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OPERATING EXPERIENCE WITH A HIGH CURRENT Cs\textsuperscript{++} INJECTOR FOR HEAVY ION FUSION*

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

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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 10⁶ 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. 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 $\varepsilon = 2 \times 10^{-6} \, \text{m-rad}$ 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. 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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addition, tests have shown that the goal of 500
cv/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.

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
current. 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 CaF₂ 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 (~1 mJ/cm²). For
example, Pilot B survives only 50 pulses under these
conditions. KBr, which has been used previously⁴,
has a slower fluorescence decay time and a lower
light yield than the CaF₂ (Eu). The CaF₂ (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
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 ~10⁶ 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 \( \pi \epsilon \times 2 \times 10^{-6} \) 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 required (~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.
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. 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 H2O 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 geometry 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.

REFERENCES