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OPERATING EXPERIENCE WITH A HIGH CURRENT Cs^{+1} INJECTOR FOR HEAVY ION FUSION

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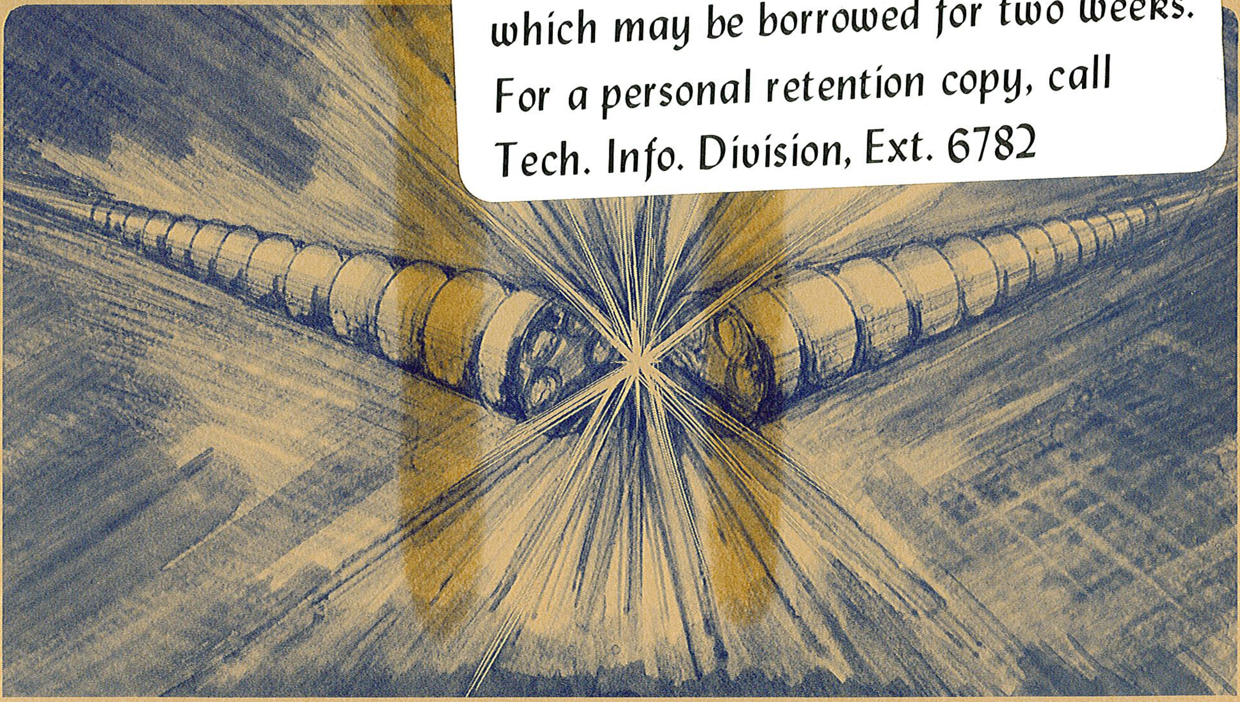
March 1981



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SUMMARY

The construction and assembly of a Cs ion injector consisting of a pulsed source and 3 pulsed drift tubes has been complete since April, 1980. The measurement program, underway since then to characterize the beam, has been interspersed with the development of diagnostic equipment. The Cs contact ionization source and each of the 3 drift tubes are driven by 500 kV Marx generators. The injector has been operated reliably at 300 kV/stage at a repetition rate of 1 pulse/4 sec. About 10^5 pulses have been accumulated.

The space charge limited diode and drift tube acceleration system were designed with the aid of the EGUN code of Herrmannsfeldt[1]. Measurements of the beam envelope have been made by means of a movable biased charge collector. Good agreement with the EGUN calculation is found. Measurements of the beam emittance have been made at the exit of the third drift tube. The normalized emittance $\pi \epsilon_N = 2 \times 10^{-6}\ \pi$ m-rad is of better optical quality than that required for further acceleration and transport in a Heavy Ion Fusion (HIF) Induction Linac Driver.

INTRODUCTION

At the 1979 Particle Accelerator Conference we reported on the operating characteristics of the Cs source for our injector.[2] In this paper we report on the complete assembly and operating characteristics of the three pulsed drift tubes which are used for acceleration of the beam from the source. The system is shown schematically in Fig. 1 along with the calculated and measured beam envelope profiles.

The system has been in routine operation at 300 kV/stage, giving a beam of 1.2 MeV Cs^+ with a total current of 355 mA in a 2.6μs pulse, which is the expected space charge limited current at that voltage and with the present grid structure. In an electrostatically focussed system at the space charge limit there is only one solution to the beam dynamics, with the exception of source temperature effects which are insignificant here, and therefore the beam envelope and particle trajectory may be measured at any voltage.

The main effort over the past year has been to develop reliable diagnostics to measure the beam envelope, total current, and emittance. In

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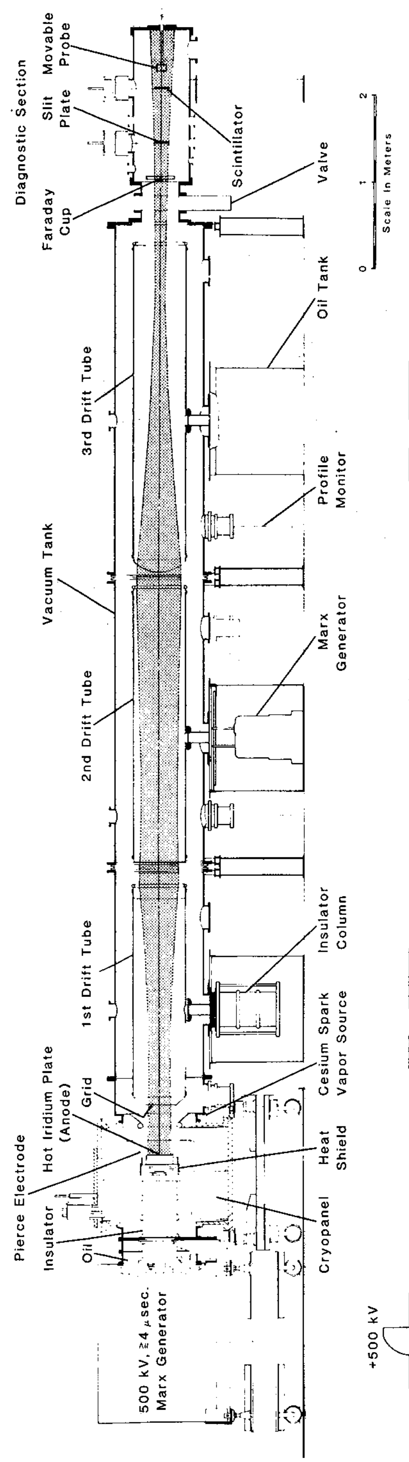
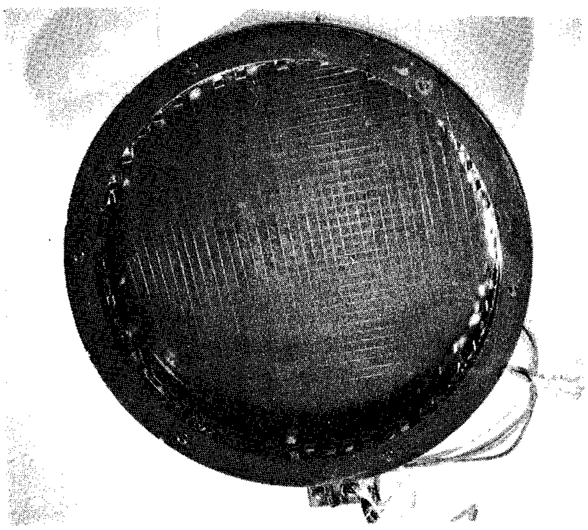


1. 3 Drift Tube Injector schematic showing beam profiles.

addition, tests have shown that the goal of 500 kV/stage is achievable. Finally, some of the future experiments for this injector will be described. Each of these items will be discussed in detail in the following sections.

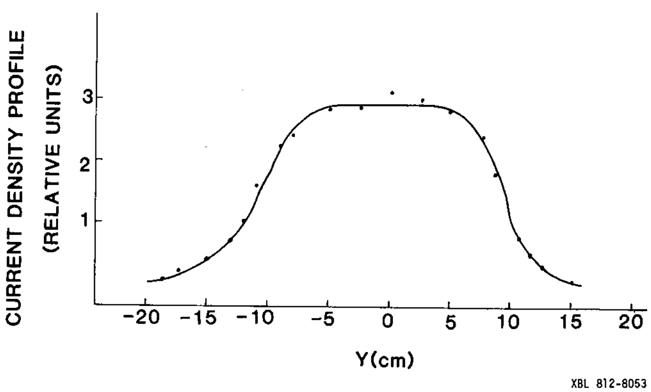
Diagnostics Development

We have invested a major share of our effort in developing reliable means of characterizing these intense, low energy ion beams. The problem of measuring total beam current has been more difficult than expected because of the high surface heating due to the short range of the ions. This leads to the evolution of an energetic plasma from the charge collector and nearby surfaces which requires a deep cup with suitable biasing to obtain reliable current measurements. We have finally arrived at an acceptable design which gives the expected saturation behavior with bias of its two grids and collector. This cup, shown in Fig. 2, has been used for all recent total current measurements.



2. Large Faraday Cup

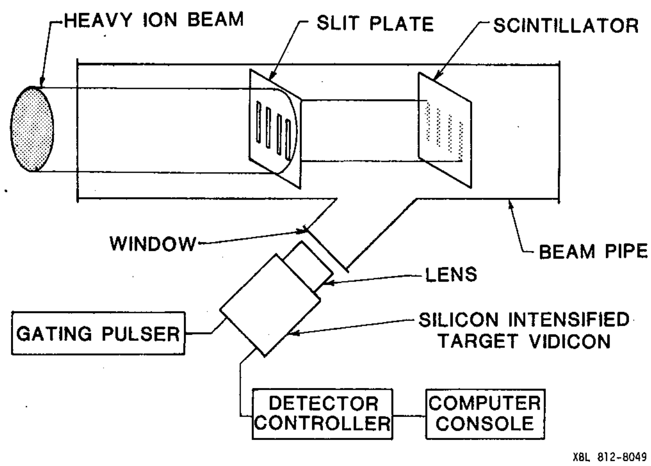
The beam envelope has also been measured by means of a small scanning charge collector. This collector could be moved independently in r,θ, and z with a precision of ±0.06 mm, ±0.1 degrees and ± 0.8 mm respectively. A typical scan of the beam profile in the diagnostic tank is shown in Fig. 3.



3. Beam Profile Scan

In addition, we have measured the beam emittance in each transverse phase plane using a plate with fine slits to reduce the spreading effect of space charge. The beam divergence was measured by both a small flag probe and a fast scintillator and camera, in order to achieve time resolution within the particle bunch.

Fig. 4 shows the arrangement of these elements in the diagnostic tank. The scintillator used recently has been a 1 μm thick layer of CaF_2 doped with europium, vacuum-evaporated onto a stainless steel plate. The scintillator is required to have a fast fluorescence decay time (~ 300 ns or faster), good efficiency of light production; and a usable lifetime in the intense beam (~1mA/cm^2). For example, Pilot B survives only 50 pulses under these conditions. KBr, which has been used previously[3], has a slower fluorescence decay time and a lower light yield than the Ca F_2 (Eu). The Ca F_2 (Eu) scintillator was viewed with an EG and G Optical Multichannel Analyzer (OMA) with a lens mounted on it. This system functions as a gateable (gating width as narrow as 40 ns), high sensitivity

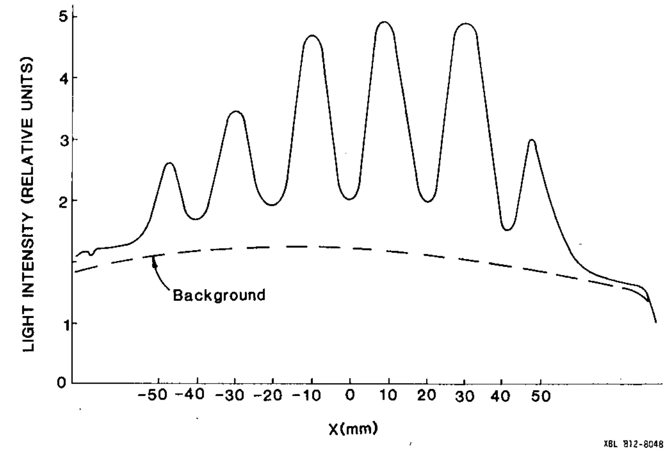


4. OMA Schematic

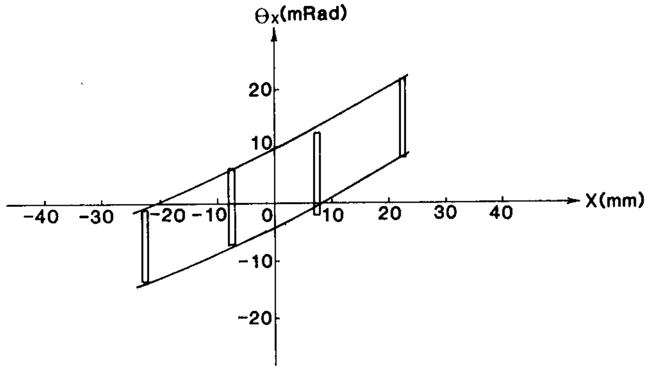
television camera. A typical light intensity pattern for 1 mm slits 15 mm apart, 62 cm from the scintillator obtained with this device is shown in Fig. 5., along with the calculated normalized emittance. The scintillator can be replaced by the movable charge collector and the pattern acquired more laboriously, point by point; an example of such data is shown in Fig. 6a. The calculated normalized emittance given by these data is displayed in Fig. 6b. It should also be pointed out that these latter measurements required a high level of machine stability and reproducibility over ~10^3 pulses.

Note that Fig. 5 represents a beam scan in the X-direction and Fig. 6 is a scan in the Y-direction, and thus results for both transverse phase planes are shown. The emittance is the same in both directions and the area $\pi \epsilon_N \sim 2 \times 10^{-6} \pi$ m-radians is of higher quality than that required for a heavy ion injector for an HIF Induction Linac for ICF purposes.

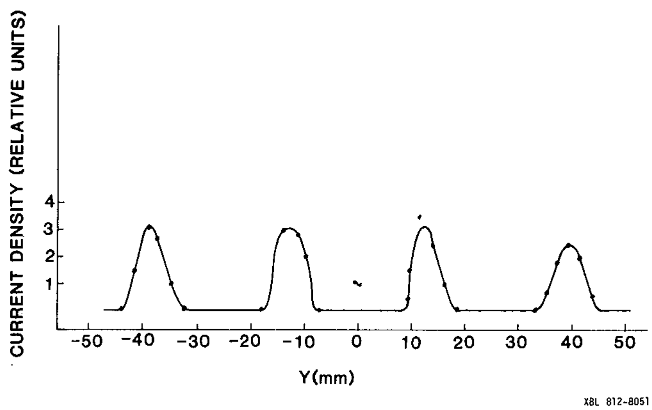
We have added a 16" gate valve between the injector and the diagnostic tank. This permits changes inside the diagnostic tank that require opening the tank to air to be made rapidly (~ 1 hour turnaround time), e.g., this has allowed use of such techniques as a cellulose nitrate film to image the ion beam. This film must be removed after each pulse and then etched for examination .



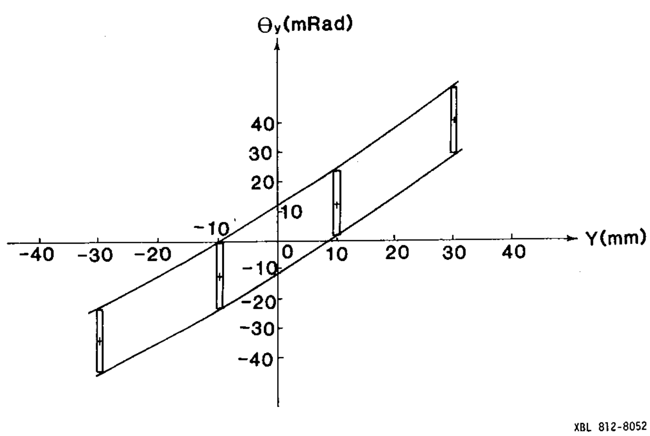
5. a. OMA emittance pattern



5. b. Phase space plot



6. a. Charge collector emittance pattern



6. b. Phase space plot

Suppression of Current Transients in the Source Diode

Because the single particle transit time through the source diode is a significant fraction of the pulse duration, we expected and saw substantial current fluctuations associated with the initiation of the current pulse. We have analyzed the effect for planar geometry and have found that current overshoot and oscillation at the leading edge of the current pulse can be suppressed by arranging for a programmed shape of the voltage pulse[4]. Approximate fitting of the real voltage shape by means of resistors to slow the voltage risetime gave a near-total suppression of the fluctuations about the space-charge limit.

High Voltage Testing

During the course of the assembly, one drift tube housing and insulator stack were set up and instrumented to determine their maximum voltage capability. The system was subjected to an argon gas glow discharge at ~ 0.1 torr of approximately 300 volts and 1.5 A with a continuous flow of argon. Monitoring partial pressures with a residual gas analyzer, we were able to effect an order of magnitude reduction overnight in the H_2O peak in the mass spectrum. Upon subsequent pumpdown and voltage-conditioning these insulator columns held 600 kV for $>$ 20 μs.

Future Plans

Now that the injector is completely assembled and running we plan to use it for the following tasks:

1. Measure gas desorption by heavy ion beam impact on surfaces at normal and glancing incidence.
2. Reduce cesium consumption by optimizing the cesium vapor spark source.
3. Develop reliable calibrated beam current detectors.
4. Develop rugged transparent scintillators: [e.g. sapphire, calcium fluoride coating (doped with Eu)].
5. Perfect emittance measurement with slits, scintillator, and OMA. Investigate linearity of beam current vs. light output.
6. Emittance control (increase) by grids.
7. Change gun perveance and look for increased beam current. Transport of higher current through the drift-tubes would require at least partial neutralization.
8. Develop electron beam probe for beam profile measurement.
9. Examine practical schemes for using multiple beams in an induction linac, including matching.

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