A FOUR BEAM CESIUM INJECTOR FOR MBE-4*

A.I. Warwick, D. Vanecek and O. Fredriksson
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Summary

Construction of a four beam injector for the MBE-4 induction linac at LBL [1] was completed in March of this year. First measurements of the four beams demonstrate that the design specifications have been met. The pulses of singly ionized cesium ions last for 2 microseconds and have variable currents up to 15 mA at a kinetic energy of 200 keV. The emittances are low, at 5mA the normalized emittance of each beam is 1.2×10^{-7} π m rad.

Design Details

Figure 1 shows the layout of the injector. Two of the four beams are shown, traversing the 4.5 inch diode gap and passing into the first quadrupole array of the electrostatic transport channel.

The Cs^+ ions are emitted thermionically from four discs of alumino-silicate. The performance of these emitters is described elsewhere in these proceedings [2]. The four emitters are 1.5 inches in diameter and provide 2 $mAcm^{-2}$ of cesium ions. They are mounted in a shaped graphite electrode supported from the end of the Marx high voltage column. The ions are extracted into a single gap diode where the 200 kV pulsed diode voltage appears. The optics are such as to focus the beams through holes in the ground plane plate without passing through any grids and they emerge from the diode almost at a waist.

Figure 2 shows the calculated space charge optics [3] for a zero emittance beam. This is a two dimensional calculation in r and z. The z axis is collinear with the central ray of one of the four beams. In order to represent the three dimensional nature of the problem, two calculations were performed with different sets of boundary conditions applied at large r, corresponding to different azimuthal directions in which there is or is not an adjacent beam. The graphite electrode was shaped, and the boundary conditions adjusted accordingly, to make these two calculations coincide, with the effect that the diode field not only focusses each beam but compensates for the beam-beam repulsion in the diode gap, which would otherwise deflect the beams through an angle of about 4 mrad. Figure 3 shows the shape of the graphite electrode.

There is an aberration at the edge of each beam (see Fig. 2) and the current density is larger there. However, the total current per beam out of the diode is 20 mA and is reduced to the operating value by collimation, removing the aberration at the same time.

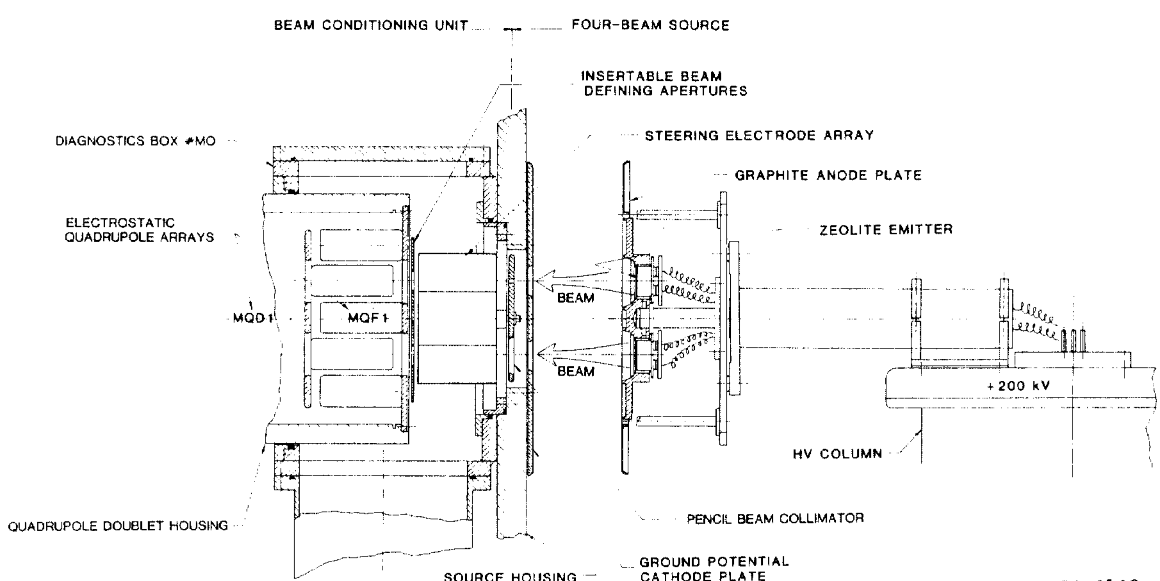

Fig. 1 MBE-4 Injector System

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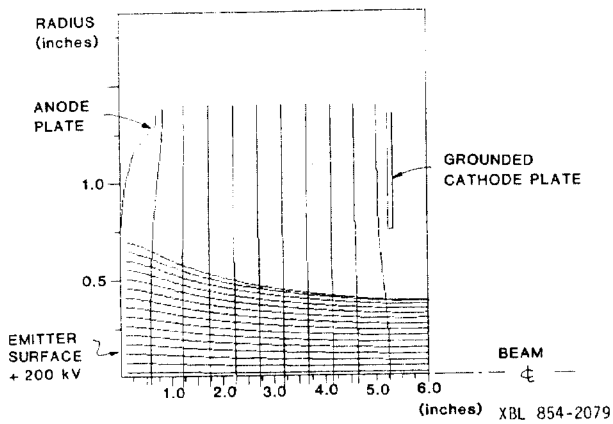

Fig. 2 Ion trajectories in the diode

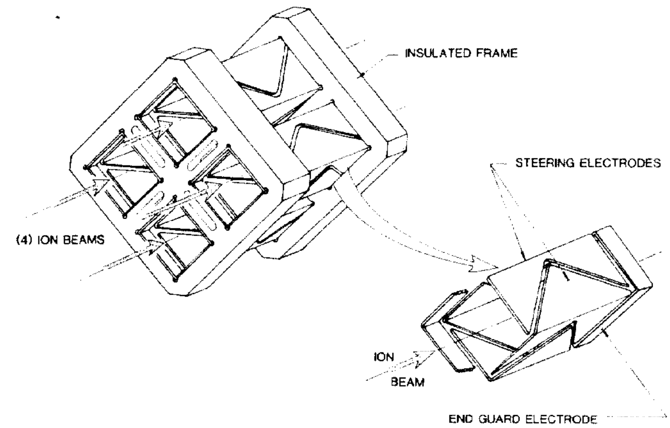

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Fig. 4 Fourfold steering array

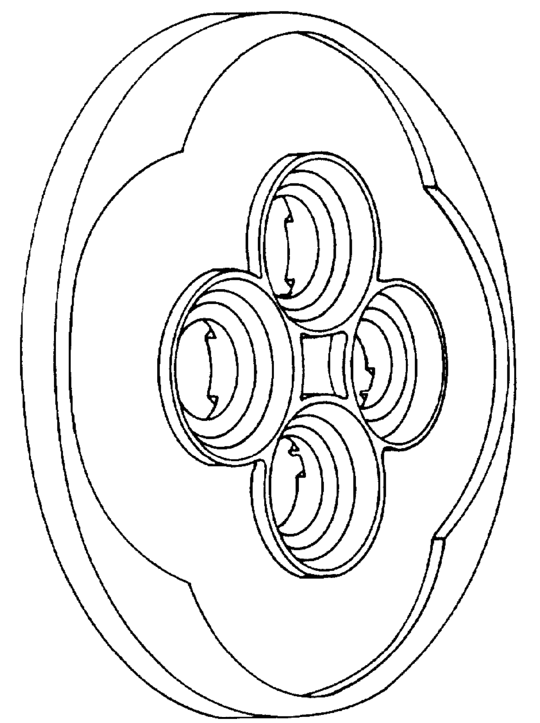

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Fig. 3 Shaped graphite electrode
Four circular holes accommodate the emitters

Collimation to a pencil beam is possible right at the diode exit, this is useful for tuning the angle of the beams with the electrostatic steerers. In normal operation the full beam passes unimpeded through these steering electrodes where small angular errors due to mechanical mis-alignment can be corrected. Figure 4 shows the design of the steering array. The electrodes are shaped to produce a transverse electric field which has a dipole character when integrated in the z direction. The strength and direction of the impulse can be adjusted independently for each beam by varying the potentials of the electrodes (four per beam). The fields are terminated longitudinally by guard electrodes. Typical corrections required are a few milliradians with voltages around ± 1kV on the electrodes.

Immediately downstream of the steering arrays are the beam defining apertures which determine the beam position, current and emittance for injection into the linac. As the steerers are tuned the beams move on the collimators by no more than 250 microns so that the aperture is always fully illuminated with usable beam. Secondary electrons are produced at these collimators and if these electrons are not removed from the region upstream of the aperture they cause increasing neutralization of the beam's space charge on a timescale of several microseconds, distorting the optics and causing time dependent transmission through the aperture. The electrons are removed by biasing the guard rings of the steering arrays to -3kV, allowing the beams to reach the collimating apertures unneutralized.

Measured Performance

Figure 5 shows oscilloscope traces of the four beams. The upper trace is the Marx voltage (200 kV) measured by a capacitive divider and the lower trace is the cesium ion current (5 mA) measured in a biased Faraday cup 50 cms downstream of the injector. These pictures are produced by several pulses overlaid on one another. Shot to shot reproducibility is very good and the four beams have the same current to within ten percent. The time delay between the leading edge of the voltage pulse and that of the current pulse is the ion flight time from the emitter surface across the diode (about 500 ns) and downstream to the cup (about 1000 ns). The trailing edge of the current pulse appears about 1000 ns after the voltage goes to zero, corresponding to the flight from the diode exit to the cup. Ions within the diode when the voltage is turned off emerge with lower kinetic energy and appear in the tail of the current pulse.

Figure 6 shows the results of a scan the emittance of one of the beams after a drift of 50 cms from the injector. For this measurement the beam current is set to 5 mA. These data are accumulated by measuring the current transmitted through a pair of parallel slits, one upstream defining x and one 10 cm downstream defining x'. Many shots are required to build up a picture of the phase space density distribution, moving the slits under computer control from shot to shot. The data is plotted with a gray scale logarithmic in intensity. We extract the normalized rms emittance

$$\pi\epsilon \equiv 4\pi\beta\gamma\left[\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2\right]^{1/2} = 1.2\times10^{-7}\ \pi\ \mathrm{m\ rad}$$

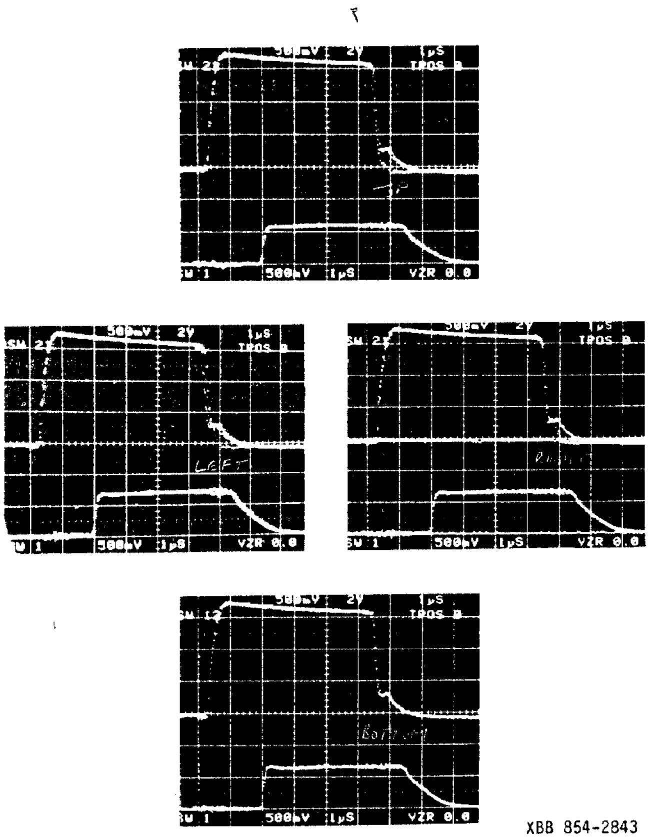

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Fig. 5 Voltage and current pulses of the four beams

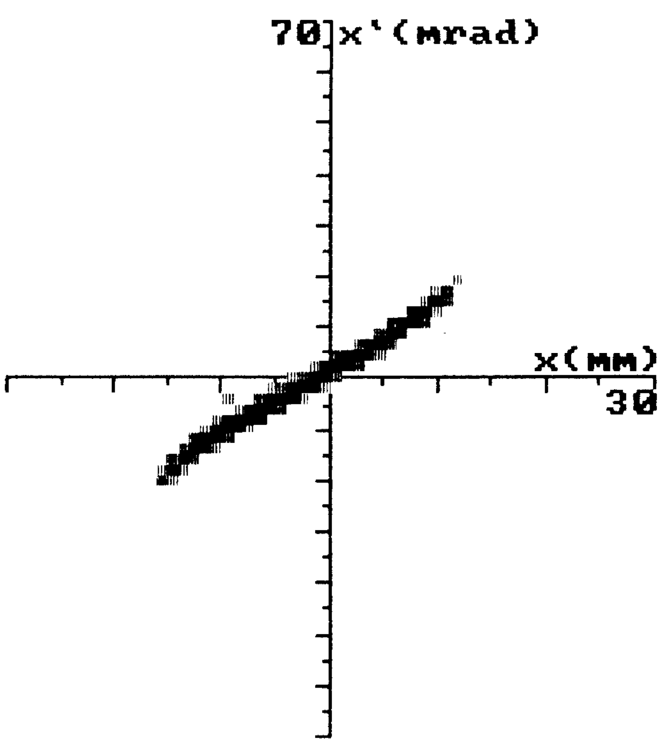

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Fig. 6 Horizontal emittance plot of one 5mA beam

The collimating apertures define the beam current and emittance. With an aperture diameter of 15 mm, 5 mA is transmitted with $\pi\varepsilon = 1.2 \times 10^{-7}\ \pi$ m rad. Increasing the aperture diameter to 21 mm transmits 15 mA with an emittance $\pi\varepsilon = 2.0 \times 10^{-7}\ \pi$ m rad.

Measurements of the emittance at the diode exit gave $\pi\varepsilon = 1.2 \times 10^{-7}\ \pi$ m rad for the full 20 mA beam, with aberrations. The rms emittance has grown somewhat during 50 cm of drift, presumably due to evolution of the phase space distribution, and is reduced to the values quoted above by collimation.

The first 8 quadrupole singlets will be used to condition the beam envelope to the periodicity required for alternating gradient transport in the linac.We expect to first accelerate the beam through an induction core during the summer of 1985.

References

[1] R.T.Avery, C.S. Chavis, T.J. Fessenden, D.E. Gough, T.F. Henderson, D. Keefe, J.R. Meneghetti, C.D. Pike, D.L. Vanecek, A. Warwick, Contribution to this conference.

[2] A.I.Warwick, Contribution to this conference.

[3] W.B.Herrmannsfeldt, Stanford Linear Accelerator Report No. SLAC-226 (1979).