DESIGN OF THE ATLAS PIIECR ION SOURCE

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The ATLAS PIIECR ion source is a major component of a project which will result in the replacement of the ATLAS tandem electrostatic injector with a superconducting linac of extremely low velocity profile and a ECR ion source operating in the continuous mode. The requirements for the performance of the ECRIS are relatively high charge state ions (2 m/q 10), good transverse emittance, low energy spread from the ion source system, and the need to place the ion source on a high-voltage platform in order to provide bunching and proper velocity matching of the beam into the linac. Therefore, our goal is to construct a source which compares favorably to the existing general purpose ECR ion source in term of charge state distribution and total current. This goal must be achieved for nearly all ions, especially materials which are normally solids. Simultaneously, the source must be designed in such way that total power consumption is minimized, but source efficiency and flexibility are maximized.

A compilation of the source parameters which we have adopted is given in table 1. An overall view of the source is shown in fig.1. The various issues which we have considered in our design process and our decisions regarding those issues are the following:

(1)R.F.Frequency and Transmitter: The desire to use only one transmitter on the high voltage platform has led us to choose a single frequency for both stages. Concern about the possible problems of RF penetration into a small first stage leads us to select 10GHz. This choice is encouraged by the possibility of the correlation of charge state distribution and frequency, although at present this effect is not always realized. The RF transmitter was ordered from MCL[1], based on a Thompson CSF tube. The power from the transmitter will be split between the two stages by a variable power splitter in the wave guide, in a way similar to the Oak Ridge design. This allows optimal flexibility in tuning the source, while using only a single transmitter, at the cost of a slight increase in complexity of operation.

The R.F. feed is designed to enter the first stage at a point where the magnetic field is above the ECR condition. The second stage waveguide should enter the source in a region between the multipole plasma cusps in order to minimize the plasma entering the waveguide.

(2)Solenoid Coil: The source will be completely enclosed by an iron return yoke in order to reduce the power requirements the solenoid coils. The coil design parameters are given in table 1 and will be constructed at Argonne. The expected power consumption is 30 kilowatts. The coils will be independently powered and can be moved with respect to each other so as to tailor the mirror ratio in a way which has some independence from the peak field. The coil assemblies will be mounted in the iron yoke in such way that all internal source alignment will be with respect to the iron yoke. The mirror ratio has a nominal value of 1.7 with a range of +/-0.2. Figure 2 shows an example of the expected on-axis magnetic field for the source.

(3)Hexapole Magnet Design: The multipole magnet design chosen is a twelve pole permanent magnet type similar to that used in the Oak Ridge ECR source[2]. We have incorporated a few variations into our design in order to gain some additional flexibility. The source vacuum radius has been increased in order to improve pumping speed and gain radial access to the second stage. In order to increase the source radius and still maintain an ECR surface from the hexapole field in the vacuum chamber, we have chosen to employ a new hexapole field material, Nd-Fe[3]. This material has a residual field strength, Br, of approximately 12 kilogauss. This has allowed the inner pole radius for the hexapole to be increased to 6.0 cm. The benefits from the increased radius are improved pumping in the second stage and radial access into the second stage.

The important issue which must be addressed in changing to the Nd-Fe material is the fact that the Curie temperature is 300°C. This value is less than half that of $SmCo_5$ and therefore more care must be exercised in designing the water cooling jacket. Our present plan calls for a continuous sheet of cooling fluid to separate the hexapole assembly from the plasma vacuum chamber. This feature and the general cross--section of the inner region of the source are shown in fig.3.

(4)Vacuum Chamber and Pumping: The plan for the vacuum chamber is shown in both figs.1 and 3. The first stage of the ECRIS will be mounted on a flange which will contain vacuum pumping for the first stage. The design is intended to allow one to easily change the first stage. In addition to variations in the first stage design for ECR-type operation, it is possible to conceive of other types of ion sources as the first stage which are then followed by the stripping of the ions in the second stage.

The pressure profile expected to be achieved in the various regions depend on two stages of differential pumping between the first and second stage. A total of three vacuum pumps are planned for the source. Because of space limitations and power consumption limits on the high voltage platform, the present plan is to use turbo-molecular pumps of 1000 l/s capacity. The extraction region will be made as porous as possible to enhance pumping. As calculated, it appears that a pressure of 10^{-3} torr in the inner region of the first stage will result in a pressure of 10^{-6} torr in the second stage central region. Under

Table 1. ATLAS PIIECR Ion Source Parameters

Magnetic Field	
Peak On Axis	4.25kG
Solenoid Magnet Power	30 kW
Solenoid Current	400 Amp
Mirror Ratio	1.7
Mirror Ratio Range	+/- 0.2
Length of Mirror	46 cm.
Hexapole Material	Nd-Fe
Number of Poles	12
Hexapole Field at Chamber	4.4 kG
RF System	
Frequency	10.5 GHz
RF Power	2.5 kW
Independent Control	both stages
Dimensions	
Solenoid Inner Diameter	22 cm.
Solenoid Outer Diameter	54 cm.
Hexapole Inner Diameter	12 cm.
Anode Aperture	8 mm
Extraction Aperture	10 mm
Vacuum Chamber Inner Diameter	10.6 cm.

these conditions, the gas usage rate would be approximately 3mg/Hr for nitrogen.

(5)Extraction Region and Near Optics: Calculations by using SLAC electron gun code[4] are underway for the design of the extraction region electrodes. The present status of the calculations are reflected in fig.4. This region is being designed to allow extraction voltage as large as 20 kV to be used and for mass to charge ratios from 2 to 10. The broad range of parameters over which operation is desired indicates that we will need a variable gap extraction electrode. Thick return yoke for the PIIECR ion source was thought to generate a sharp falling-off character of the magnetic field, and to give a strong focusing just around the extraction and the einzel lens. Calculations showed that the focusing was strongly dependent on the mass to charge ratio(m/q). Resultantly, drastic change of the optics was observed in the range from the m/q=2.0($^{4}He^{2+}$) to 10.0($^{238}U^{23+}$) as shown in fig.5.

Because the calculated focusing effect could compensate a diverging edge effect due to a so-called missing current without a slanted electrode, it may be possible to use a flat electrode of the extraction hole in actual operation by adjusting the magnetic field distribution of the solenoid. In addition, the space charge effects which can be expected from beam currents of the order of a few milliamps and no space charge neutralization of the exraction region indicate that a shallow initial waste is desired. Therefore, an electrode which has a normal surface with respect to the extraction plate appears to be a good choice for this application. The remainder of the beam transport system on the voltage platform will be electrostatic in order to minimize power consumption. The first einzel lens is shown in fig.1 and its position in the transport system can be seen in fig.6.

(6)High Voltage Platform: The PIIECR source will be mounted on a high voltage platform which will be operated at voltage up to 350 kV for injection into the low velocity superconducting linac presently under development. The difficulty of delivering power to the platform and removing excess heat strongly encourages us to develop a system which is as power efficient as possible consistent with our performance goals. The total power required for the source and beam transport elements will be approximately 80 kilowatts. Of this amount approximately 50 kilowatts will be dissipated into a fluid cooling system. The longitudinal optics requirements encourage us to maintain high voltage stability, better than one part in 10,000, on the platform. This requires very low leakage currents to ground through the cooling system. Therefore, we will need to employ a two stage cooling system which uses a high resistivity fluid between ground and the platform and uses water for the cooling of the magnets.

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References

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4. Hermannsfeldt, W.B., Nucl. Instr. and Meth.,187 (1981) 245

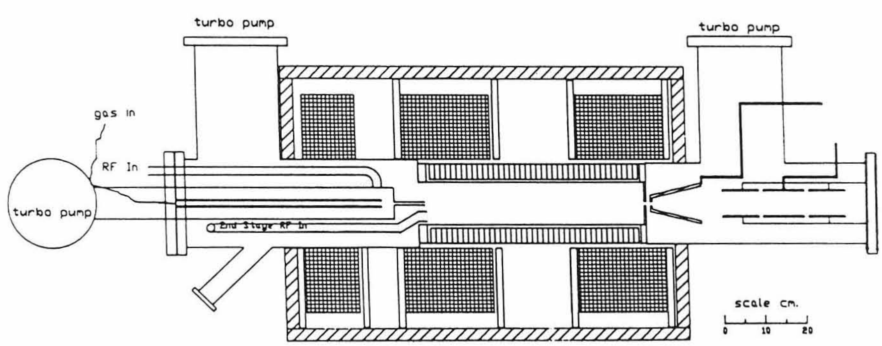

Figure 1. ATLAS PIIECR ion source design plan.

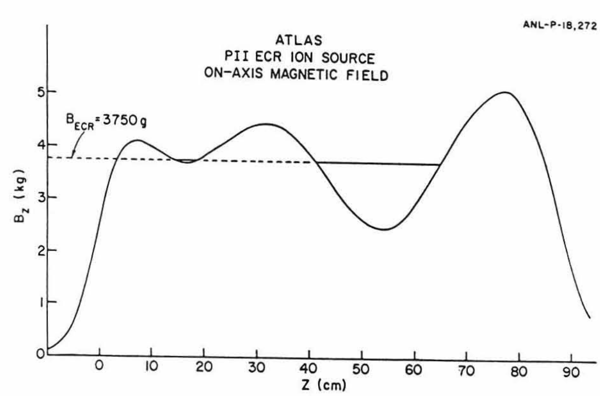

Figure 2. ATLAS PIIECR on axis magnetic field.

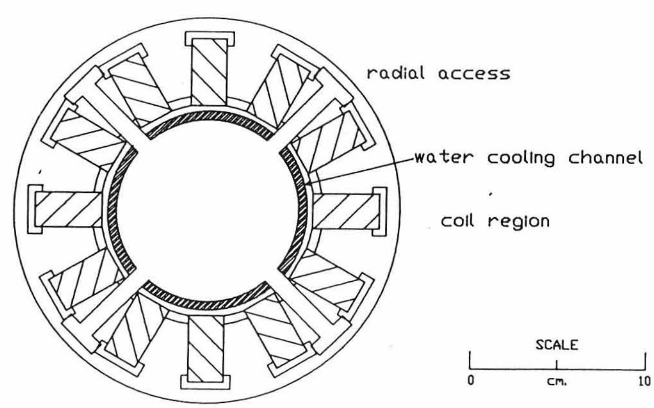

Figure 3. ATLAS PIIECR hexapole assembly cross-section.

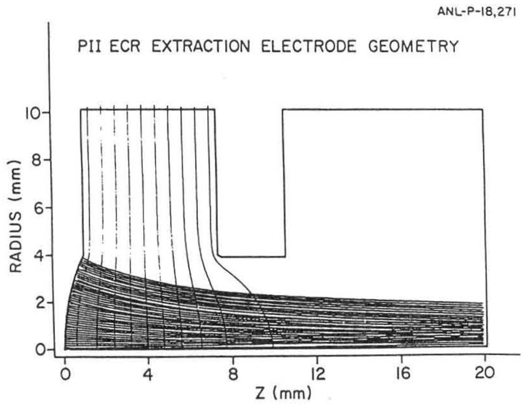

Figure 4. ATLAS PIIECR extraction electrode geometry for the near source region. This example calculation shows an assumed beam of 0.6 milliamps, Vext=10.0 kV, and m/q=7.64. The fringing magnetic field from the solenoid field is also included in the calculation.

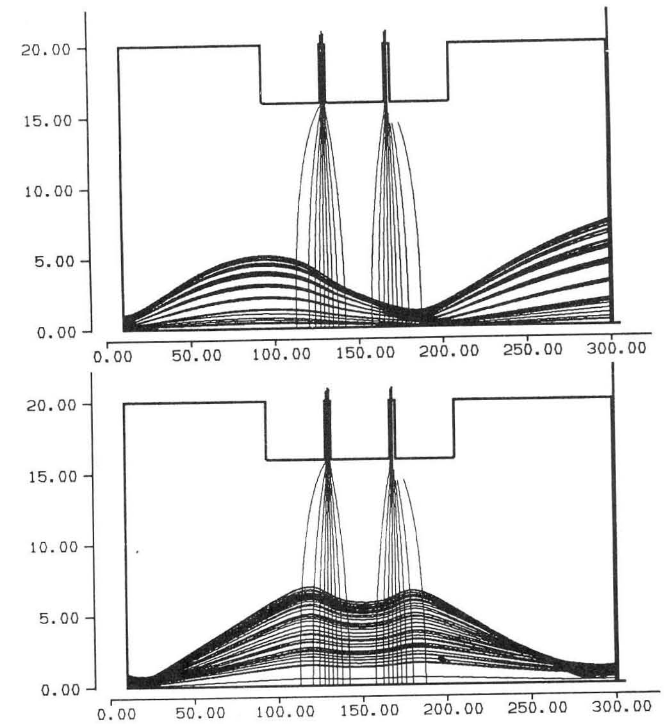

Figure 5. ATLAS PIIECR beam envelops just after the extraction region, and around the einzel lens for m/q=2.0(upper) and m/q=10.0(lower). Vext=10.0 kV (upper and lower), Vlens=7kV (upper) and 15 kV(lower), lens, and mesh unit=2.0mm.

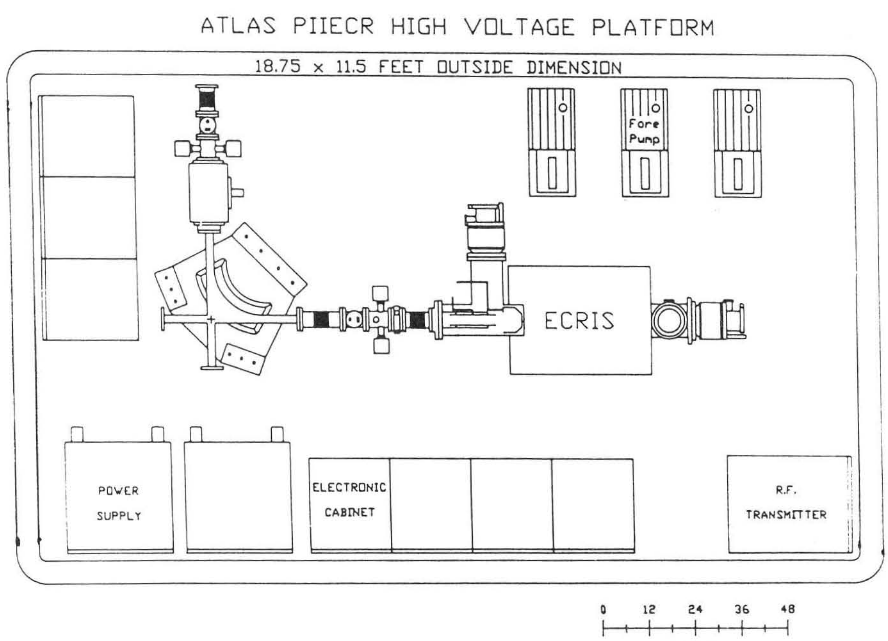

Figure 6. ATLAS PIIECR high voltage platform plan. The platform will be operated at a voltage up to 350 kV.