Title
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Publication Date
1988-06-01

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UNIVERSITY OF CALIFORNIA

Accelerator & Fusion Research Division

Presented at the 7th International Conference on High Power Particle Beams (BEAMS '88), Karlsruhe, FRG, July 4–7, 1988

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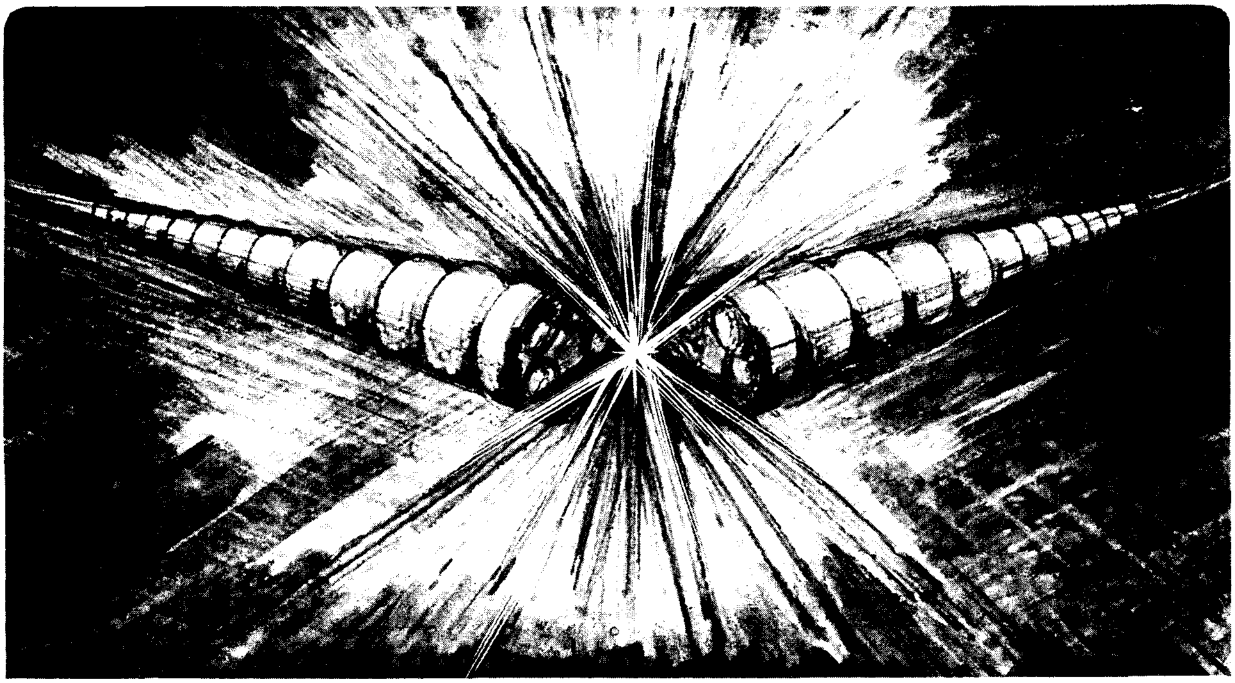
June 1988



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* This work was supported by the Office of Energy Research, Office of Basic Energy Sciences, U.S. Dept. of Energy, under Contract No. DE-AC03-76SF00098.

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ABSTRACT

Construction of a sixteen beam (0.5 A per beam) injector for use in scaled heavy ion fusion experiments is underway at LBL. The machine was designed and partially constructed at LANL. The injector is designed to use carbon arc sources which will provide 25 mA/cm^2 of extractable current density. The plasma from the arcs is confined electrostatically from drifting into the ion gun before firing the extraction pulse. The acceleration column consists of a set of aperture lenses which both transport the beam and attenuate backstreaming electrons. The acceleration column is mounted inside a 28-inch diameter brazed alumina insulating module. The high voltage for the injector is provided by an inductively loaded and graded Marx generator which resides inside a pressure vessel filled with a 65 psig mixture of 30% SF_6 and 70% N_2.

Data is presented showing the performance of single and multiple carbon arc sources. Measurements show that adequate current density is available. Emittance measurements and efforts to improve emittance and reproducibility are shown. Tests with a 5-tray section of the full 18 tray generator are described showing the evolution of the generator design.

INTRODUCTION

An injector is being constructed at LBL for the Induction Linac Systems Experiment (ILSE).[1] Some design and construction had already been done at LANL. The device is expected to produce 16 beams of C^+ ions at 500 mA/beam and 2 MeV ion energy. The normalized emittance of each beam is to be no more than 5×10^{-7} π m-radians. The emittance requirement is determined by expected emittance growth in ILSE and focusing requirements at the end of ILSE. The pulse length is 1 μsec.

HIGH VOLTAGE GENERATOR

A picture of the entire injector is shown in Fig. 1. On the left inside the pressure vessel, the 2 MV pulse generator is shown. The generator consists of 18 plastic trays mounted on cantilevered beams. Each tray has two .06 μfd 100 kV capacitors and two spark gaps plus charging resistors and trigger circuitry. The center to center spacing of the trays is 7.25 inches. Around each tray there is an inductive corona ring consisting of 96 turns of .010 inch diameter wire on a 38 inch diameter lucite form and with a winding length of 3 inches. The rings are connected to every other spark gap and provide an inductive grading of the Marx circuit as well as creating a critically damped waveform at the output with a 34 μsec risetime to peak voltage. The slow risetime is required to allow voltage equilibration along the accelerating column prior to current pulse injection into the column. Stray capacitances are the cause of non-equilibration with a fast rise pulse. Dielectric insulation is provided by a 65 psig mixture of 30% SF_6 and 70% N_2. The output of the generator is connected to the left dome in Fig. 1 which houses the motor generator. The motor generator provides local power for the sources and their controls.

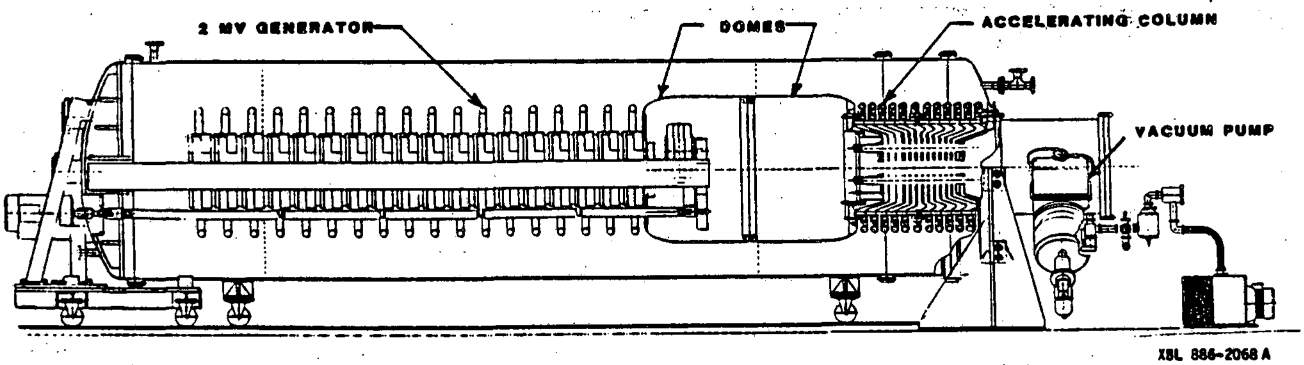

Fig. 1 2 MV Injector.

A five tray subsection of the original Marx design[2] was obtained from Los Alamos and tested to full charge voltage. Several component and placement problems became apparent and the circuit was revised. It was operated for about 50 shots before failure. Four of the inductive corona rings have been tested to 10% above their maximum impulse loading (200 kV) and are being placed in a five tray subsection of the full generator. Tests are imminent and they will verify the circuit and component placement designs for the full generator. New lucite trays are being used to replace the original commercial plastic trays which contained unnecessary penetrations. Also only half of the subsection trays have triggers while the original design called for all gaps to be triggered. If the jitter is satisfactory (50 ns), this approach will save many trigger components and reduce the probability of failure. The five tray subsection tests are all being carried out in the actual injector pressure vessel using two 500 kV, 4 kΩ calibrated resistors in series as a dummy load.

ION SOURCE

A carbon arc ion source[3,4] is being developed for use in the injector. The source and its associated plasma switch and extractor are shown in Fig. 2. A surface flashover trigger inside the cathode generates a plasma which drifts out into the main arc gap. This plasma shorts the gap which is connected to the output of an L-C pulse forming network (PFN) that is pre-charged. The arc fires and plasma from the cathode spot flows down a drift region to the double grid plasma switch. The downstream grid is biased negatively with respect to the upstream grid. The plasma electrons are repelled back toward the arc and the ions flow through this negative grid forming a virtual anode on the downstream side. The plasma is kept from entering the extraction gap and the extraction surface is determined by the grid.

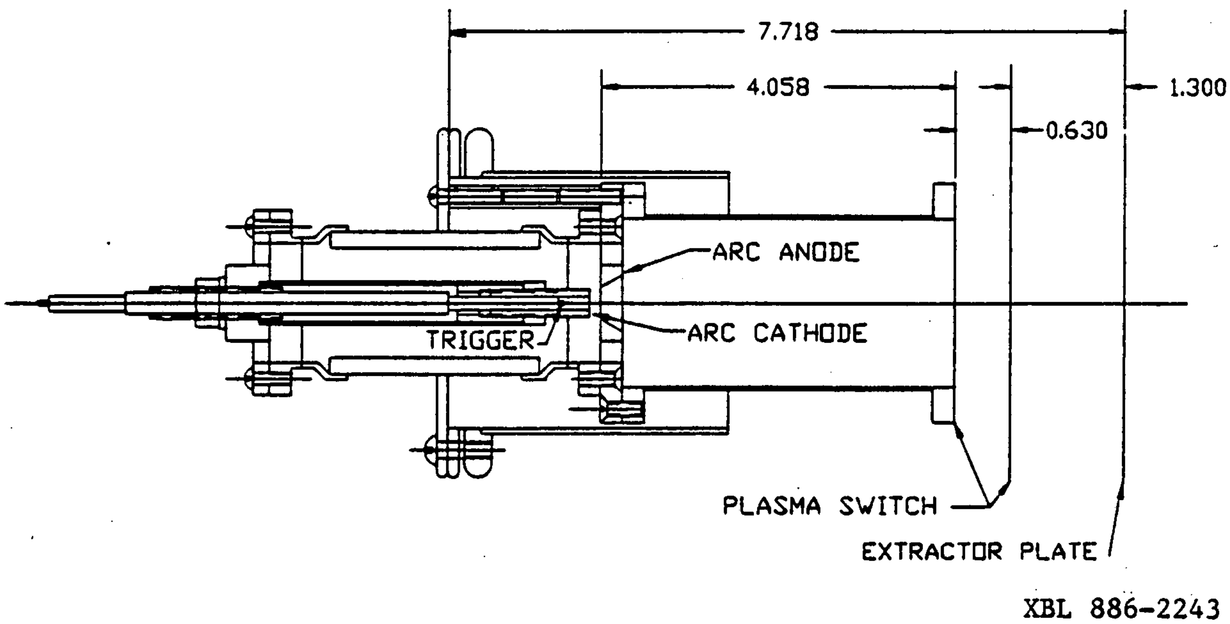

Fig. 2 Carbon Arc Source with Plasma Switch and Test Extractor Gap.

Child-Langmuir current densities of 25 mA/cm^2 have been obtained from this single arc source but when the emittance was measured, the beam was found to be erratic and "holes" in the emittance distribution were found. Various positions of the trigger were tried to create a better trigger plasma in the gap. A trigger of the I. Brown design[5] was tried. Finally, a three arc source which replaced the cylindrical carbon cathode in Fig. 2 with three rods fitting within the original cathode envelope was tried in the hope that the random plasmas from the individual arcs would combine to yield a smoother plasma. None of these approaches noticeably improved reproducibility. When the second grid of the plasma switch was changed from a 100 x 100 mesh with .001 inch stainless steel wires to a 200 x 200 mesh with .016 inch wires, the plasma shut off was much easier to obtain at lower voltages (50-75 volts compared to 110-150 V). The holes in the emittance distribution disappeared and normalized emittance of 6.88×10^{-7} π m-radians was obtained for a 1 inch diameter beam. The design calls for a 2 inch diameter beam. Test with a 50 x 50 mesh showed it impossible to shut off the plasma except with very low arc currents. Even when shut off was obtained the emittance data was very erratic and scattered. Experiments are continuing in the area of multiple arcs and more data about the actual plasma properties inside the source will soon be obtained.

ACCELERATING COLUMN

The accelerating column is shown in Fig. 3. The electrodes reside inside 28 inch diameter brazed ceramic modules. The voltages are connected through niobium rings brazed between the 85% purity alumina elements. Not shown in the figure is a liquid resistor divider on the outside which grades the column and provides most of the critical damping for the high voltage generator. Inside, the electrodes are mounted to stainless steel clamp rings that allow the electrodes to be changed if needed. The entire insulator consists of two 18 inch long modules which provide plenty of mechanical strength to support the weight of the electrodes and the source equipment located in the right dome in Fig. 1.

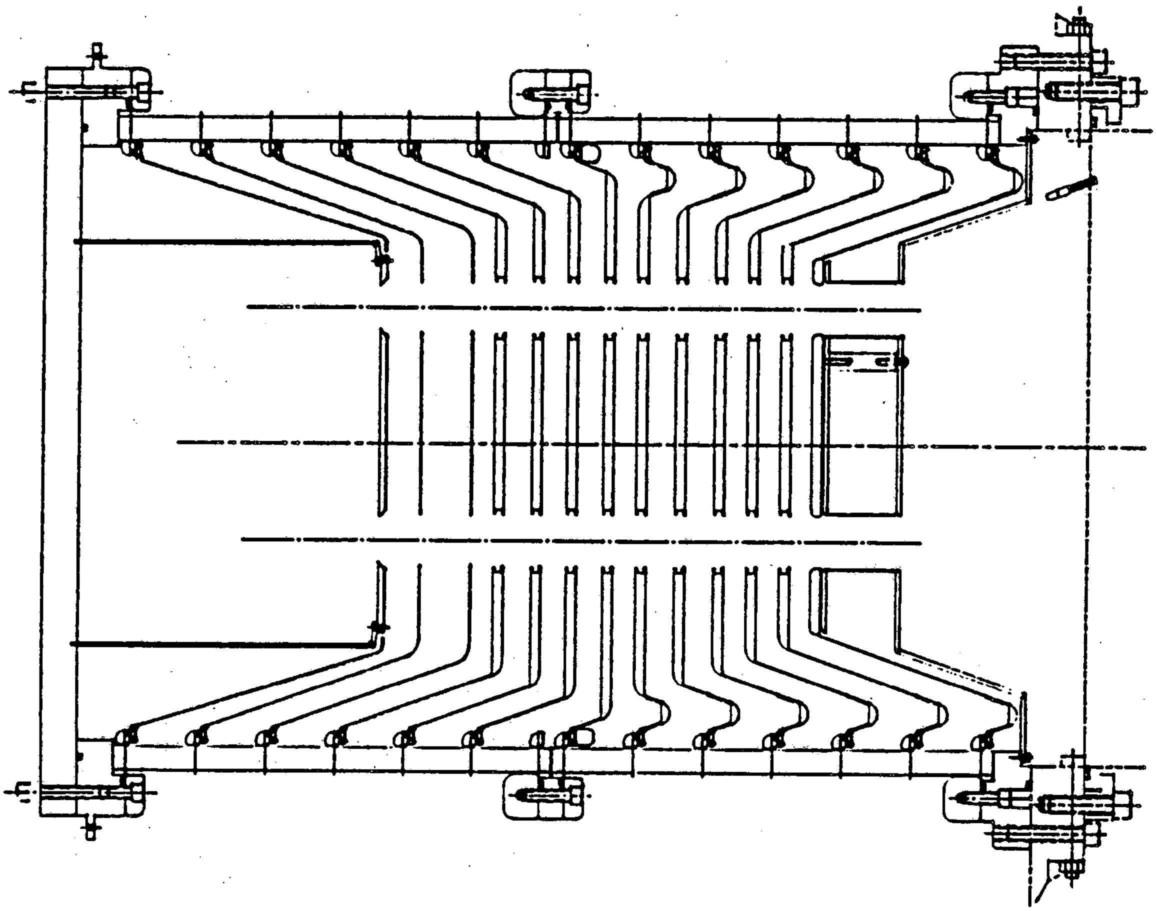

Fig. 3 Accelerating Column Interior.

The electrodes are being made from titanium to reduce secondary electron generation which could lead to breakdown. The structure near the inside of the insulator is designed to orient the electric field to drive electrons away from the surface. This reduces the probability of avalanching along the insulator. The source is located to the left of the first electrode. A mesh is placed in the hole of the first electrode and the source is pulsed to inject current into the column after the main acceleration voltage is applied to the column. This planar current valve gap is 9.8 mm and the valve voltage is 13.6 kV. The first gap in the column is 69.4 kV and thereafter all the gap voltages are 175 kV. The fourth electrode in the first of a set of "split end" electrodes which form a set of aperture lenses which not only focus the beam but deflect secondary electrons made at the electrode surfaces to prevent them from being accelerated back toward the source. The gaps in the split electrodes are all 8 mm with the electrode thickness at the inner radius of the holes 1.5 mm. The hole radius of the upstream member of a pair is 29 mm and of the downstream member 28 mm. The last electrode is contoured to reduce the peak field stress due to the exit aperture. The value is 125 kV/cm. This is followed by a 76.2 mm electron trap at 3 kV negative with respect to ground. This electrode provides a 980 V barrier for electrons on axis. The final electrode is a ground plate. The final radius of the beam is 20 mm and the divergence due to optics is 7 m radians. The normalized emittance due to aberrations is about is about $4 \times 10^{-8}\ \pi$ m-radians. The total length of the column from emission surface to ground exit is 57.37 cm. These electrodes are being built and will be installed in the column once the 2 MV generator is operating satisfactorily.

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ACKNOWLEDGMENT

This work was supported by the Office of Energy Research, Office of Basic Energy Sciences, U.S. Dept. of Energy, under Contract No. DE-AC03-76SF00098.

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