experiments have addressed the issue of transport phenomena by fixing the atomic constituents of the material and varying the concentration. A more detailed analysis of the data is underway and will lead to an improved understanding of these processes.

REFERENCES

1. W. C. Mead et al., "Laser Irradiation of Disk Targets at 0.53 μm Wavelength," Phys. Fluids 26, 2316 (1983) and references.
2. H. N. Kornblum and R. L. Kauffman, "Measurement of 0.1 to 3 keV X Rays from Laser Produced Plasmas," Rev. Sci. Instr. 57, 2179 (1986).

FIGURE CAPTIONS

1. A schematic of a thin dot target. The gold dot is surrounded by plastic. The laser burns through the 2 μm plastic overcoat to expose and heat the gold.
2. A streaked image of the 2 to 3 keV emission from a thin Au dot target. The change in slope occurs when the gold is heated and expands into the corona.
3. An overview of the measurements used to study the dilution targets. The emphasis in these experiments is to understand the total energy balance in the experiments.
4. The change in x-ray spectrum as a function of gold concentration in Au:Be mixtures. This measurement was performed with the Dante soft x-ray spectrometer.
5. Sample time integrated Au M-band spectra; a) 1/100 Au:Be mixture, b) 1/100 Au:Be mixture (transmitted) and c) a pure Au.