BEAM-TARGET INTERACTION EXPERIMENTS FOR BREMSSTRAHLUNG CONVERTER APPLICATIONS*

S. Sampayan, G. Caporaso, Y-J Chen, S. Falabella, , D. Ho, T. Houck,
E. Lauer, J. McCarrick, R. Richardson, D. Sanders, and J. Weir

Lawrence Livermore National Laboratory, Livermore, California 94550 USA

Abstract

The DARHT II accelerator uses a pulsed high current electron beam and Bremsstrahlung converter target to generate an intense x-ray source for radiography. For the past several years, we have been performing an investigation of the possible adverse effects of (1) backstreaming ion emission from the Bremsstrahlung converter target and (2) the interaction of the resultant plasma with the electron beam during subsequent pulses. These effects would manifest themselves in a static focusing system as a rapidly varying x-ray spot. To study these effects, we are conducting beam-target interaction experiments on the ETA-II accelerator (a 6.0 MeV, 2.5 kA, 70 ns FWHM pulsed induction LINAC). We have determined spot dynamics and characterized the resultant plasma for various configurations. Our experiments show that the first effect is not strongly present when the beam initially interacts with the target. Electron beam pulses delivered to the target after formation of a plasma are strongly affected, however. We have also performed initial experiments to determine the effect of the beam propagating through the plasma. This data shows that the head of the beam is relatively robust, but that backstreaming ions from the plasma can induce a dynamic focus toward the tail of the beam. We survey the results of our experiments and attempts to suppress the adverse effects we have observed.

1 INTRODUCTION

The DARHT II system is a multi-pulse, single-axis flash radiography system being built at Los Alamos National Laboratory. This system is designed to be capable of taking closely spaced radiographic images so as to produce time-sequenced images of the test object.

The DARHT II accelerator is nominally a 20 MeV, 2 kA, 2 μs single pulse accelerator. Four pulses at the target over a 2 μs window are derived from this single pulse with a fast kicker system. The electron beam interacting with the converter target (typically tantalum) generates an intense x-ray cone that produces a radiographic image on a fast detector array.

As the electron beam interacts with the target surface, a plasma promptly develops. The beam electrons create a strong space charge field in front of the target from which ions can be extracted and accelerated in a direction opposite to the electron beam propagation. These ions partially neutralize the beam space charge and defocusing of the beam results.

The second effect results from the direct interaction of the electron beam with the target plasma on subsequent pulses. Such an interaction, depending on the interaction length and plasma density, may have an adverse effect on the beam propagation and the resultant spot on the converter target.

Our on-going experimental program is to study the interaction of the electron beam with the x-ray converter target. In these experiments, we focus on the dynamics of the spot behavior measuring x-ray spot blur across an edge (so called “roll-bar” technique), and 2-d imaging with a gated, multiframe, pinhole camera. Further, we are characterizing the properties of the plume by using various plasma diagnostic techniques.

2 EXPERIMENTAL

We described our experimental set-up and preliminary experiments in a previous paper [1]. Figure 1 shows a representative sample of images from the x-ray pinhole camera. Gate time of each image is approximately 6 ns and spacing between images is 7-10 ns. Time position relative to the beam current pulse is shown in the lower portion of the figure.

Images taken with the beam at normal incidence show an almost constant spot diameter. An intensity profile through the center of each image shows a 1 mm spot diameter (FWHM) for this beam current of 1.4 kA. We observe similar results from this current up to the maximum ETA-II operational current of approximately 2.0 kA. These data show an almost constant spot radius with a variation of approximately 25%. Additionally, in this data, we do not observe evidence of backstreaming ions with the Faraday cups (figure 2). In this figure are shown our expectation for observing various species of fast backstreaming ions from the target.

As most models predict that the backstreaming ion effect can manifest itself in the focus more promptly for lighter species, we conducted multiple experiments with light element surface layers (down to mass 2) or with lighter element target substrates (down to mass 12). In all these experiments, we were unable to observe a dynamically varying spot diameter or any evidence of backstreaming ions.

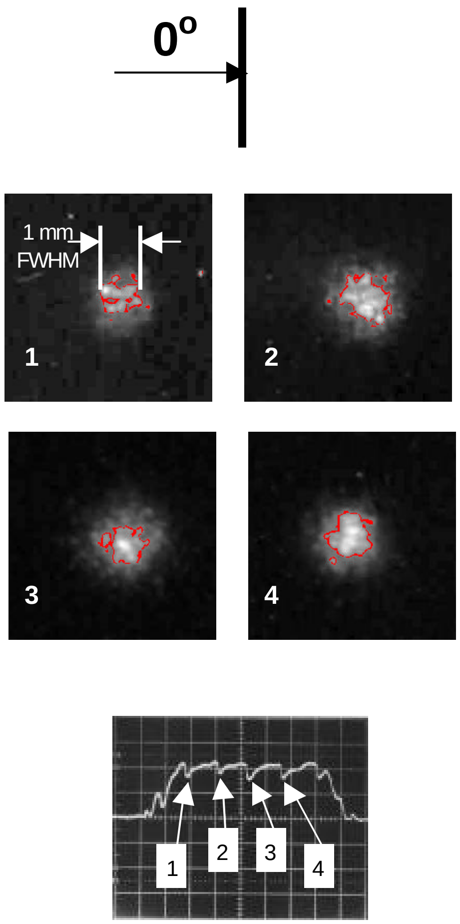

Figure 1: Representative example of x-ray pinhole camera images for 0° beam incidence. Fiducials correspond to gate time of each photo relative to the beam current pulse on target.

By contrast with this data, we focused a high power laser at the electron beam target interaction point to create a plasma from adsorbates and ensure a source of ions was present (figure 3a). Under such conditions, we observed a dynamic spot accompanied by a very prompt positive signature in the upstream Faraday cups (i.e., indicating ions) within 30 ns following the end of the beam pulse (figure 4). We performed these same sets of measurements with a plasma source in the vicinity of the beam and observed similar results.

As a means to limit the effects of the target plume and fast backstreaming ions, we implemented a dielectric barrier in front of the converter target. Figure 5 shows the free expansion of the target plume. Placing a thin dielectric barrier in front of the target suppresses this expansion and limits the extent that the beam can interact with this plume.

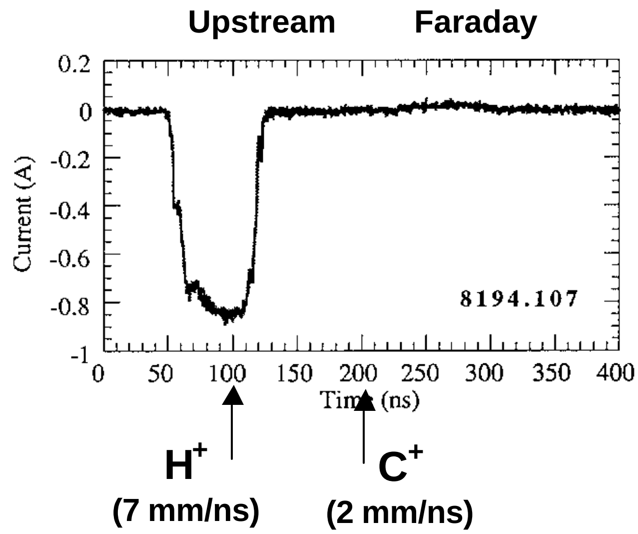

Figure 2: Faraday cup signature in the vicinity of the target. Large negative signal is from the beam electrons. Arrows at 100 ns and 210 ns represent location of expected backstreaming ion signature.

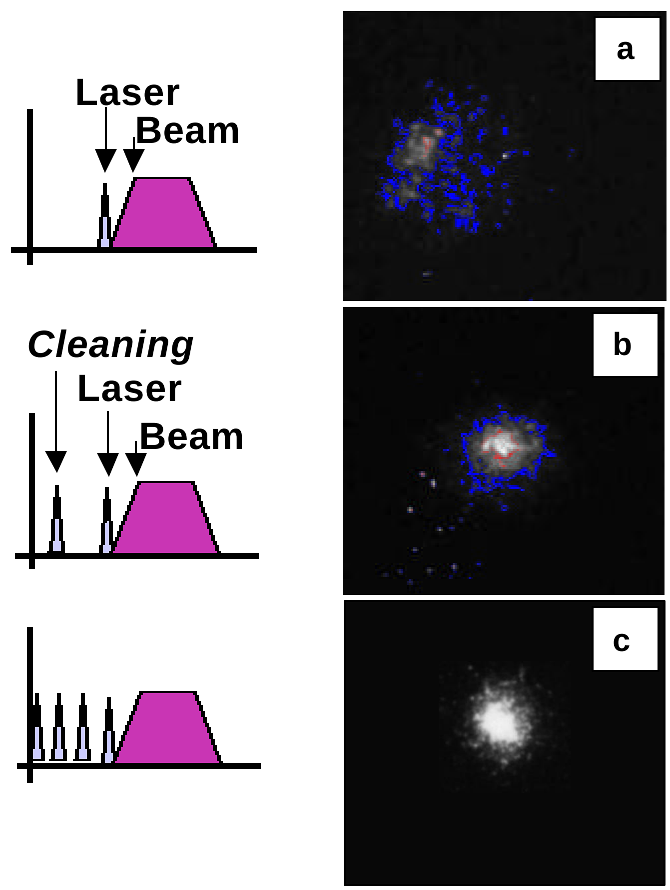

Figure 3: Spot size variation at the end of the e-beam pulse. a) Disrupted spot resulting from a laser induced plasma at the target. Backstreaming ions were observed during this shot. Result of b) single pulse laser cleaning of the surface and c) multipulse laser cleaning of the surface.

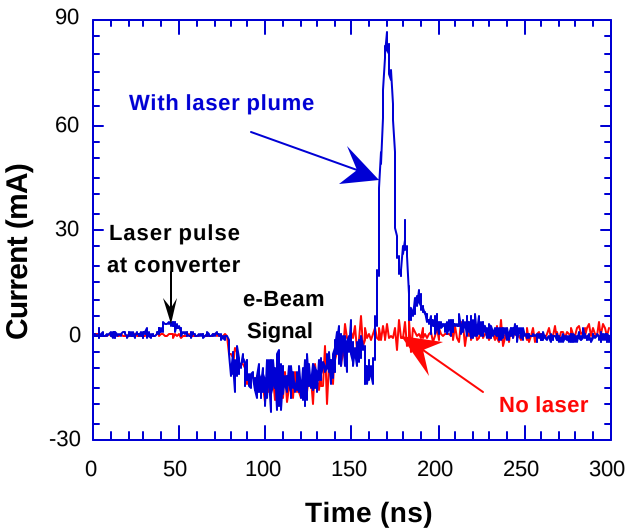

Figure 4: Fast ion signature with and without a laser generated plasma.

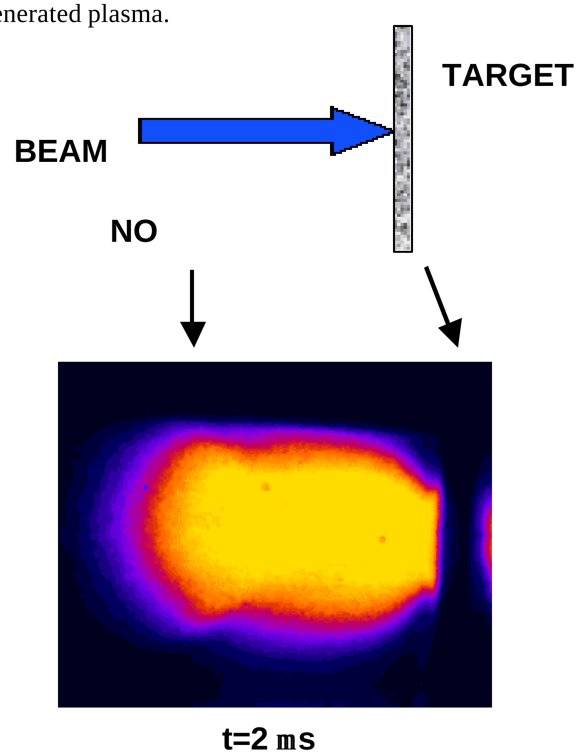

Figure 5: Image of the expanding plume from the converter target

With this dielectric barrier in place, we induced a plasma with the laser at the e-beam target interaction point. Under these conditions, we observe an almost constant spot diameter. This result is compared in Figure 7 to our previous result without laser cleaning (Figure 3a).

3 SUMMARY

We have developed and implemented methods for suppressing the backstreaming ion effect to ensure a constant x-ray spot diameter for multipulse radiography targets. Initial tests were performed with a laser-induced plasma. We demonstrated that we were also able to suppress the backstreaming ion effect by laser cleaning the surface or with a mechanical barrier.

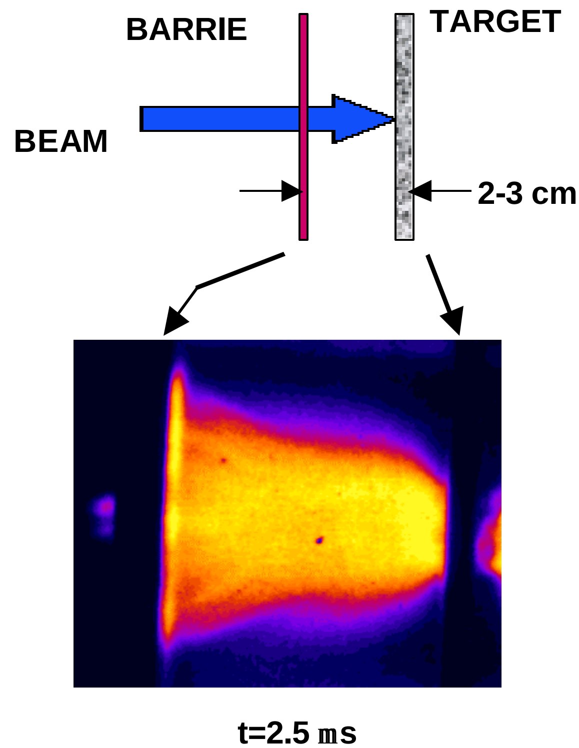

Figure 6: Suppression of the target plume expansion with a dielectric barrier.

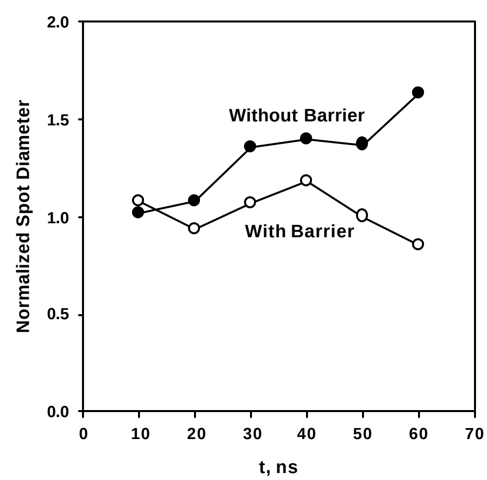

Figure 7: Laser induced plasma in the vicinity of the beam-target interaction point. X-ray spot size comparison with and without a dielectric barrier in place.

REFERENCES

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[1] S. E Sampayan, et. al. “Experimental Investigation of Beam Optics Issues at the Bremsstrahlung Converters for Radiographic Applications”, in *Proc. 1998 Linear Accelerator Conf.*