NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or other employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

DIAGNOSTICS PROGRAM FOR A MAGNETICALLY INSULATED ION BEAM FOR INERTIAL

CONFINEMENT FUSION*

by

MASTER

E. J. T. Burns, D. L. Johnson, A. V. Farnsworth, Jr., J. E. Smith,
R. L. Keener, L. P. Mix and G. W. Pharo

Sandia Laboratories, Albuquerque, New Mexico 87185

Inertial confinement fusion (ICF) schemes require an ion beam density of $10^{13} - 10^{14}$ ions/cm² on target.¹ At Sandia Laboratories, several ion diodes are being developed for possible use in an inertial confinement fusion to drive ICF targets.² The ion beam in the target plane is characterized by the nuclear ion energy of several MeV, ion temperatures of several keV, and carbon. Both proton and carbon beams are being produced and analyzed. This paper describes here some of the diagnostics used to study ion beam density profiles from the diode, through the drift section to the target.

The proton and carbon fluence and flux are measured with activation foil samples and biased charge collectors, respectively.^{4,5} In the activation technique, a portion of the beam is intercepted by a carbon or magnesium target allowing the reaction $C^{12}(p, n)C^{13}$ to occur. The positron decay is measured after irradiation allowing determination of the incident beam. Corrections for the naturally occurring deuterium must be made depending on the beam relative voltage and current profiles. The activation technique is useful for proton energies above 460 keV and carbon energies above 6 MeV. The biased charge collectors are useful for measuring proton and carbon current densities for beam voltages greater than 100 keV. The carbon is separated

*This work was supported by the U.S. Division of Energy.

from the proton beam by far the slower fall-off direction by thin plates. The biased charge collectors and entrance lock line are limited to a maximum intensity of about 1 mnd/cm^2 . Further increases at higher currents require fine screen attenuation.

A time resolved x-ray pinhole camera has been used to observe the carbon and carbon beam profiles via induced x-ray excitation and then analysis of the targets, respectively. This camera used fine pinhole and two independent gated CCD detectors with effective exposure times of less than five nanoseconds. The resulting electron images were transported along a pinhole terminal magnet field, amplified on a second CRT plate, then oriented into a phosphor to produce visible images. These plasma images were transported along a fourth plate directly to Polaroid film. The pinhole array was covered with thin light windows which separated the carbon from the carbon and target chamber. The spatial resolution of the camera is this camera is limited by the pinhole array, typically five to ten μ . This camera was successful in observing the early time proton-induced x-ray k-shell emission in an aluminum target followed by late time carbon ion heating of an expanded low density aluminum plasma.

Time resolved optical spectral measurements of the anode plasma are used to determine its temperature which is correlated to the charge state of the carbon ion accelerated. The spectrometer system is a Grasse-Turner optical spectrograph coupled to an image converter camera. The optical spectrometer is capable of viewing 70 nm between 225 and 700 nm on a given shot. Coupled with electron density measurements from a holographic interferometer system estimates of the different carbon ion populations in the anode plasma are made. These carbon ion populations are compared with the populations measured in the drift section and target area by a Thomson parabolic mass spectrometer system.⁷

Soft x-ray, vacuum ultraviolet (VUV) spectroscopy was used to determine the response of approximately one proton per plasma grid element targets to an intense beam of hydrogen and carbon ions.¹⁰ Electron temperatures were deduced from line intensity ratios from a carbon ion excited, optically thin plasma with a high resolution, 1,00 lines/cm grating, one meter radius incidence spectrograph. Brightness temperatures and total radiated power to proton deposition were determined with a triple array of microchannel plate x-ray diodes (XRDs). This data was used in conjunction with coupled resistive hydrodynamic calculations to deduce the friction ion current density.

References

1. M. J. Glaser, *Phys. Rev. Lett.*, **31**, 648 (1973).
2. D. J. Cooke, A. V. Barnesworth, Jr., E. L. Gohl, G. J. Jones, G. W. Zisman, submitted to *J. Appl. Phys.*
3. D. J. Cooke, G. W. Zisman, A. V. Barnesworth, Jr., and E. L. Gohl, *Phys. Rev. Lett.*, **31**, 1103 (1973); E. L. Gohl, G. W. Zisman, and D. J. Cooke, *Phys. Rev. Lett.*, **31**, 1104 (1973).
4. E. L. Gohl, J. Gohl, and G. W. Zisman, *Phys. Rev. Lett.*, **31**, 1105 (1973).
5. G. Heiserberger, N. Papopoulos, Jr., J. Glaser, and G. W. Zisman, *J. Phys.*, **48**, 1659 (1973).
6. E. L. Gohl, J. Gohl, G. W. Zisman, and G. W. Zisman, *Phys. Rev. Lett.*, **31**, 1106 (1973).
7. M. J. Glaser, G. W. Zisman, and E. L. Gohl, *J. Appl. Phys.*, **44**, 2153 (1973).
8. E. L. Gohl and G. W. Zisman, unpublished Sandia Report No. 77-0772.
9. E. L. Gohl, E. L. Gohl, A. V. Barnesworth, and G. W. Zisman, submitted to *J. Appl. Phys. Lett.*