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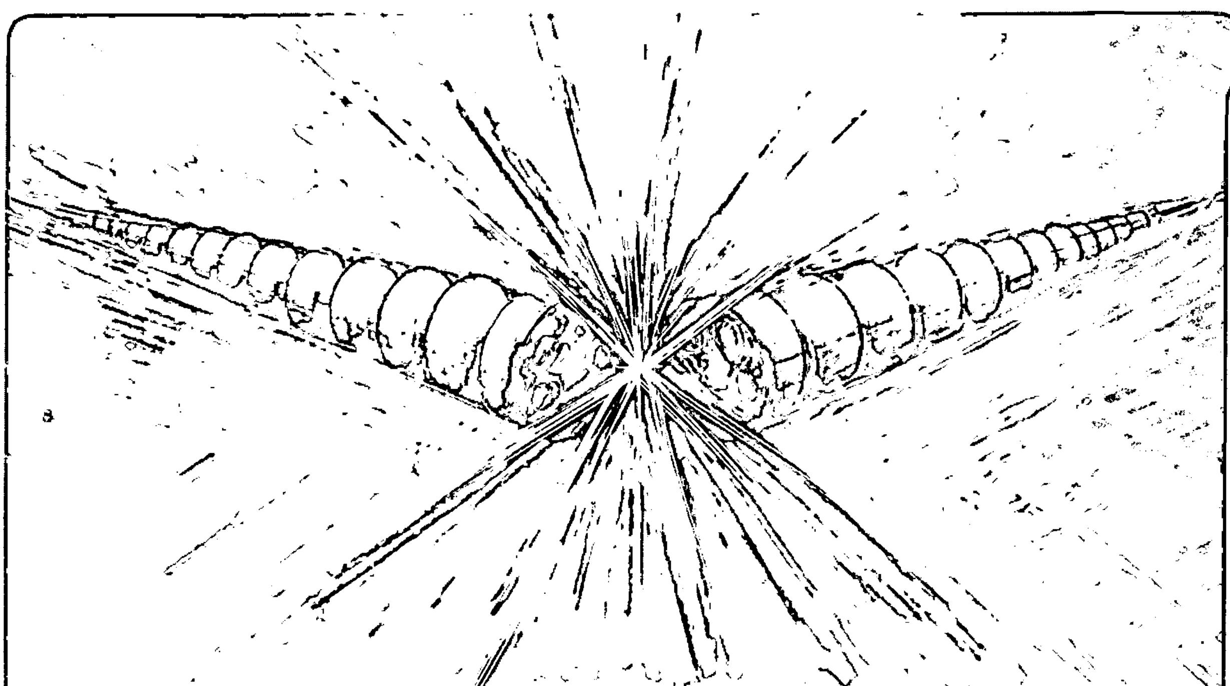

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Abstract. LBL is developing a multi-beam injector that will be used for scaled accelerator experiments related to Heavy Ion Fusion. The device will produce sixteen 0.5 Amp beams of C+ at 2 MeV energy. The carbon arc source has been developed to the point where the emittance is within a factor of four of the design target. Modelling of the source behavior to find ways to reduce the emittance is discussed. Source lifetime and reliability is also of paramount importance to us and data regarding the lifetime and failure modes of different source configurations is discussed. One half of the accelerating column has been constructed and tested at high voltage. One beam experiments in this half column are underway. The second half of the column is being built and the transition to 2 MV experiments should begin soon. In addition to beam and source performance we also discuss the controls for the injector and the electronics associated with the source and current injection.

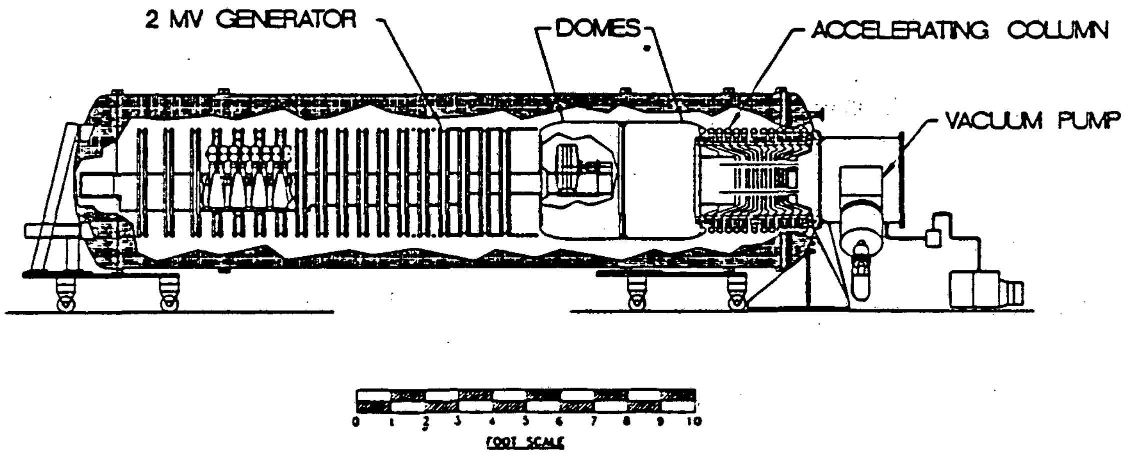
INTRODUCTION

As part of the Heavy Ion Fusion Accelerator Research (HIFAR) program, LBL is building a 16 beam injector which can be used for scaled accelerator technology experiments in subsequent stages or for stand alone beam experiments. The design specifications come from the requirements for the proposed Induction Linac Systems Experiment (ILSE) (1). This is a scaled set of experiments using C+ ions to study space charge limited electrostatic and magnetic transport, beam combining, achromatic bending of beams, and drift pulse compression. All of these operations are to be undertaken using beams with velocity tilt. The injector is to provide:

16 Beams
2MeV Particle Energy
500mA C+ per Beam
$5X10^{-7}$ π m-rad Normalized Emittance per Beam
1 μ sec Pulse Length
0.1% Current and Energy Flatness
12 sec. Repetition Rate

A drawing of the injector is shown in Fig. 1. The entire system resides inside a stainless steel pressure vessel which can be pressurized to 80 psig. of SF_6 for high voltage insulation purposes. The acceleration voltage pulse is made by an inductively graded Marx generator. A separable dome structure houses the electronic components that power the source and current injection pulses as well as the controls and data feedback systems for these units. Acceleration is by a "conventional" aperture lens column consisting of titanium electrodes mounted inside brazed aluminum oxide insulator modules.

Fig. 1. 2 MeV Injector

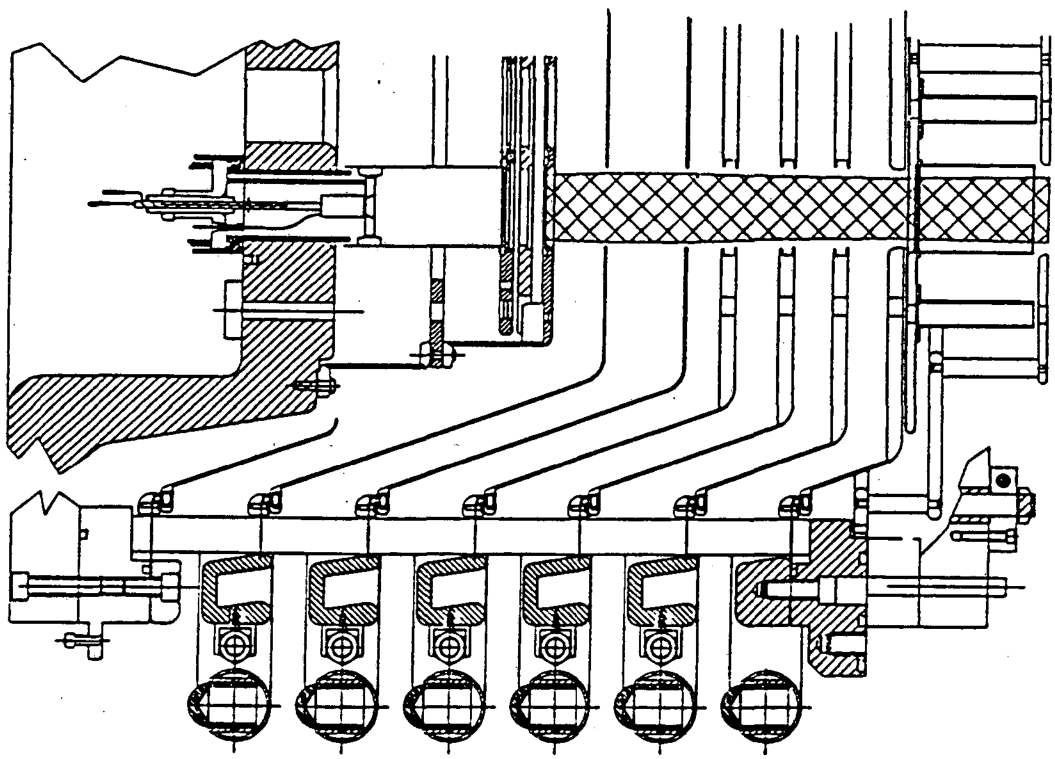


HIGH VOLTAGE GENERATOR

The 2 MV accelerating potential is generated by a Marx discharge which is deliberately slowed by inductive grading. It consists of eighteen plexiglass trays with two capacitors and two sparkgaps mounted on each tray. The coils for inductive grading are mounted at each tray and each of the eighteen coils has 17mh self inductance. The resulting pulse is approximately critically damped with a 30 μ sec rise time. The slow rise time allows voltage time to stabilize on the column electrodes without overshoot due to parasitic capacitances. Damage control spark gaps are located between trays and across coils to protect the system in case of ground fault. The first six stages are triggered and the next to last stage has its trigger electrode capacitively coupled to the high voltage terminal to assist in erection. The trays are mounted on plastic impregnated wood beams which obviate the need for any columnar insulators which would make a larger vessel necessary.

The Marx was tested with ten trays running into an open circuit to allow ringing up to full voltage. This test verified that dome pressure vessel spacing was adequate for 2MV service with 80 psig. SF_6. At the present time, the emphasis is on 1MV single beam tests of the column. A twelve tray system is in use for this and it operates routinely in this voltage range. The Marx is difficult to fire below 500KV terminal voltage but then works nicely at 700KV and above.

Fig. 2. Injector Column - First Half



ACCELERATING COLUMN

The accelerating column is shown in Fig. 2. This is one half of the full column. Ions are emitted from the source on the left. The cross-hatched area shows the location of the beam as it passes through the column. The electrodes can be seen to be connected to the outside of the insulator module through thin niobium washers. The outside diameter of the insulator sections is 28 inches. The outside of the column insulator has a liquid resistor to properly grade the voltage along the column. The resistor is hidden inside some toroidal shield rings. The beam starts at an electrode which is at the terminal potential. The source assembly is pulsed positively with respect to this electrode to extract ions from the source with a 1 μ sec welds are used. The column broke down when first assembled and tested with the Marx. Design voltage (944kv) was not reached and the column was disassembled. Most of the damage occurred toward the the bottom of the column where debris had settled. After improvement of clean room procedures and damage repair, the column was reassembled and special precautions were taken to prevent contamination during assembly to the pressure vessel. The column was D.C. conditioned section by section with a current limited supply. All of the standard 175 KV sections were conditioned to 200KV and the first section, designed for 69.4KV, was tested to 20% above design. Once the conditioning was complete the column was kept under vacuum while electronics were assembled in the dome. The column was then taken gradually up to 1.04 MV and conditioned very quickly with only two breakdowns occurring in the process. After the column was shown to be satisfactory, the attempt to extract beam began.

Everything was set to get beam at a column voltage of 750KV to reduce the probability of damage in case of a breakdown. Noise problems were encountered in the dome. The current valve pulser fired prematurely and the dome had to be partitioned with a metal wall to separate the side containing the motor generator from the side containing the controls and the various pulsers. The low signal front end of the current valve pulser had to be modified to make it less susceptible to noise spikes coming in on the 400Hz AC line from the motor generator which, by the way, was filtered. The noise causing the pretrigger was not the noise from the Marx trigger generator. Pretriggering occurred in cases of slow Marx erection when the terminal voltage had reached only 50 KV. This was considerably later than the initiating trigger signal.

Looking at Fig. 2 one sees that there is a gap immediately upstream from the beginning of the cross-hatched beam envelope. This is the current valve gap across which a 10-13.6KV, 1 μ sec pulse is applied to inject current into the column after the terminal voltage has peaked. The injected current passes through an electro-deposited grid consisting of .0007" nickel conductor in a 70X70 wire/inch pattern, which is located in the aperture of the electrode. This grid is a 90% transmission mesh designed to allow as much current as possible from the valve to enter the column. It also maintains planer optics in the valve. Electric field from the first acceleration gap penetrates through this mesh causing long pulse extraction. Tests are underway on a backward biasing scheme to prevent long pulse ion leakage into the column. The field leakage amounts to a few per cent of the field in the first acceleration gap.

INJECTOR CONTROLS

Our first attempt at source circuit implementation was to be fairly simple. Communications with the source involve monitoring the 400HZ alternator, delivering firing triggers to the source and to the current valve, monitoring arc current and current valve voltage, and controlling a stepping motor. The major factors driving the choice of a fiber optic cable were the availability of high pressure optic feedthroughs and the potentially high light losses imposed by using a number of bulkhead fittings in the fiber optic lines.

We chose 200micron cables, and an eight channel pressure feedthrough (250psi test) with SMA905 fiber optic termination. We developed the capability to do this termination in house. Since we were forced to run the fiber optic lines along the Marx to the dome, we used fiber optic patch panels at each end. The fiber optic lines are delivered to the dome inside a PVC tube that slides inside a second PVC tube. This allows ease of fibre optic disconnection during maintenance work on the machine.

The hydraulically driven alternator in the "left" dome is referenced to the dome, filtered, and then connected to the"right" dome AC distribution box via a shielded connecting cable which must, like the fiber optics, be disconnected when the machine is opened at the dome.

Triggers are generated with Maxwell's 40150 system which has a fiber optic link transmitter and receiver. Marx spark gap noise is seen within the dome and tends to prematurely fire both the arc and current valve pulser. The current valve pulser has been desensitized to the point where it can be operated at the 760KV level. Stepping motor control over a fiber optic RS232 line is similarly adversely affected by Marx noise. This will be an area that will require continual concern and improvement.

All eight fiber optic lines are currently in use. We are presently acquiring a second ILC (Intelligent Local Controller) from the Advanced Light Source Group. We hope to then locate this second ILC in the Marx dome via a single fiber optic line which will serve as an IEEE 485 bus. when this is accomplished we would then have 4 ADC's, 4 DAC's, 12 binary out, and 12 binary in lines as a basis for future design.

ION SOURCE

The ion source has been described elsewhere (3). It is a carbon arc source which uses an electrostatic plasma switch to restrain plasma flow until the extraction pulse is applied. The plasma switch is basically a planar gap consisting of two grids with the downstream grid biased at -45 to -70 V with respect to the upstream grid. Electrons in the arc plasma are then turned back toward the source and a virtual anode is formed near the grid. The optics for ion extraction are thus determined by the switch grid geometry. The ion emitted by the source is determined by the cathode material.

The source is being developed in parallel with the injector. Present versions easily supply the 500mA of C+ ions needed for the injector. The normalized emittance for two inch extraction apertures is 2.0 - $2.5 \times 10^{-6} \pi$ m-rad. The plasma switch can contribute significantly to this emittance. A modelling effort (3) has pointed the way to a possible solution to the problem. This involves dropping the plasma switch voltage during beam extraction to allow electrons from the arc plasma to partially penetrate through the plasma switch mesh and thus shield ions from the wire electric field. The ions would then gain less transverse velocity from the switch mesh. Simulations using the GYMNOS code (3) show that it should be possible to get to $1.3 \times 10^{-6} \pi$ m-rad using this technique.

The lifetime of the source is another issue. The present sources typically last 20-30k shots before their emittance degrades. We do our emittance measurements on a shot by shot basis with each shot giving one point in the field phase space plot. Eventually the plasma flashover triggers which initiate the source discharge become covered with carbon from the arc and the source starts to misfire. This shows up as a gradual deterioration in the emittance data. Several methods have been investigated to allow remote cleaning in the vacuum without more than transient improvement. The trigger has also been reconfigured but the source would then not fire. Efforts are underway to develop a source that does not require a flashover trigger.

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