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Author

Clark, D.J.

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TESTS AND DEVELOPMENT OF DUOPLASMATRON AND
MULTI-APERTURE HEAVY ION SOURCES FOR AN RF LINAC

D. J. Clark, R. M. Richter, E. Zajec, R. Brokloff

Lawrence Berkeley Laboratory

and J. E. Osher

Lawrence Livermore Laboratory

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The goal of the program of ion source development for an rf linac has been to produce currents of up to 100 mA of the heavier gaseous ions such as argon and xenon, of good emittance ($.02 \pi$ cm mr, normalized) and charge state 1^+ following the recommendation of the 1976 Summer Study.¹ Existing facilities and hardware utilized included the 470 kV Bevatron injector, the 750 kV injector for the 50 MeV ESCAR linac, the 80 kV Bevatron test stand, a 20 kV LLL test stand and existing duoplasmatron and CTR sources. A summary of test results is shown in Table I. We have also benefitted from the experience of the CTR source groups at LBL and LLL, and discussions with K. Ehlers.

At the Bevatron injector beams of 30 mA of neon and 25 mA of xenon were accelerated through the low gradient column to 470 kV, using the Bevatron duoplasmatron source. The beams were pulsed with 0.5 ms duration at 2/sec. No beam emittance or charge state measurements were made in this set-up.

The 750 kV injector with its high gradient column was used to accelerate neon to 500 kV, using the standard duoplasmatron. 15 mA was measured, with an emittance of $.02 - .05 \pi$ cm mr., normalized, with mainly 1^+ charge state. The transmission was not optimum for Ne^{1+} , but only for Ne^{3+} and above, because of the column quadrupole strength limitation. Ne^{3+} was about 1% of the total beam.

The requirement of 100 mA of Xe^{1+} corresponds to an equivalent (scaled) proton current of 1.1 amps from the same source at the same extraction voltage, so the high output current capability of the multi-aperture source (tens of amperes of protons) matches the requirement better than a single-aperture duoplasmatron or PIG source. Figure 1 shows a survey of source current and emittance. The CTR sources of LBL and LLL appear brighter than duoplasmatrons, so one of these was selected for development on the 80 kV Bevatron test stand. A source previously used by the LBL CTR group² was kindly loaned to us and was modified by adding an accel.-decel. extraction system similar to that used in J. E. Osher's MATS III source.³ The LBL source is shown in Figs. 2,3. 13 circular holes of 2 mm dia. within a 1.5 cm diameter are used in the extraction aperture plates. The predicted current is 10 mA Xe^{1+} . Development has been aimed at transporting the beam 1.3 meters to a Faraday cup using a magnetic quadrupole triplet, and understanding the effect of various source parameters upon beam intensity, divergence and transport. Typical source operating parameters for good transmission are: +20 kV on source, +10 kV on extractor (accel.-accel.), arc pulse 1 ms wide, 2/sec. Langmuir probe measurements show the plasma to be uniform to 5% across the apertures. Beam current is 5 mA at the source and 1.2 mA focused into a 4 cm dia. cup 1.3 m downstream, expected to be mostly Xe^{1+} . Tests with a biased mesh in the beam gave no improvement in transmission, indicating space charge neutralization is probably adequate. Gas pressure measurements along the beam line show pressures of $1-5 \times 10^{-5}$ torr, giving a calculated 10% loss due to charge exchange to Xe^0 . A larger aperture single extraction hole (4 mm instead of 2 mm dia.) has been recently tested and gives a factor of 3 increase in brightness compared to the 2 mm hole case. The extraction mode in this case was

18 kV accel. and 1 kV decel. Future measurements are planned on beam divergence, emittance, and charge state distribution. A beam profile monitor and more pumping will be added.

A test on krypton using a MATS Iii source³ was done by J. Osher at Livermore. A 25 aperture accel.-decel. extraction system was used. A d.c. current of 75 mA at 20 kV was measured calorimetrically at 1.1 meters from the source. The emittance appeared to be comparable to the $.02 \pi$ cm mr required. The beam current scaled approximately as $V^{3/2}$ over the range 10-20 kV. This excellent space-charge neutralized transport comes close to meeting the Summer Study goal.

Also under study is the design of a new type of structure for a high gradient column. In seeking a simple, low-cost design the insulators will be made of two flat plates rather than a series of circular rings. A preliminary model is planned using lucite instead of ceramic; later a ceramic version will be designed if first tests are promising.

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REFERENCES

1. ERDA Summer Study of Heavy Ions for Inertial Fusion, LBL-5543, p. 4 (1976).
2. W. R. Baker, et al., BNL 50310, p. 145 (1971).
3. J. E. Osher and G. W. Hamilton, LBL-3399 p. VI - 7-1, (1974).

FIGURE CAPTIONS

- Fig. 1. Survey of ion source current vs. emittance, before accelerating column. Emittance is divided by 2 before plotting for those duoplasmatron measurements made after a column, to allow for column blow-up.
- Fig. 2. LBL CTR multi-aperture source, adapted from early model.
- Fig. 3. LBL CTR multi-aperture source.

Table I. Heavy Ion Beam Summary

Source Type	Ion Type	Voltage (kV)	Source		Column		After Column	
			I (mA)	E_n (π cm mr)	(kV)	Gradient	I (mA)	E_n (π cm mr)
Ducplasmatron	Ne				470	Low	30	
	Xe				470	Low	25	
	Ne				500	High	15	.03-.05
LBL-CTR								
13-2mm aper.	Xe	20	11+1.2					
1-4mm aper.	Xe	18	6+1.2					
LLL MATS III	Kr	20	75	~ 0.2				

Note: Charge state of ions is believed to be mostly +1.

LBL Multi-Aperture Source
(Early CTR Model, '71)

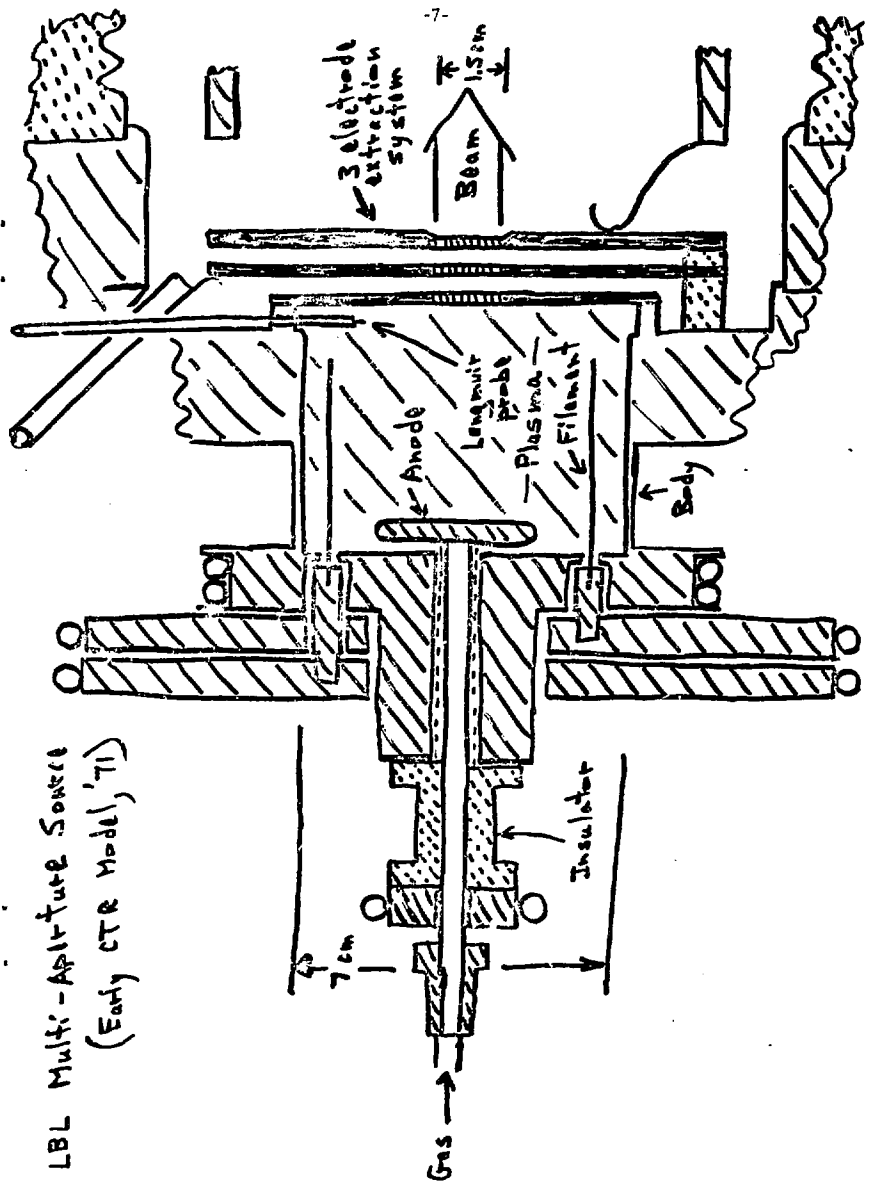


FIG. 2

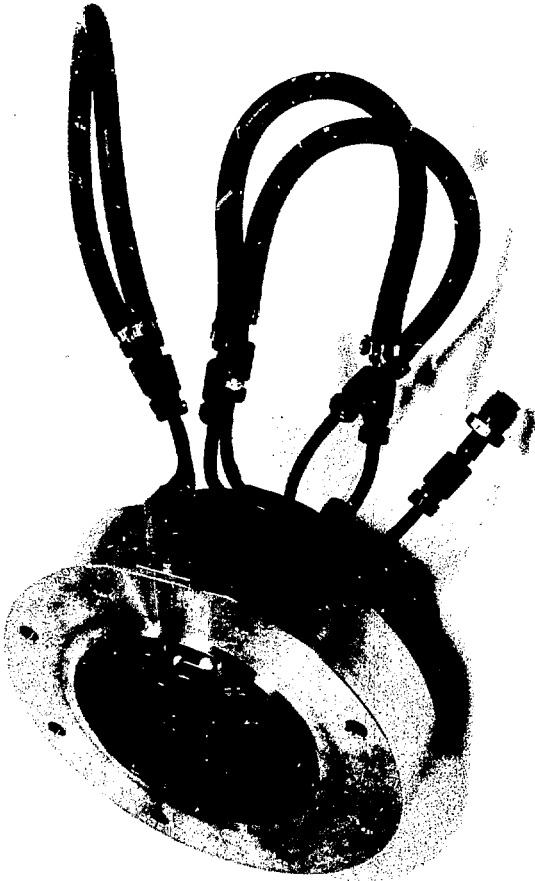


Fig. 3