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# A Note on Collective Acceleration of Barium Ions in a Preformed Anode Plasma

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**Abstract** Barium ions in a preformed anode plasma were collectively accelerated up to a peak energy of about 1.1 GeV (7,8 MeV/amu) using an intense relativistic electron beam generated by a 500 kV-16 kA-10 ns beam source.

In a previous paper[1] (hereafter to be referred as I) were reported the first experimental results on collective acceleration of barium ions in a preformed barium anode plasma by an intense relativistic electron beam (IREB). It was shown that some barium ions had been accelerated up to a peak energy of 270 MeV using a 500 kV-16 kA-10 ns IREB source. This Note reports that barium ions were accelerated up to a peak energy of about 1.1 GeV using the same IREB source.

Experimental apparatus, a schematic diagram of which is shown in Fig.1, was the same as described in I, except that the length of the drift tube was shortened by 30 cm and that the capacitance of the power supply for the plasma gun was changed from 62.5 $\mu$F to 16 $\mu$F.

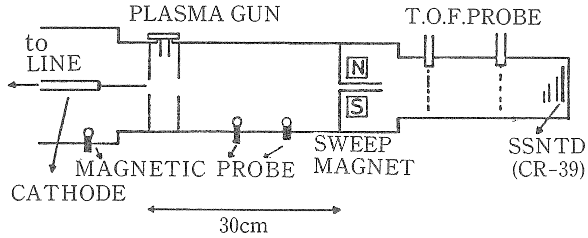


Fig. 1. A schematic diagram of the experimental apparatus.

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Ion energies were determined from time of flight method and from depth of ion tracks recorded on CR-39 plates as described in I. A combination of stacked polyethylene-telephtalate (Lumilar) foils and CR-39 detector was also used. The stopping power tables of Northcliffe and Schilling[2)] were used for analyzing the data.

Figure 2 shows an example of the ion signals detected by two time-of-flight probes separated 15 cm apart. In this case four peaks appear in the signals. The ion energies determined from time between the first rises of two signals, from time between first peaks, from time between second peaks, from time between third peaks and from time between fourth peaks are 7.8 MeV/amu, 3.4 MeV/amu, 0.85 MeV/amu, 0.48 MeV/amu and 0.22 MeV/amu, respectively. The value 7.8 MeV/amu corresponds to 1.1 GeV for barium ions.

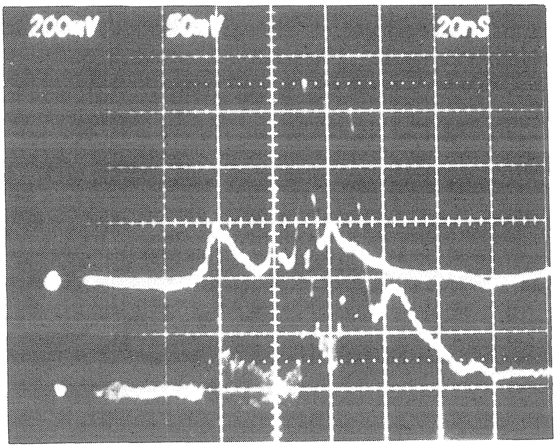


Fig. 2. An example of the ion signals.

In Fig.3 ion energy per amu determined from time between the first rises of the two time-of-flight signals is plotted as a function of the delay time between the first rise of the current of the plasma gun and the IREB pulse. The ion energy was maximum at the delay time $\tau \sim 25$ $\mu$s, and the maximum energy was about 1.1 GeV.

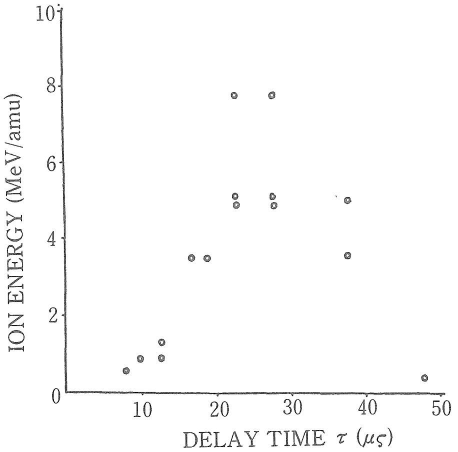


Fig. 3. Ion energy per amu vs. the delay time $\tau$.

Without the sweeping magnet, negative signal was observed to arrive at the ion probe. Time of its peak coincided with time of first rise of the ion pulse. This indicates that a strong coupling exists between the electron beam and the accelerated ions.

At $\tau \sim 25$ $\mu$s the electron density of the preformed barium plasma reached its maximum which was about $10^{13}$ $cm^{-3}$, and the diode impedance matched nearly with the impedance of the Blumlein line of the IREB generator. The beam current at 10 cm downstream from the partition wall at the downstream side of the anode space, which was inferred from a magnetic probe signal, became also maximum about this delay time, the maximum beam current being about 12 kA, as shown in Fig.4. Figure 5 shows the ion energy as a function of the beam current.

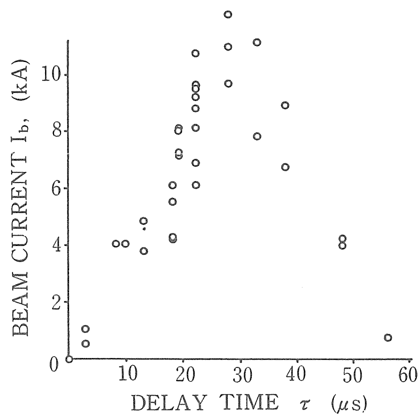


Fig. 4. Beam current at 10 cm downstream from the downstream side of the anode space.

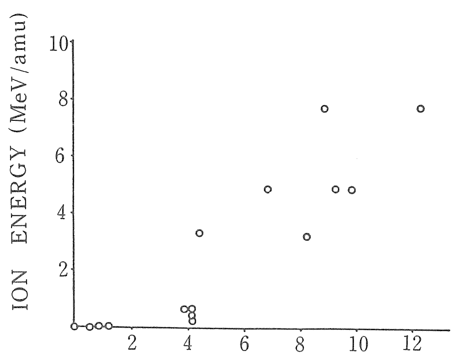


Fig. 5. Ion energy per amu vs. the beam current.

Radcolor films (radiation sensitive films) were attached at the end of the drift tube to know the IREB profile at that place. It was found that $\tau < 17$ $\mu$s the beam did not reach the end of the drift tube, while $\tau > 30$ $\mu$s the beam deviated toward the downstream side of the flow of the gun plasma.

These results indicate that for effective ion acceleration to be observed the high current IREB should propagate straight to the entrance to the diagnostic section. In this experiment most efficient IREB propagation was realized at the delay time about 25 $\mu$s.

The ion energy inferred from the track depths was $\gtrsim$ 210 MeV for barium ions. In the stacked foils and CR-39 combination six Lumilar films with 4 $\mu$m thick were used and there were ions which penetrated these six films. The ion energy inferred from this measurement was $\gtrsim$ 270 MeV for barium ions.

Ion energies obtained in this experiment were higher than those obtained in the experiment described in I. Also reproducibility was better in the former than in the latter. This may be due to the tendency of the beam to deviate to the downstream side of the flow of the gun plasma. It is plausible that, even if the beam reached the end of the drift tube in the latter experiment, the beam deviation was much larger than in the former because the tube length was longer in the latter than in the former, and only its edge containing rather low energy ions went into the ion diagnostic section. Now an experiment is being carried out to confirm this conjecture and to improve the plasma symmetry for effective ion acceleration.

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## References

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