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DISCLAIMER

BEAM-TARGET INTERACTION EXPERIMENTS FOR BREMSSTRAHLUNG CONVERTER APPLICATIONS*

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Abstract

We are investigating 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 for multi-pulse radiography facilities. These effects would primarily 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, electron accelerator). We are measuring spot dynamics and characterizing the resultant plasma for various configurations. Thus far, 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 still manifest itself as a dynamic focus toward the tail of the beam. We report on the details of our experimental work to suppress these effects.

1 INTRODUCTION

We are presently working on Linear Induction Accelerator (LIA) based radiography projects under the US Department of Energy (DOE). These projects, known as the Dual Axis Radiography Hydrotest Facility II (DARHT II) and the Advanced Hydrotest Facility (AHF), are an element of this Country's strategy of science based stockpile stewardship (SBSS). The DARHT II is presently being built at Los Alamos National Laboratory and it is planned that AHF will be built at the Nevada Test Site. The DARHT II machine is a multi-pulse, single-axis flash radiography machine. The AHF machine is envisioned as a multi-pulse, multi-axis flash radiography machine designed for full 3d imaging. These machines are being designed to be capable of taking a sequence of closely spaced radiographic images so as to produce a time sequenced image of the test object.

DARHT II uses a kicker system to provide a sequence of 4 pulses over a 2 μs window. On AHF, the process of producing these radiographic images consists of generating a 10-15 shot burst of 200 ns electron beam pulses at a 1 MHz repetition rate. These pulses are further chopped into a series of 50 ns sub-pulses and are redirected through a series of magnets to converter targets at each axis. The electron beam impacting the converter target generates an intense x-ray cone which produces a radiographic image on a fast detector array.

The converter target consists of an 0.5-1 mm thick tantalum or tungsten foil. The electron beam is focused to <1 mm and allowed to impinge on this target to create the x-ray pulse. Two effects are of concern. As the electron beam interacts with the target surface, a plasma promptly develops. As the beam electrons creates a strong space charge field in front of the target, ions can be extracted and accelerated in a direction opposite to the electron beam prorogation. These ions partially neutralize the beam space charge and defocusing of the beam results.

The second effect results from the direct interaction of electron beam with the target plasma on subsequent electron 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 at LLNL 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]. Additional diagnostics that we are implementing are shown schematically in Figure 1. Among those additional diagnostics are interferometer systems and a Laser Induced Fluorescence system (LIF). The interferometer

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systems allow observation of the spatial extent, expansion velocity, and density of the target plasma. The LIF system, which consists of a tunable dye laser system and gated spectrometer, allows: (1) measurement of the desorption delay time of neutrals from the target, and (2) measurement of the neutral density as a function of time. The tunable laser is used to excite a particular species of interest at a defined location and time; the spectrometer is used to record the subsequent transition to a lower energy state.

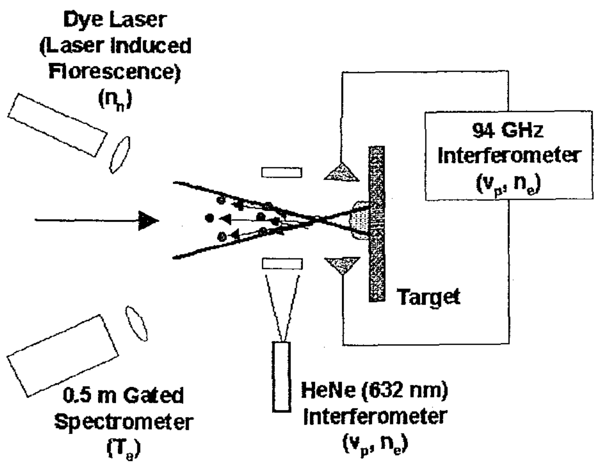

Figure 1: Modified target experiment layout. Neutral diagnostics are being added to system.

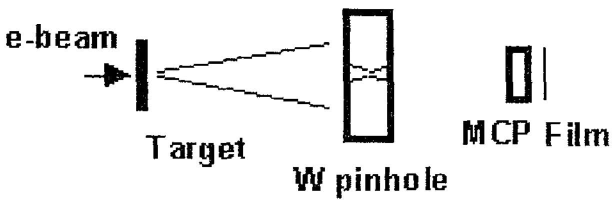

Figure 2: Single channel of the x-ray pinhole framing camera. System consists of six such channels to allow a full 2-d, time resolved observation of the x-ray spot.

As the principal objective of our experiment is to observe the dynamic behavior of the x-ray spot, we have implemented a method of direct observation of the x-ray spot. This device consists of tungsten pin-holes imaged onto an x-ray photocathode and amplified with a gated micro-channel plate (Fig. 2). The camera we are using creates 6 sequentially gated images so as to produce a 6 frame movie of the hard x-rays produced from the target interaction during the 70 ns (FWHM) beam pulse. Calculations show optimum sensitivity of the camera to be from 1-2 MeV with a 20% decrease at 5 MeV (Fig. 3).

Additional diagnostics (not shown) include imaging instruments: consisting of gated, image intensified cameras for observation of Optical Transition Radiation (OTR) from the target surface; and ion diagnostics: consisting of multiple Faraday cups to observe plasma velocities and to obtain estimates of the plasma density. And an alternate method to measure the x-ray spot: the so called "roll-bar" technique. This technique infers spot size from the blur across a hard edge.

To simulate the effect of a high repetition rate multipulse, we have implemented an 0.8J Nd:YAG laser focused on the target. The laser beam can be directed to the target and timed to produce a plasma of sufficient density so as to simulate target debris as would encountered in a multipulse electron beam system.

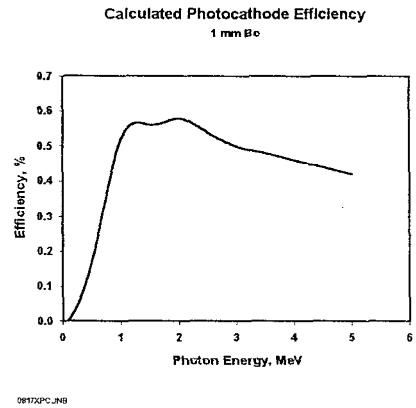

Figure 3: Pinhole framing camera photocathode response.

3 RESULTS AND DISCUSSION

Figure 4 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 Fig. 5.

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 of 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.

We performed electron beam/laser induced plasma experiments. To perform this set of experiments, we pulsed the Nd:YAG laser just prior to beam time. This laser pulse generated a prompt plasma and the electron beam from ETA-II was used as a probe pulse to determine e-beam/plasma interaction effects. Typical data from the final frame of the x-ray pinhole framing camera is shown in Fig. 6a. A plot of the spot diameter dynamics shows an almost constant beam diameter throughout the pulse with a prompt expansion at the end of the pulse (dotted line, Fig. 7). This laser induced dynamic spot is accompanied by a very prompt positive signature (i.e., indicating ions), within 30 ns following the end of the beam pulse, in the upstream Faraday cups.

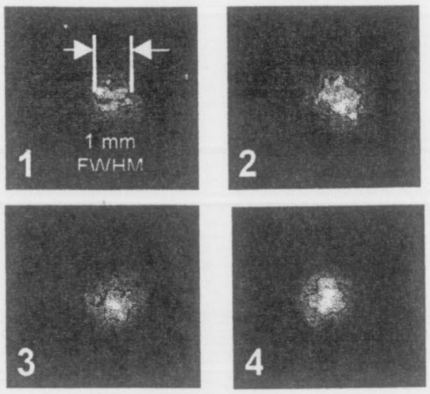

Figure 4: Time resolved sequence of x-ray spot images.

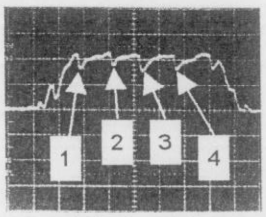

Figure 5: Timing fiducials superimposed on beam current trace taken at the target. Numbers correspond to frame numbers above.

In order to ascertain the primary mechanism of this laser induced plasma dynamic spot (which we presume to be a backstreaming light ion effect due to surface contaminants), we attempted to clean the target surface with a laser prepulse. This laser prepulse was applied approximately 100 μs prior to the laser pulse used to induce the simulated target plasma. We find that the spot dynamics can be minimized (Figs. 6b and solid line, Fig. 7) with this prepulse.

Initial experiments (without a cleaning prepulse) to determine beam propagation effects through a plasma were done by triggering the laser a fixed time prior to the e-beam. This delay allowed the laser induced plasma plume to expand. From the measured speed from the Faraday cups and integration of the signal, we are able to infer an average plasma density and beam/plasma interaction length for a given delay. For a typical data set and a delay of 100 ns prior to beam time, we infer densities of about 5×10^{18} cm^{-3}. We performed measurements with various delay times and observe that the head of the beam (i.e., first 20 ns) can propagate through the target plasma with minimal effects for 1.5-3.0 cm. We observe defocusing toward the tail of the beam presumably due to backstreaming ions.

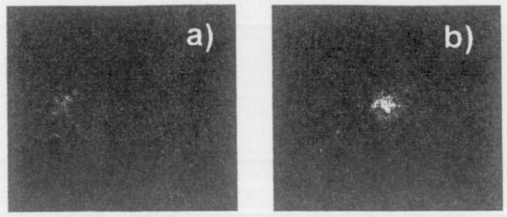

Figure 6: Final frame showing late time expansion of the x-ray spot (a) without and (b) with a laser cleaning prepulse.

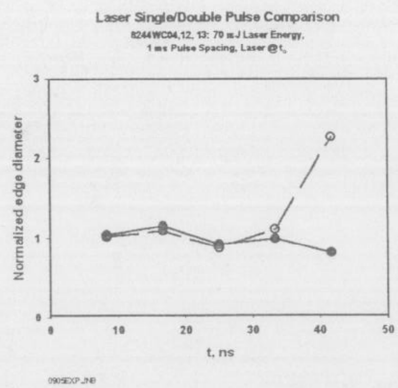

Figure 7: X-ray spot expansion generated by a laser induced plasma (dotted line) and effect of a cleaning target surface with a laser prepulse 100 μs prior to normal laser pulse.

4 SUMMARY

We have described our ongoing experiments to determine the effects for a multipulse Bremsstrahlung converter target used for radiography. An ion backstreaming and plasma interaction effect have been defined as the two of the most predominant mechanisms which could degrade the focal spot on the target. We are unable to observe the first effect. The second effect manifests itself in a similar way only after transitioning 1.5-3.0 cm of plasma.

5 REFERENCES

[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.*