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X-RAY IMAGING TO CHARACTERIZE MeV ELECTRONS PROPAGATION THROUGH PLASTIC TARGETS

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ABSTRACT

A high intensity laser pulse incident on an overdense plasma generates high energy electrons at the critical surface which propagate into the plasma. The details of this propagation are critical to the fast ignition process. The energetic electrons emerge as a jet on the far side, but the spread and propagation direction of the jet within the plasma is not well known. By embedding several thin high-Z layers in a CH film, one can directly image the progress of the electron beam. It loses enough energy to heat the medium through which it travels to hundreds of electron volts. At that temperature, a gold film buried under CH emits sufficiently hard thermal x-rays to allow imaging the heated area with an x-ray pinhole camera. The film can be thin enough to also see the emissions from another layer near the front of the film. If these two images are visible simultaneously, one can measure the beam spread and propagation direction within the plastic.

1. INTRODUCTION

The fast ignition (FI) inertial fusion concept [1] depends critically on converting the energy in the laser ignition pulse to a stream of ~1 MeV electrons and propagating them through a dense plasma to heat a compact spot in the target. Conversion of the energy carriers from photons to electrons is required because the plasma becomes opaque at a density of ~1 g/cc, considerably before it reaches the >200 g/cc ignition volume. For these densities, the plasma frequency, below which the plasma is strongly absorbing, is in the x-ray range [2]. To date, the direction of energy transport within such plasmas has been largely assessed by looking at the jets emerging from the back of a foil up to a few hundred microns thick [3]. These jets are seen to propagate normal to the back surface; some data shows that this is independent of the direction of the incident photon beam or the orientation of the front surface [4]. Some modeling suggests that the diameter of these jets is strongly decreased by the presence of the back surface [5]. So we need a more direct measure of the beam propagation in dense plasmas; one which can be used away from sample surfaces.

2. EXPERIMENTAL SETUP

The low x-ray cross section of carbon relative to higher *Z* elements offers a possible solution to this problem. At 1 keV, the minimum detectable x-ray energy for the pin hole camera (the low energy limit for the x-ray pinhole camera is ~1 keV because of the ~1 μm thick beryllium foil protecting the film from light), the x-ray absorption length is ~6 μm in CH, rapidly increasing with energy [6]; high-*Z* elements absorb up to 60 times more strongly (*Table 1*). This enables the use of films so thin that their low resistance will not perturb the high energy electrons or their return current [7]. A film of gold only 0.1 μm thick is already 30% opaque and will emit 30% of black body radiation. This radiation would be only slightly attenuated in exiting the CH film. Moreover, a second buried film would be visible under the first with only another 30% attenuation of its signal (Fig. 1).

Table 1: 1 keV x-ray absorption lengths for selected elements. A foil of, *e.g.*, Au only a few tenths of a micron thick could radiate brightly through 100 microns of CH. (CH absorption calculated assuming a C density of 1 g/cc.)

Element	**Absorption Length**		
	1	**2**	**4 keV**
CH	5	33	270 μm
Aluminum	3.1	1.2	10.0
Molybdenum	0.2	1.0	1.0
Iron	0.1	0.8	4.8
Tantalum	0.1	0.2	0.6
Silver	0.1	0.7	0.7
Manganese	0.2	0.9	6.0
Nickel	0.1	0.5	3.4
Copper	0.1	0.5	3.1
Gold	0.1	0.5	0.4

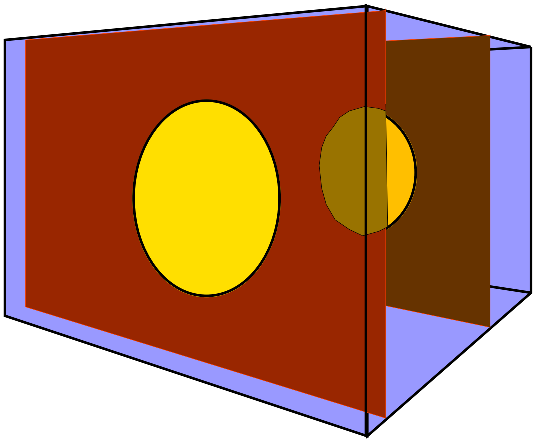

Fig. 1. Schematic of target foil with two high-*Z* tracer layers embedded in CH. It is viewed from behind with the laser impinging on the far side. The tracer layers are thin enough to be partially transparent, so both spots can be seen by the x-ray camera.

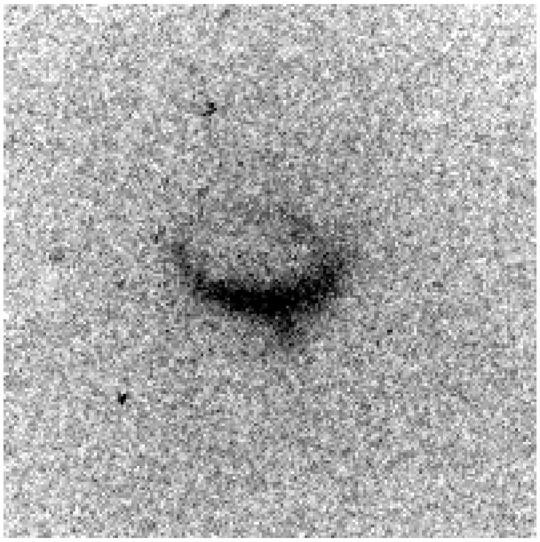

Fig. 2. x-ray image from the back of a 100 μm CH foil backed with 0.5 μm Au/5 μm CH, and viewed through 100 μm CH filter in addition to the standard 1 μm Be foil (No. 29041209). A CH foil without a high-*Z* layer does not show any image.

It has in fact provedz possible to look at the beam structure by adding a 0.5 μm gold or aluminum tracer layer buried under a CH surface. Koch *et al.* [8] have demonstrated that the passage of high energy particles through the film deposits energy (either directly or through the associated return current) which heats the film sufficiently to be visible through >100 μm of CH (Fig. 2).

So one can set up the geometry shown in Fig. 1. A foil with two tracer layers, one near the front of a foil, and one near the back, would give images which are self-referencing. With one image showing the initial spot location, size, and structure, one can get beam direction, structural evolution, spread as it propagates through the foil. There is substantial shot-to-shot variation, and shot locations are not precisely determined *a priori* so that this information is not easily acquired with single tracer layers on successive shots. In addition, these foils can be some distance from the front or back surface, and we can see the character of the beam away from the perturbing surfaces.

3. SUMMARY

In conclusion, we have shown high-*Z* multiple tracer layers will enable tracking high energy electron beams within an overdense CH plasma far from the plasma boundaries. These foils can be so thin that they should cause minimal perturbation to the propagation of the beam. This will allow determination of the high energy electron direction and beam spread and investigation of the effects of boundaries on their structure.

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