PERFORMANCE OF THE TEXAS A&M ECRIS

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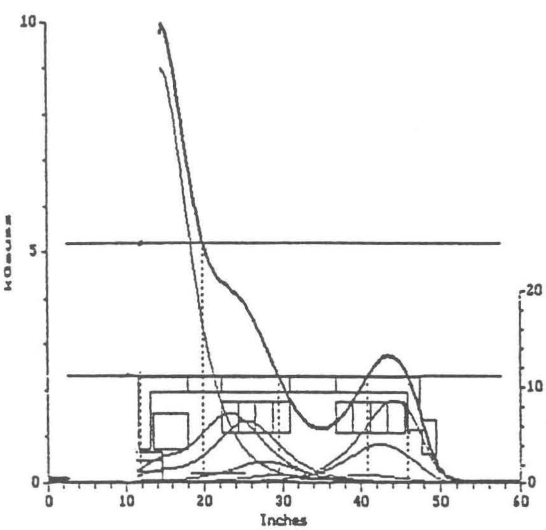
ABSTRACT

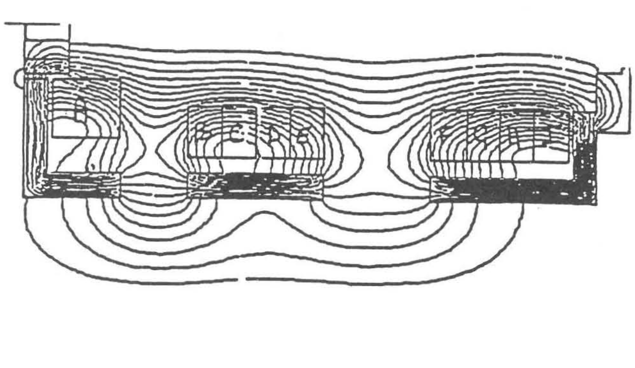
The Texas A&M ECRIS (Electron Cyclotron Resonance Ion Source) is a two stage, 14.5-6.4 GHz, source in operation since August of 1989. Injection in the K500 cyclotron was accomplished 3 months later. Since then minimal development time has been available and only essential modifications have been made. The source has produced beams as diverse as H-He+ molecules to $^{181}Ta^{24+}$ for acceleration by the cyclotron. After a brief description of the source and the injection line we report on their performance. Our plans and their development are then discussed.

1. DESCRIPTION OF THE SOURCE

The Texas A&M ECRIS is a production source. It was conceived[1] as such and built[2,3] at the Cyclotron Institute for injection into the K500 cyclotron. Figure 1 shows a sketch of the principal elements of the magnetic structure and the associated field profiles. The microwaves are provided by a 14.5 GHz transmitter for the first stage and a 6.4 GHz transmitter for second stage, thus the magnetic bottle is inherently tilted. Both stages are injected at the high field side and extraction is done through a Pierce system.[4] The minimum B configuration is achieved by the superposition of a permanent magnetic hexapole field made from Sm-Co, [Cf. Fig 1(b)], onto a mirror field produced by 9 coils separately adjustable [A to I in Fig. 1(a)]. This allows ample tuning capacity and provides reasonable margin to upgrade the source and test new ideas. The radius of the plasma chamber is 2.5 inches.

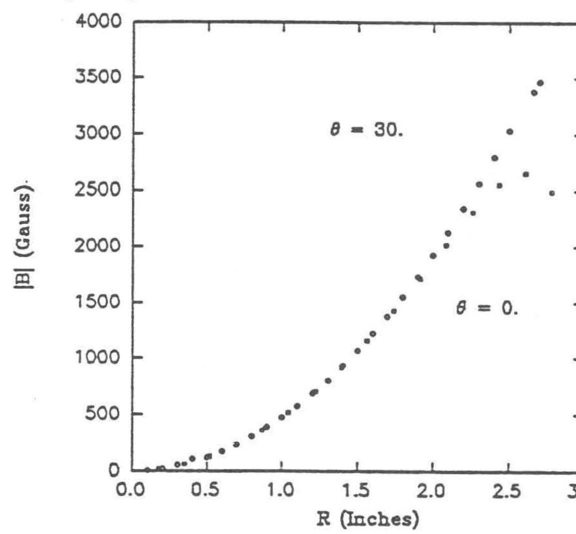
1(a)





2. OPERATION AND PERFORMANCE OF THE SOURCE

In day-to-day operations, the best solution for the mirror field is always very close to the one shown in Fig. 1(a). Minor adjustments for different beams usually result in a better production and higher stability. In Fig. 1(a), the mirror ratio on axis is approximately 2.1, and the total dissipated power is about 69 KW.



1(b)

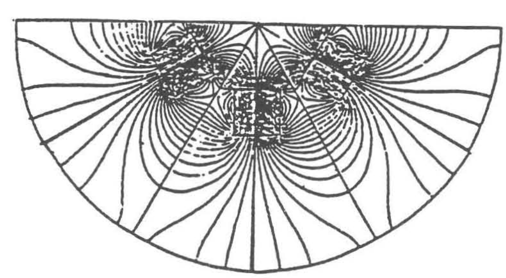


Fig. 1. A sketch of the principal elements of the magnetic structure and the associated field profiles. (a) The mirror field. (b) The hexapole field. The radius of the plasma chamber is at 2.5".

Figure 2 shows typical extracted currents for several ions ranging from $^{14}N^{5+}$ to $^{Nat}Pb^{33+}$. Keeping in mind the scaling laws of ECRIS[5] one can compare this source to other 6.4 GHz ECRIS. (e.g. Refs. 6, 7, 8). It is clear that the orthodoxy observed in the design of this source[1)] paid off. The data in Fig. 2 show a very good production capacity. As for its stability, once this source has been tuned, it usually stays stable until the injected gas pressure drops significantly.

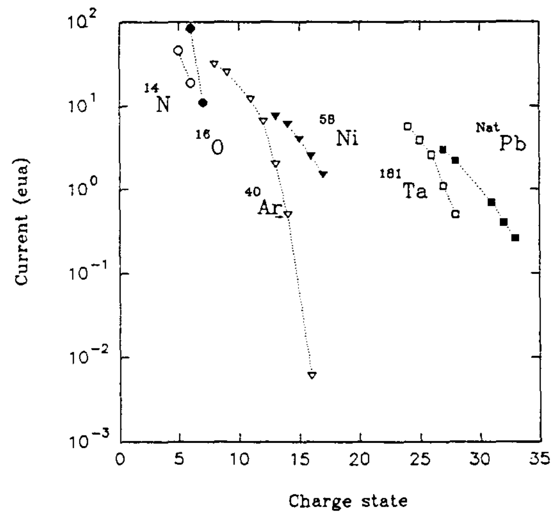


Fig. 2. Typical extracted currents for several ions ranging from $^{14}N^{5+}$ to $^{Nat}Pb^{33+}$ measured on a plate intercepting the beam after the analysis magnet (ILC02).

3. DESCRIPTION OF THE INJECTION LINE

As shown in Fig. 3, the output of the source is analyzed in a 90° magnet. A small bend (marked BM15-H in Fig. 3), allows for injection of another source into the cyclotron. The second 90° magnet bends the beam into the vertical part of the beam line which ends in a spiral inflector. The exit of the latter is in the median plane of the cyclotron. The beam size along the injection line is controlled by five solenoids with the last two being naked. Another 90° magnet (marked BM-AT) can bend the beam to be used before acceleration. It is usually used for atomic physics experiments.[9)]

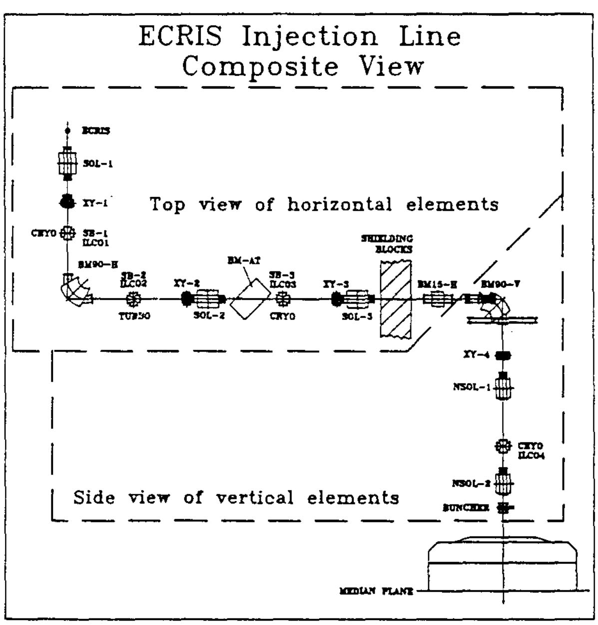


Fig. 3. The injection line components.

4. TRANSMISSION

Since the plate ILC04 is in the fringe field of the cyclotron, one expects to read less current on ILC04 than on ILC02 even for 100% transmission. The ratio of these two currents is shown in Fig. 4 for different beams accelerated since August of 1991 (solid circles). The ratio of the beam measured at the extraction radius of the cyclotron to that measured at ILC04 is indicated by open circles. And finally, the ratio of the beam extracted from the cyclotron to that measured at the extraction radius is shown by solid squares. We use data since August 1991 because the buncher was mounted on the injection line at that time. Also, the last time the main coil was moved was in July of 1991. Although the position of the main coil has been optimized for better extraction, one can see the dependence of the ratio of extracted beam to internal beam on gamma (E/E0) (solid squares). (*)

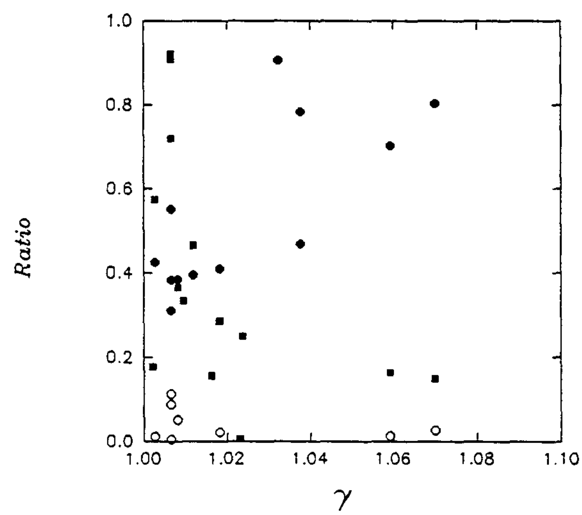


Fig. 4. The ratio of the current measured on the plate ILC04 to that measured on ILC02 (solid circles). The ratio of the beam measured at 26.5" to that measured on ILC04 (open circles). The ratio of the beam extracted from the cyclotron to that measured at the cyclotron extraction radius (solid squares). (Cf. paragraph 4)

5. PLANS

Since 1986, when this source was designed,[1)] several significant developments happened in the ECRIS field, two of which have direct bearing on our plans.

5.1. Permanent magnet material

NdFeB is now widely used and has proved to be at least as safe as the Sm-Co. Since it can be magnetized to much higher values than Sm-Co, the space needed to fit a hexapole of a given strength is smaller and so is the inner radius of the coils. This point is among (if not the) most important point to be considered in any attempt to design a better source (whether for production or stability).

5.2. First stage

Among several questions that have to be addressed when upgrading our source, is the necessity of the first stage and, if at all, what should replace it. Experiments with biased plates[10,11] and with an electron gun[12] have shown substantial increase of the output of the source when these devices are used with a main stage only. We have tested a 3.5 cm diameter copper plate in our source and found very encouraging results.[13] In Table 1 the results obtained with the plate and the main stage are compared to those obtained with both stages. An effort is under way to compare the usage of an electron gun to that of a plate.[14]

(*) Depending on the charge state and the beam velocity the vacuum in the cyclotron can become another major source for beam loss.

Table 1

	with first stage	with plate
$^{20}Ne^{8+}$	12.0 μa	17.5 μa
$^{20}Ne^{9+}$	0.75 μa	1.1 μa
$^{40}Ar^{11+}$	5.1 μa	18.0 μa

6. REFERENCES

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