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ECR Ion Source for the Injector AVF Cyclotron at RIKEN

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ABSTRACT

An ECR Ion Source for AVF-Ring Cyclotron complex is now under construction at RIKEN. The Source will be used to produce relatively light heavy ions (up to Ar). The first beam will be scheduled in march,1988. After one year development, the beam will be injected into AVF. The design of Ion Source and beam injection line is described.

INTRODUCTION

RIKEN Ring Cyclotron is now working with a heavy-ion linac (RILAC), and the construction of an AVF cyclotron injector was started. A Duoplasmatron Ion Source and an ECR Ion Source will be installed as external source of the AVF. The M/Q value of ion which the AVF can accept is less than 4. For Ar ion, charge state must be higher than 10. Principal design of the ECR Source is based on LBL Source, but for the stronger magnetic confinement, the magnetic field in the plasma stage is higher, and this results in using high frequency microwave (10GHz).

ION SOURCE DESIGN

Main parameters of the Source are listed in table 1. A schematic view of the Source is shown in fig. 1. The Source is consists of two stages. The 1st stage is for plasma filamentation and the 2nd stage for production of highly charged ions. Two gas injection lines are installed at the 1st stage and one line at the 2nd stage for gas mixing.

1. Magnetic field

In the 2nd stage, a mirror field is created by solenoid coils and six bars of SmCo5 permanent magnet. Axial and radial magnetic field profiles are shown in fig. 2. The mirror coil is divided into eight sections, and eight power supplies are controlled independently, which can change the magnetic field profile. Mirror field in the 2nd stage can be high enough to test tangential field effect[2]. But from magnetic pressure point of view, B^2 value at the extraction hole is higher than that of center of the chamber wall. This means the diffusion of the plasma is caused mainly to the hexapole walls, and may reduce the extraction current. If this is true, optimum magnetic field at the extraction hole will be about 4.5kGauss. Using a return yoke, the mirror coil power consumption is reduced, and Xray from plasma chamber also shielded. Hexapole magnet bars are placed inside the vacuum chamber enclosed in jackets and cooled. Size of the 2nd stage plasma chamber is 10cm in diameter and 52cm in length. Long size chamber can reduce magnetic field gradient at ECR surface to about 100G/cm,which is better for electron accelaration by ECR and increases the electron temperature[3]. In the 1st stage, there is only solenoidal field. By changing the solenoid coil current, ECR surface position can be changed.

2. RF

10GHz microwave is injected into both 1st and 2nd stage through 27mm ID circular wave guide. In the 1st stage, RF is injected radially from high magnetic field region. By so call beach effect RF reflection will be reduced. In the 2nd stage, RF is injected axially. For efficient RF absorption in plasma, a chamber must be a multimode cavity. It is pointed out that the chamber diameter D is more than twice as large as the RF wavelength λ[4]. In our case, D/λ is 2 in the 1st stage and 3.3 in the 2nd stage. RF power to both stages can be changed independently by using two variable attenuators in the RF power supply. The RF signal source is a Gunn oscillator,and divided into two lines,amplified by GaAs FET and klystron amplifier(Thomson TV851). Maximum RF power is 1kW for the 1st stage and 2.5kW for the 2nd stage.

3. Vacuum

In the 1st stage cavity, the pressure will be about 10^{-4} torr, but in the 2nd stage it must be less than 10^{-6} torr to reduce charge exchange collisions with neutral atoms. A 500 l/s TMP is installed at the 1st stage,and two 1500 l/s TMPs at the 2nd stage and the extraction region. To avoid the discharge at unnecessary region, a 20mm ID quartz tube is installed in the 1st stage.

Table 1 Main parameters of the ECR Source

1st stage	
magnetic confinement	solenoidal field
chamber diameter	60 mm
	20 mm(quartz tube)
chamber length	250 mm
RF	10 GHz CW 1kW max
pump	520 l/s TMP
2nd stage	
magnetic confinement	mirror+hexapole field
mirror ratio	1.4 to 1.8 (variable)
chamber diameter	100 mm
chamber length	520 mm
RF	10 GHz CW 2.5kW max
pump	1500 l/s TMP
extraction	
acceleration voltage	3 to 25 kV
suppression voltage	0 to -10 kV
extraction gap	5 to 45 mm (variable)

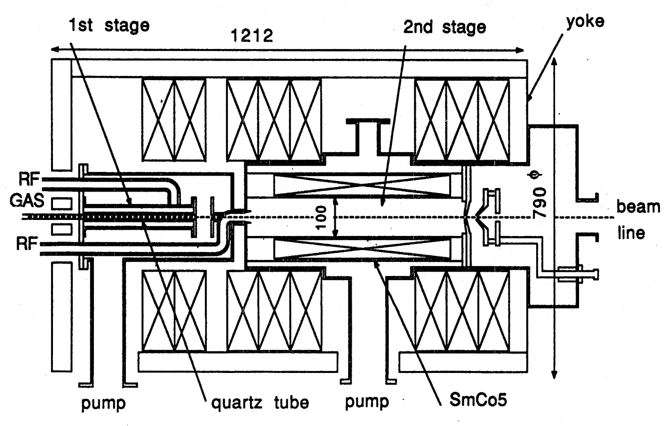
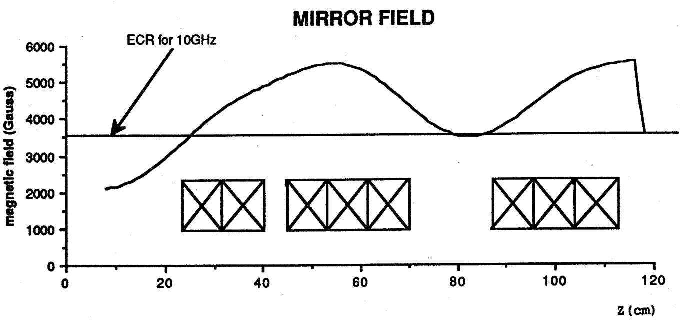


Fig. 1 Schematic drawing of the ECR Ion Source.



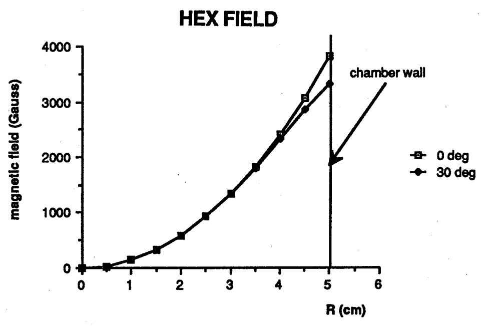


Fig. 2 Magnetic field profile.

4.Extraction

The extraction voltage is varied from 3 to 25kV determined from the injection condition to the AVF cyclotron. The extraction hole is 10mm in diameter, and the gap between the extraction hole and the extraction electrode can be changed from 5mm to 45mm. To reduce secondary electrons from the ground electrode, the extraction electrode is biased at the negative voltage. In the case of the low extraction voltage, the suppression voltage can be high so that the sufficient field gradient is obtained at the extraction gap.

BEAM TRANSPORT LINE

The extracted beam from the ECR Ion Source is transported and axially injected into the AVF cyclotron. A schematic drawing of the beam injection line is shown in fig 3, and the beam envelope from the 1st order TRANSPORT calculation is shown in fig 4. Beam emmitance from ECR Ion Source is supposed to be 200π mm.mrad, which is about same as the AVF acceptance using a spiral inflector. As the beam shape from the ECR Source is rotationally symmetric, solenoid focusing elements are better than quadrupole lenses for easy tuning.

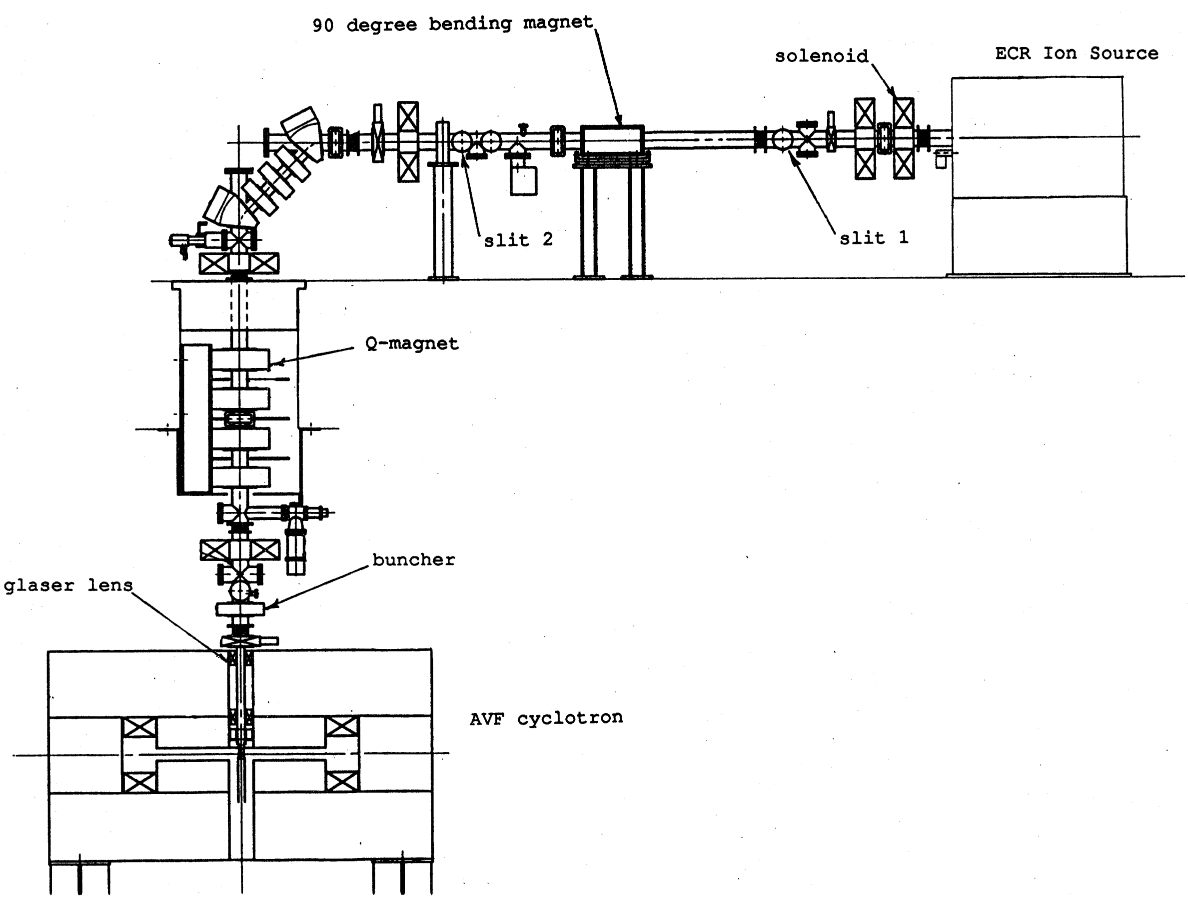


Fig. 3 Schematic drawing of the beam injection line to the AVF cyclotron.

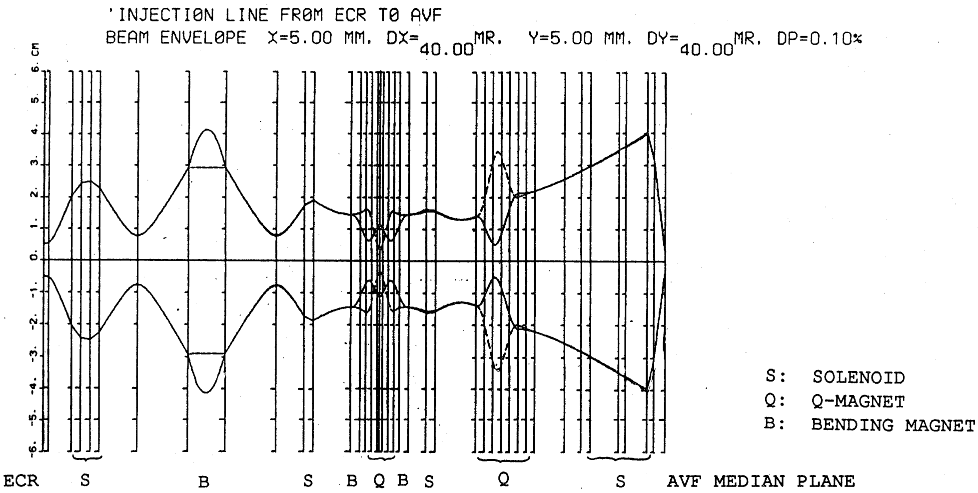


Fig. 4 Beam envelope of the transport line.

Using a doubly focusing bending magnet, the beam shape is rotationally symmetric before the matching section. After the ECR Source, double solenoids can make the emittanece ellipse at the slit 1 erect even if the ellipse at the extraction hole is not erect. Axially bending section is achromatic. A Q-magnet quartet is placed in vertical section to match the beam emittance to the AVF acceptance. A sawtooth single gap buncher is planned to installed 2m upstream from the inflector to bunch the beam. The space charge effect is negligible when the current is less than 10μA. The beam pipe is made of stainless steel with 4" ID for high pumping conductance. The pressure in the beam line is maintained less than 10^{-7}torr to reduce the beam loss by charge exchange with the residual gas. For the magnetic shield to reduce the steering effect by the leakage flux from the AVF, the beam pipe is covered with 2mm thick iron plates.

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