6. 28 GHz superconducting ECR ion source

In order to achieve 1pμA U-ion beam at 350 MeV/u, more than 15 pμA of U^{35+} ion beam is required from an ion source unless we use the first charge stripper. To produce such high intensity of highly charged heavy ions, we have to use higher magnetic mirror ratio and the higher microwave frequency (> 18 GHz) to increase the plasma density and ion confinement time.

Figure 1 shows the schematic drawing and magnetic field strength of the superconducting ECR ion source that has an operational frequency of 28 GHz. To obtain lager plasma volume, we will use special geometrical arrangement of the solenoid coils as shown in Fig.1. Using this arrangement, we will obtain 3~4 times larger volume than that for classical magnetic field configuration as shown by dashed line in fig. 1. The sextupole field is generated by the six racetrack coils wounded around a pole piece. To obtain good plasma confinement at 28GHz, we need the maximum mirror magnetic field strength of 4T and radial one of 2T.

Calculations using the three dimensional codes TOSCA were used to develop the superconducting magnet structure. Table 1 shows the preliminary coil parameters to produce magnetic field strength shown in Fig.1. The inner and outer diameters of solenoid coil1 are 290 and 450 mm, respectively. Estimated total stored energy is 300 kJ under this condition. Optimization of the sizes and geometries of the coils is now underway.

We found that the magnetic field gradient at the resonance zone plays essential role to increase the plasma density and electron temperature. The field gradient strongly depends on the minimum magnetic field strength (B_{min}) of mirror field [1,2]. Using this coil arrangement, we can change the B_{min} without changing maximum magnetic field (B_{ext} and B_{inj}) independently to optimize the magnetic field gradient at the resonance zone.

The inner diameter and length of the plasma chamber will be 12 and 50 cm, respectively. The plasma chamber wall will be made from Al to donate cold electrons to the plasma to decrease the plasma potential [3,4]. Furthermore, the Al is very resistant to the plasma etching. This reduces contamination in the plasma of the ions from the wall. The biased electrode will be installed to obtain the same effect as the Al chamber wall [5]. Water cooling of all surfaces in contact to the plasma also planned to minimize the temperature effects caused by plasma and microwave heating at high microwave power.

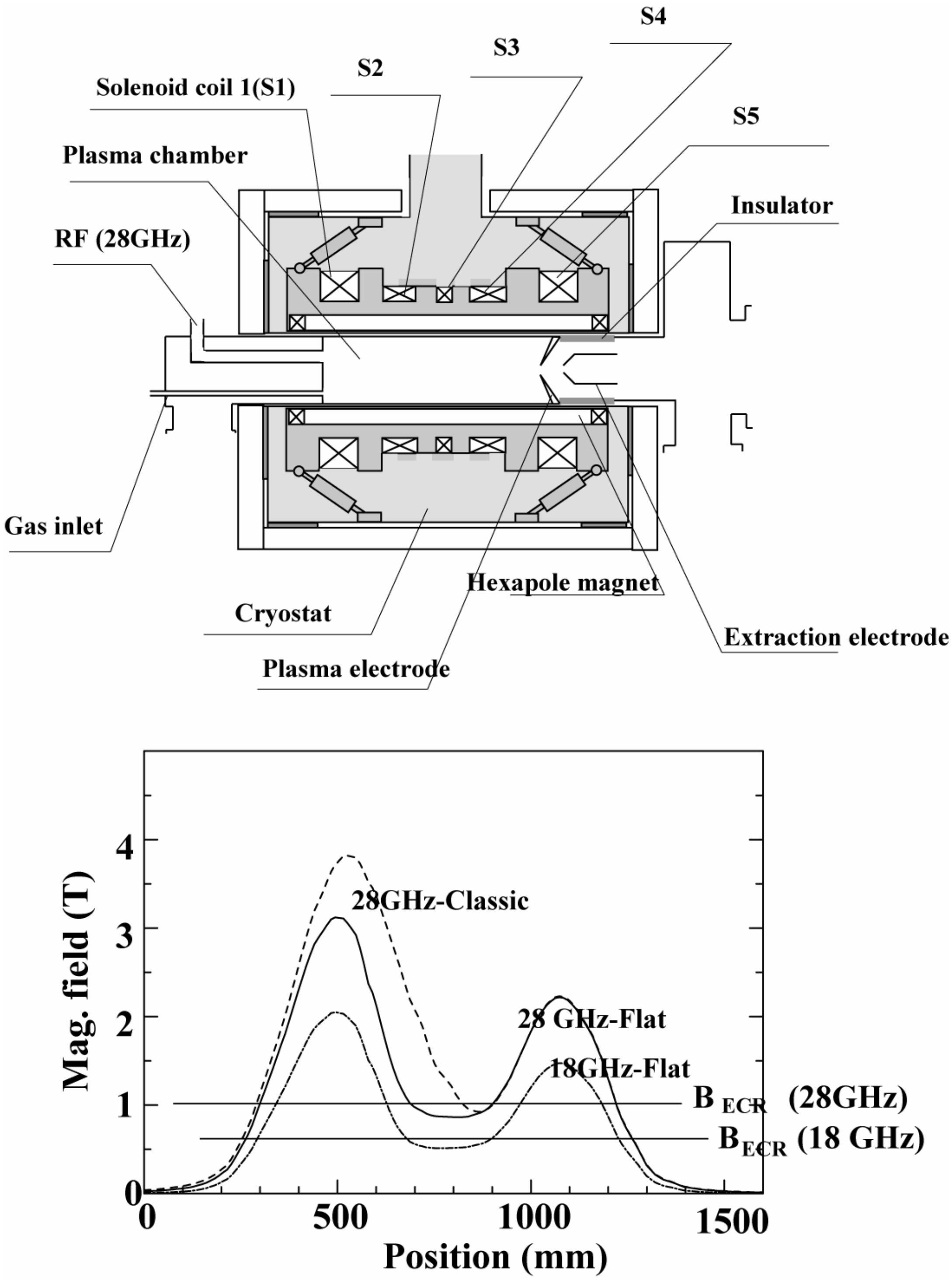

Fig.1. Geometrical arrangement of the coils of new SC-ECRIS (upper figure) and magnetic field configuration (lower figure).

Table 1. Parameters of the solenoid coils.

	S1	S2	S3	S4	S5
Current density(A/mm^2)	120	-110	100	-100	110
Dimension(mmxmm)	120 x 80	75 x 45	45 x 45	75 x 45	100 x 80
Current(A)	320	-293	266	-266	293
Number of turn	3600	1265	760	1265	3000

At lower microwave frequency (<18 GHz), one of the high performance ECR ion source is the AECR-U at the LBL, which has an operational frequency of 14 GHz. [6] The beam intensity of U^{35+} ions is about 16 eμA at the RF power of 1kW as shown in Fig.2.

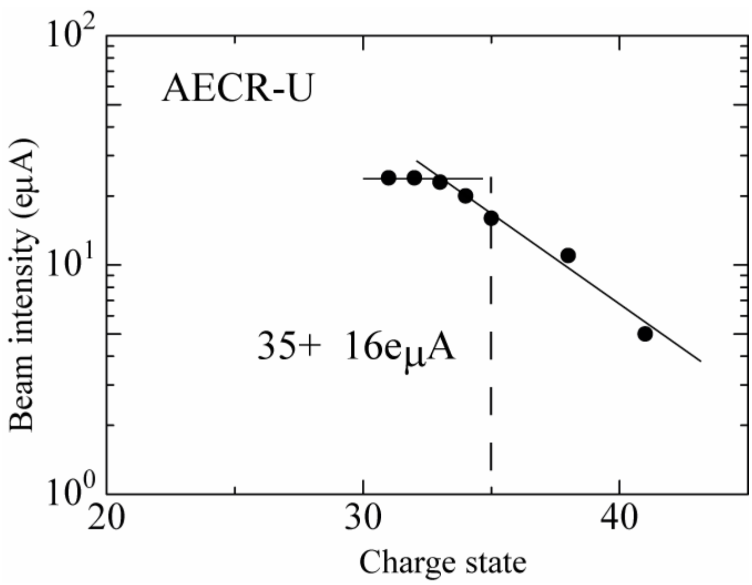

Fig. 2. Beam intensity of U ions from the AECR-U.

The volume of the resonance zone of new RIKEN SC-ECR ion source described here is 10 times larger than that of the AECR-U. The microwave frequency is two times higher. This means that in principle the new ion source can produce 40 times higher intensity than the AECR-U. However, we have to use higher microwave power (~10 kW) to obtain high enough electric field gradient at the resonance zone, because the plasma chamber volume is quite large (about 8 L), which is ~10 times as large as the volume of the AECR-U.

The expected total current from the ion source will be higher than 10 mA. In this case, the normalized emittance of highly charged heavy ions is estimated to be 1 πmm・mrad, which is mainly due to the space charge effect. Under this condition, we have to supply very high extraction voltage (higher than 60 kV) to obtain good emittance (unnormarized emittance of ~150 πmm・mrad) for matching the acceptance of the RFQ linac. The ion source will be equipped with a movable accel-decel extraction not only to improve the extraction conditions, but also to compensate the space charge effect.

Estimation

Cost:	290 Myen
Manpower:	5 persons
Period:	2006 - 2007

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