TEMPORAL SPOT SIZE EVOLUTION OF THE DARHT FIRST AXIS RADIOGRAPHIC SOURCE*

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Abstract

The Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility at Los Alamos National Laboratory utilizes two orthogonal linear induction accelerators to generate x-ray pulses for radiography of hydrodynamic experiments. The radiographic spot size is a critical parameter for the performance of the facility. Time resolved images of the radiographic spot of the first axis of the DARHT facility have been acquired and correlated with the radiation pulse.

INTRODUCTION

Electron beam interaction with Bremsstrahlung converter targets have been previously studied [1,2]. Interaction between the electron beam and the Bremsstrahlung converter target generates ions which dynamically alter the radiation spot during the pulse. An earlier study of an electron beam impacting foils has identified the process of thermal desorption of absorbed impurities and subsequent ionization of the desorbed neutral molecules as the source of ions [3].

The negative potential of the electron beam traps the ions in the core of the electron beam and accelerates the ions away from the converter target. This ion channel reduces the space charge in the core of the electron beam resulting in increased focusing and causes the radiographic spot to change during the pulse.

EXPERIMENTAL SETUP

The electron beam of the first axis of DARHT is 1.7 kA, 19.8 MeV, 80 ns FWHM with a 60 ns flat-top. The shape of the radiographic pulse is illustrated on the right side of each image in Fig. 2.

The Time Resolved Spot Size (TRSS) system images the radiographic spot through a 200 micron diameter tungsten pinhole onto a 50 mm diameter 1 cm thick segmented scintillator with an optical magnification of 5. A Monte Carlo model (MCNP) of the tapered pinhole determined that the pinhole blur Point Spread Function (PSF) is a Lorentzian distribution with a FWHM = 0.272 mm. This PSF is deconvolved with the image during data analysis.

The scintillator is a 50 mm diameter 10 mm thick tungsten matrix with 250 micron holes on a 355 micron pitch. Each of these holes is filled with a 250 micron diameter NE102 optical fiber. Internal reflections prohibit the use of a single solid scintillator to characterize the spot sufficiently. Four separate time integrating 16 bit Charge-Coupled Device (CCD) cameras image the same scintillator through the use of beam splitters and turning mirrors. These cameras can be gated independently with a minimum reliable gate width of 10 ns. Camera gates of 10ns duration were used to probe the evolution of the spot during the 80ns FWHM radiation pulse. The camera and scintillator configuration is shown in Fig. 1.

Bit noise from the micro channel plates in the CCD cameras due to the radiation noisy environment is minimized with shielding and further reduced with a custom software program that reduces the noise without corrupting the spot image. Flat-field and Dark-field corrections are performed on the data after the bit noise has been reduced. Details of the analysis have been previously reported [4].

Calculation of the size of the spot is accomplished by comparing the spatial frequency of the Modulation Transfer Function (MTF) where the amplitude is 50% with the 50% amplitude spatial frequency of a uniformly illuminated circular disk [4]. The spot size calculation method used here provides spot size information in a given direction (horizontal). The images were rotated in 5 degree steps through 180 degrees to obtain spot size as a function of angle. Reported numbers here are the average spot size with the error bars indicating the standard deviation of the rotational spot size.

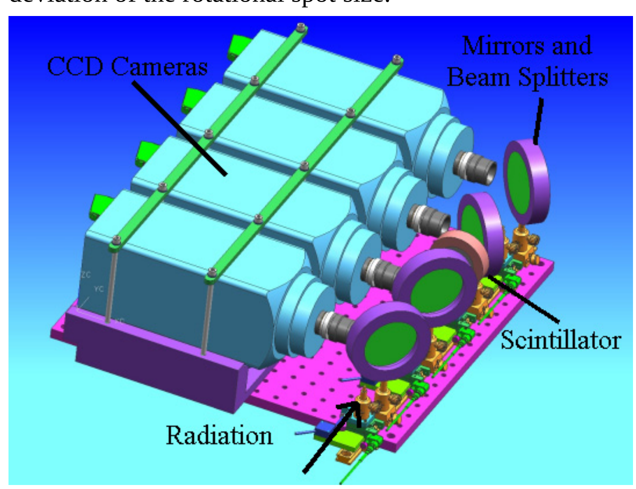

Figure 1: TRSS Camera System

RESULTS

The 10ns time slice imaging results are shown in Fig. 2. The first image in Fig. 2 shows a fully integrated spot. All other images in Fig. 2 are 10ns time slices timed as illustrated. The 50% MTF spot size for the entire integrated pulse and for each 10 ns time slice are graphed in Fig. 3.

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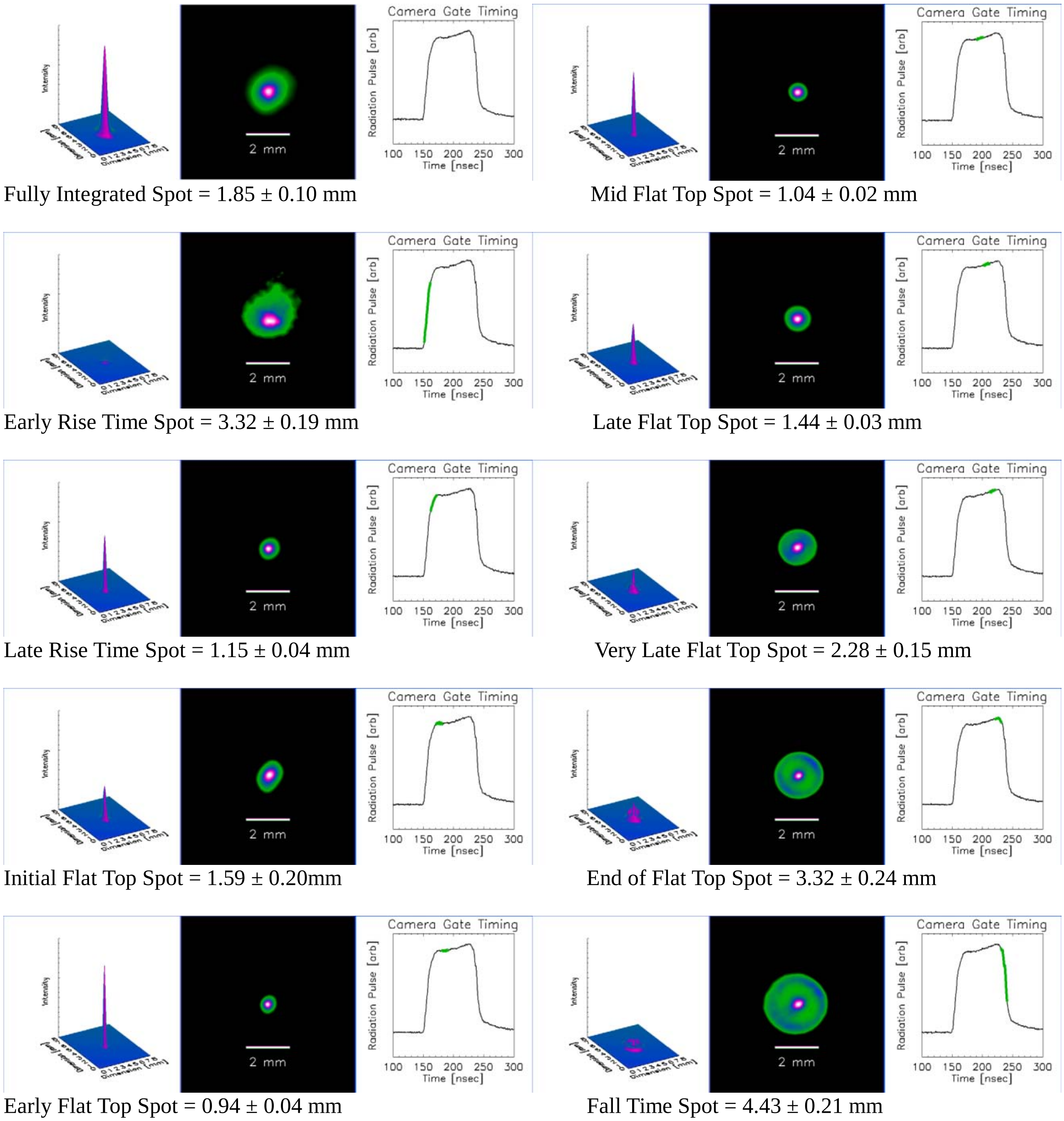

Figure 2: Spot Size Images. The first image gate width is 150 ns covering the entire pulse. All other images are at 10 ns gate widths as shown, illustrating the spot size evolution.

In order to obtain a minimum total integrated spot size, the final focusing solenoid magnet is set to focus the flat top of the electron beam downstream of the converter target. This solenoid focus setting allows for the dynamic evolution of the spot size due to ion focusing.

The spot is large during the rise time of the beam as expected due to the low energy of the beam. Very little dose is produced during this portion. Fig. 4 illustrates the dose for each pulse as measured by a radiation detector during the 10 ns time slices and compares to the total integrated intensity of each image.

During the late rise time immediately before the flat top, the spot size is small. The electron beam energy is slightly lower than the flat top energy, and is focused directly onto the surface of the converter target.

The initial flat top is under focused. The focus point is behind the surface point of the converter target.

The early full energy flat top is when the spot size is the minimum in this data set. Ion focusing has started sweeping the focal point to the surface of the converter target at full energy. Ion focusing now causes the spot size to grow as the focal point sweeps upstream of the target.

This initially under focused beam continually evolves into an increasingly over focused beam as result of ion focusing. Starting at the end of the flat top, the ion focusing has become so pronounced that the spot develops a structure with a central core surrounded by a halo. This structure continues to grow for the remainder of the pulse.

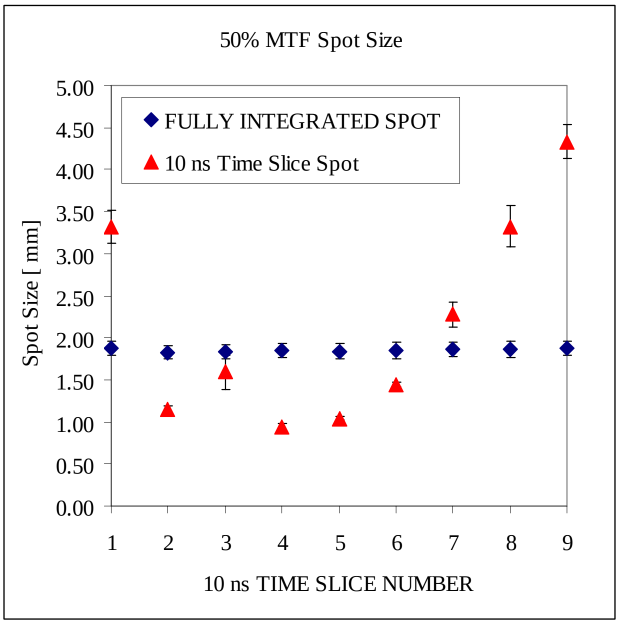

Figure 3: Spot Sizes of Time Sliced Images

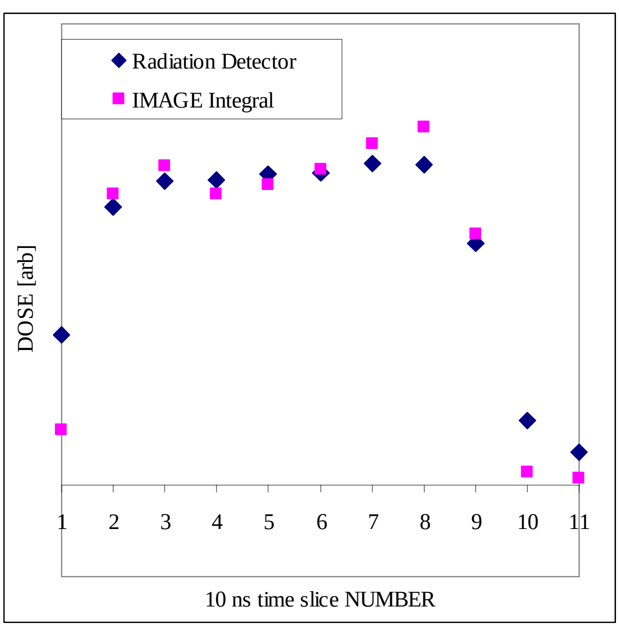

Figure 4: Dose for each 10 ns gate time.

SUMMARY

Beam target interaction causes the radiographic spot to vary dynamically during the radiation pulse of the first axis of DARHT. Back streaming ions from the target caused by electron beam impact provides a likely source for the spot size development. Additional experiments with the TRSS system and computer modeling will serve to further confirm this explanation and evaluate mitigation techniques.

ACKNOWLEDGEMENTS

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