MEASUREMENT OF BEAM DIVERGENCE ANGLE WHICH IS SMALL ENOUGH TO ENCOURAGE OUR FUTURE DEVELOPMENT OF MEDIUM MASS ION DRIVER

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Abstract

We are still continuing our effort to apply the cryogenic technique to the pulsed ion beam generation and the target ablation experiments with such ion beams. In this article, the most recent progress and the most interesting results in this field are described shortly. The origin of this kind of research work exists in our early work shown in [1], for example, where we produced the pure nitrogen beams with our cryogenic diodes.

One of our experiments is to produce pulsed ion beams with a cryogenic anode diode. We used N_2O ice as the ion source to get medium mass ion beams. The anode was cooled with a cryogenic cooler. A pulsed power machine (PICA-3) at Yokohama was used to produce ion beams. The diode characteristics were measured together with the ion beam characteristics. A biased ion collector, Thomson parabola track detector were used to measure the time of flight of the beams and the beam energy and species. The beam divergence angle was estimated with a multi-pinhole camera with the time integrated track detector. This divergence angle was compared with the case of the light ion beams, and the future direction was discussed for the development of the medium mass pulsed ion beams as one of the ICF beam candidates.

The another of our experiments is to irradiate cryogenic targets with pulsed ion beams. As the allowed space for this article is restricted to be 4 pages at the maximum, we describe below only several sentences for this part. The remainder will be shown in other place in the future.

I. EXPERIMENTAL APPARATUS

The schematic diagram of a pulsed ion beam generator is shown in Fig.1. The cross-sectional view of the diode section is shown in Fig.2. We used a so-called beam extraction type magnetically insulate diode to produce ion beams. The inner and outer diameters of the ring-shaped anode ion source were 122 and 98mm. The anode was cooled by a refrigerator system which circulated the gas He between the cold head and the anode. The thermal shroud with the liquid nitrogen cooling was also used to suppress the heat income to the anode. Fig.3 shows the vapor pressure of various materials as a function of the material temperature. The X-Y plot of the material characteristic temperature is shown in Fig.4, where X and Y correspond to the temperature for the equilibrium vapor pressure of 10^{-4} Tore and the material melting point. The schematic diagram of a Thomson parabola ion spectrometer (TPIS) [2] is shown in Fig.5. We adopted two kinds of geometry for the beam diagnostic as are shown in Fig.6 and 7. The former is the arrangement for the arrayed pin hole camera together with the anode of the diode, and the latter is the arrangement for the single pin hole camera which cooperates with the beam collimator.

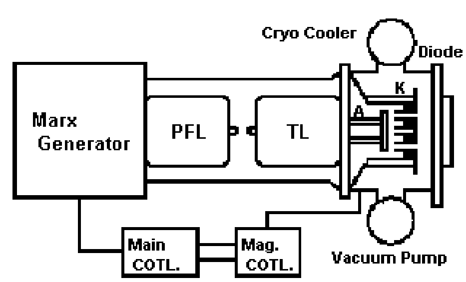

Figure1. Block diagram of pulsed power apparatus .

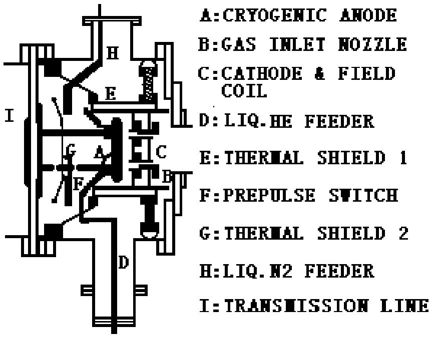

Figure 2. Cross sectional view of ion diode chamber

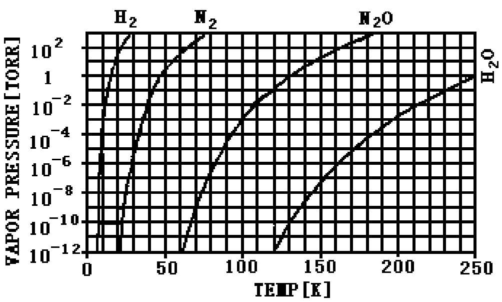

Figure 3. Vapor pressure as a function of temperature

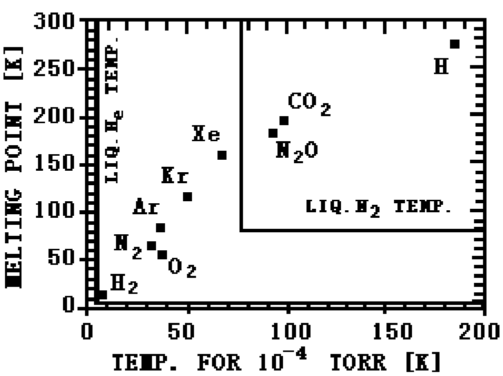

Figure 4. Useful materials and characteristic temperature.

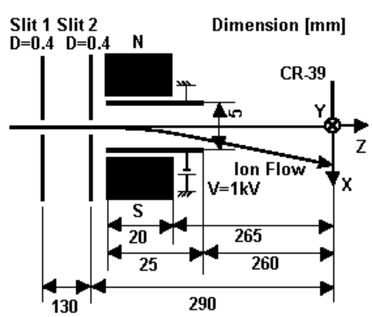

Figure 5. Thomson parabola ion spectrometer.

II. EXPERIMENTAL RESULTS

The vacuum pressure of the diode chamber was 5.1×10^{-5}Torr with the use of the turbo molecular pumps. The obtained lowest temperature of the anode was 53.7K. We used N_2O as our ion source material. As the equivalent temperature of the N2O for the equilibrium vapor pressure of 5.1×10^{-5}Torr is 88K in Fig.3, the anode temperature of 53.7K was enough low to get the stable solid condition of the N_2O. The color of the ice was white.

Typical CRT traces of the transmission line voltage and the ion current are shown in Fig.8. We placed a beam ion collector (BIC) at a distance of 60cm from the anode. The output voltage of the Marx generator was about 600kV, the peak voltage of the transmission line was 353kV, and the peak ion current (the second peak at 360ns) was about 240A The second peak was also

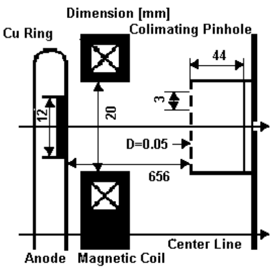

Figure 6. Configuration of arrayed pinhole camera

double humped which included the singly and doubly ionized medium mass ion beam. The most part of the beam was nitrogen, while a small part was oxygen. The first peak corresponded to the proton beam in this figure, where the proton was introduced to get a timing marker. We did not have this kind of impurity peak, if we extracted ion beams under the purer anode condition.

Examples of the ion tracks on the detector plate of the TPIS are shown in Fig.9. Separation between the singly and doubly

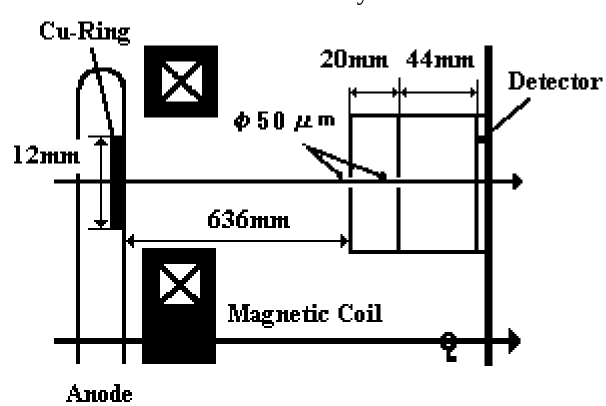

Figure 7. Configuration of second pinhole camera.

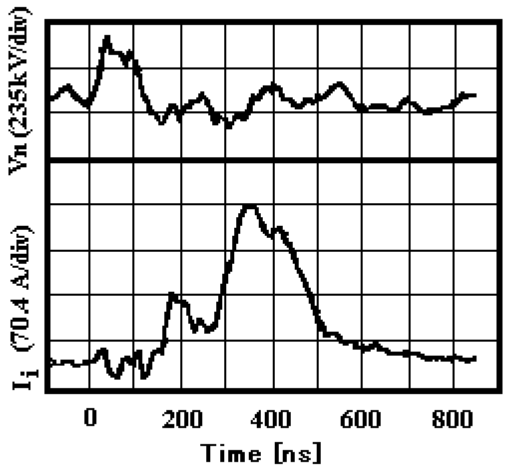

Figure 8. Typical CRT traces of TL voltage and ion current.

ionized beams is obtained while the separation between the N and O groups is not clear. The diameter of the black dots corresponds to the space resolution of this diagnostic system.

An example of the pin hole camera images under the arrangement of Fig.6 is shown in Fig.10, which was analyzed by a 1.5mmx1.5mm on the anode. In this case, the pin holes with 50um diameter and 3mm separation distance were placed on an aluminum thin foil. The plastic for beam detection was the CR-39 or the equivalent. We analyzed Fig.11 under the assumption that the ion intensity profile is similar to the Gauss function. We obtained the respective beam intensity profile at the respective radial position (as is shown in Fig.12). With this series of profiles, we then obtained the beam divergence angle along the radial direction of the anode surface. An example of the results is shown in Fig.13. The source divergence angle was 3-6mrad in this figure. This value is enough small as is described and expected in [2]. So

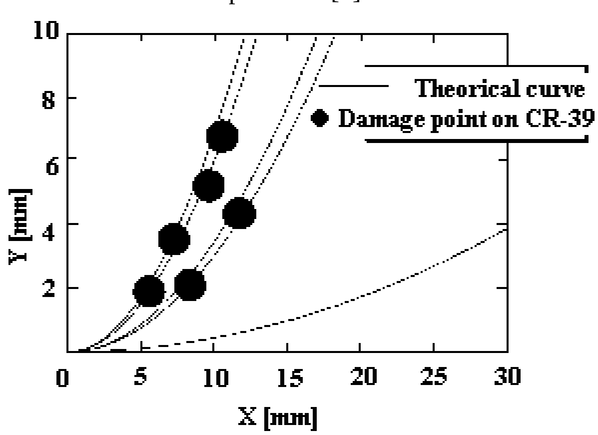

Figure 9. Examples of ion tracks on TPIS.

that, this kind of medium ion source is very hopeful as one of the future ion source to be developed.

A pin hole camera image was taken also under the arrangement of Fig.7, from which we got the beam intensity profile (as is shown in Fig.14) to measure the divergence angle

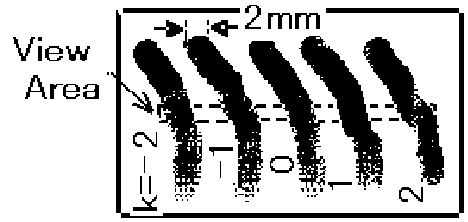

Figure 10. Examples of images of arrayed pin hole camera.

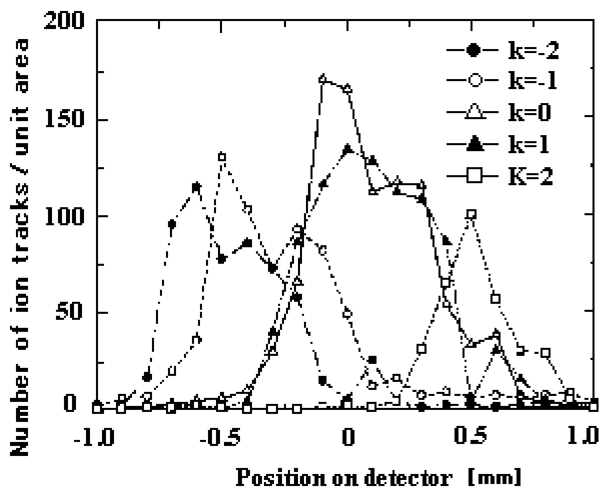

Figure 11. Beam profile behind respective pinhole.

associated with a short distance beam propagation. The value of the angle was estimated to be 2.55mrad.

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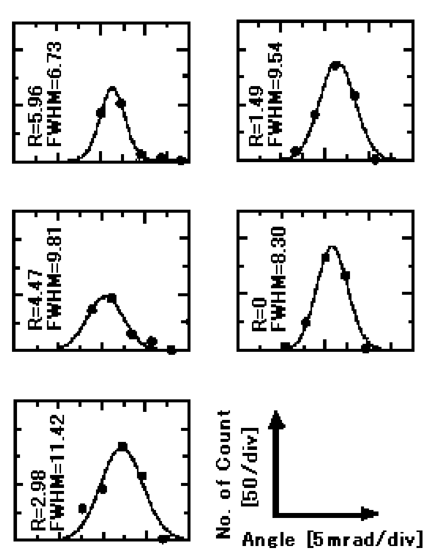

Figure 12. Beam profile at respective radial position.

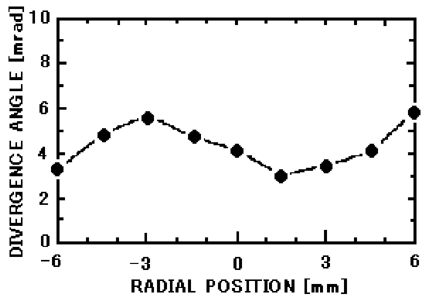

Figure 13. Beam divergence angle vs. anode radial position.

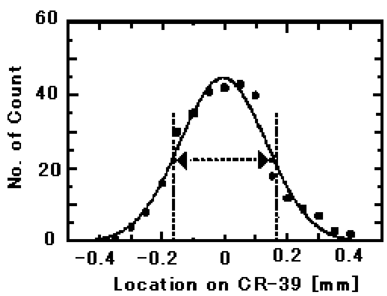

Figure 14. Beam profile on detector plate.

III. ABLATION OF CRYOGENIC TARGET

We observed the ablation plume with an advanced high speed camera. A pulsed power machine (PICA-4) at Yokohama was used in our experiments. Most recently we got clean vacuum of the target chamber with the use of a cryogenic vacuum pump. Time-integrated and time-resolved ablation luminosity were observed with a YBCO target with and without the covering surface of the H_2O ice [3]. The spectra of the plume were also observed. These results were compared with our former results without the clean vacuum. We also tried to make thin films with cryogenic target. The Rhepp-1 machine at Albuquerque was used, and the cryogenic target (YBCO or Carbon) covered with O_2 or N_2 layer was irradiated with various ion beams. Thin films (YBCO or C_3N_4) was tried to be produced on various substrates with and without heating. Various film diagnostic methods including a thickness meter, an X-ray diffraction meter and a RBS meter at Albuquerque, Yokohama and Ithaca, for example, were used to investigate these films. The details will be shown elsewhere, because there is not enough space to do so.

IV. SUMMARY

We could produce the medium mass ion beams with the energy and current value of 100-360kV and 296A. The beam specie was mainly nitrogen with a small part of oxygen. Although the experimental apparatus and the setting were not in the high level and not so sophisticated, we could obtain very low divergence angle of 3-6mrad at the ion source. This value was seemed to qualify the requirement for the beam source in the ICF driver research [4]. The same kind of angle for the proton beam with the same apparatus and the same kind of setting was 15-60mrad. This means that the medium mass ion beam shall be strongly recommended to be studied in more details in the near future.

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VI. REFERENCES

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