Design of an ECR Ion Source at 14GHz

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Abstruct

Three ECR ion sources for multi-charge ions have been developed at INS. Recentry,An ECR ion source at 14GHz has been designed.The design concept is presented.

Introduction

An ECR heavy ion source named HyperECR has been designed to work at 14.25GHz microwave frequency. It is now known that a good vacuum at the ECR zone where the multiply-charged ions are produced is one of the most important prerequisite for good performance of the source,as well as the high microwave frequency. In the present design,a configuration of the source components compatible with a good vacuum,high efficiency of the microwave power transmission and magnetic field strength needed for formation of a closed ECR zone at 14.25GHz has been searched for. In addition ,the magnetic field which is usually designed only to satisfy the ECR condition has been made as strong as the conditions permit. This feature has been adopted with an expectation that the stronger field can confine the plasma better and can guide ions more strongly.

Magnetic field formation

Three ECR ion sources have been developed and are in operation at INS. Table 1 lists some of their parameters. From experiments with these ion sources[1,2], it was found that the HiECR source has produced satisfactory results except at 14.25GHz. Basically this source was designed for 10GHz. From the measured magnetic field strength,distances from the ECR shell to the plasma chamber were roughly calculated for each situation. They are also shown in Table 1. Because the magnetic field is too weak for HiECR at 14.25GHz,the distance is only 4mm,which is minimum in the Table. So It is possible that 4mm is not enough to keep the electron temperature high and to accelerate electrons effectively. From this reason,the distance is designed at least 10mm for HyperECR Ion Source. The inside diameter of the plasma chamber is designed to be 50mm,which is more than two wave length. Therefor, the ECR shell diameter for HyperECR Ion Source should be less than 30mm.

At first,magnetic field of several configulations were computed with PANDIRA to look for the model which satisfy the requirements.The configulations were based on HiECR ion source. Most efforts have been paid to increase the field strength. Before to decide the direction from which the microwave is fed,it also took time to estimate the magnetic field of a sextupole which had a hole(ϕ25mm) in radial direction. But once to decide that direction,the sextupole field was almost fixed,because the sextupole magnet has only a few parameters,length,inside diameter, and thickness. The material is Nd-Fe-B(NEOMAX35H) and this is best choice available now. The distribution of the absolute magnetic strength, which is made from the solenoid field and the sextupole field,decides the ECR shell diameter. But in this case, because of the almost fixed sextupole field,the ECR shell diameter only depend on the solenoid field.

Table 1. Some parameters of ECR Ion Sources at INS.

type	rf freq. (GHz)	B at ECR (kgauss)	Diameter of chamber(mm)	R of shell(mm)	Dist.to chamber(mm)
HiECR	6.4	2.3	70	21	14
	10	3.57		24	11
	14.25	5.1		31	4
NIRS-ECR	10	3.57	70	20	15
SF-ECR	6.4	2.3	104	31	21

With the computation,it was found that the mirror field with these two solenoid coils strongly depends on the inside diameter of the sextupole iron york,which does not effect a lot to the sextupole field. From the results of computations about the solenoid field and the sextupole field,absolute magnetic field inside the plasma chamber can be figured out,and using these values,an ECR shell diameter can be calculated. At first the sextupole field was determined as shown in Fig.1. Using these values,the relation between a minimum field strength of the mirror field and an ECR shell diameter can be easily calculated(see Fig.2). Based on this calculatin, the minimum field strength is estimated to 4.2kgauss or more to keep the ECR shell diameter less than 30mm. Fig.3 shows the designed solenoidal magnetic field at 500A.To attain this minimum field strength,the dimensions of the cylindrical iron york between two coils were determined to have the inner diameter 200mm and the outside diameter 220mm.

The positions of the two solenoid coils are adjustable axially about 10mm for each one. This mechanism adds more flexibility to change the minimum field strength.

Both sides of the plasma chamber are made of iron,and they keep the vacuum together with the plasma chamber. They work to form the magnetic field to keep strong the maximum magnetic field strength of the mirror field. In this paper they are called york chambers. These types of magnetic fields produced by the solenoid coils are saturated at 19.5kgauss in iron yorks near the center axis because all the magnetic flux will concentrate in them. To get more flux at center axis region,these york chambers can be attached high-μ materials,for example,Ferro-Cobalt(Fe 50%,Co 50%), in which magnetic field will saturated about at 23.5kgauss. With selection of the material and the figure,magnetic field strength can be optimized.

Vacuum

An ECR ion source at 14GHz or more need much iron yorks in center axis region to produce strong magnetic field in that area, so,it is difficult to be consistent with high conductance,in most cases.But dividing the york chambers azimuthally in six portions, three for yorks,and other three for vacuum pumping,has possibility for that consistency.York chambers have large inside diameter -ϕ96mm- for high conductance.

The plasma chamber will be pumped out with 150l/s turbo molecular pump from the gas inlet side and 500l/s turbo molecular pump from the ion extraction side,respectively.

For the protection of oxidation of iron yorks,and minimize degasing from surface,the surface of york chambers are plated with Ni.

Microwave

From experiment of HiECR Ion Source,it was found that to feed microwave axially is very effective and easy. From optimization of several ions,it became clear that 150W microwave power is enough to feed for HiECR source.

To feed microwave radially from side wall of the plasma chamber decrease the field strength of the sextupole magnet. Because this method requires to make a hole to the sextupole magnet, and the vacuum seal with frange needs a lot of space to make sextupole magnet separates more from the plasma chamber. This method decrease sextupole magnetic field,which mean that ECR shell become close to the plasma chamber. The magnetic field strength is most important for 14GHz ECR ion source,so this method should not be use,and axial feeding method are chosed.

Ion extraction

The position of ion extraction electrode is adjustable in axial direction ± 25mm with keeping good vacuum. Flexible tubes are used in this mechnism. The alignment of ion extraction parts is critical for ion transportation. So these are adjustable by three shafts and each shaft have a gear to move together by chain belt.

The possition and dimention of ion extraction electrode are not easy to figure out definitely with caliculation,so it have much flexibility to find out the best configurations. The possition of einzel lens can be selected independently of the extraction electrode.

Also Ferro-Cobalt can be attached to reform magnetic field for an efficient extraction.

Electron beam

A piece of LaB_6 is attached at the top of a quartz tube,from which ionizing gas is fed. In operating condition,inside the quartz tube,the gas pressure is 10^{-4} Torr order,so gas is easily ionized,especially at ECR magnetic field region. Dense low-charged ions made inside the quartz tube will diffuse to the plasma chamber,in which gas pressure should be 10^{-7} Torr order,and dense electron beam from LaB_6 will work to make high-charged ions.

The LaB_6 piece will be heated by Ions and electrons inside the quartz tube and also plasma inside the plasma chamber. LaB_6 easily emit electrons after heating.

With the inside diameter of the LaB_6 part,differential pumping will be controlled. This will be adjusted so that the pressures inside the plasma chamber and inside the quartz tube are well balanced to produce much multiply-charged ions.

Bias voltage to the LaB_6 piece will work for supplying electrons to the plasma chamber.

Probably the possition of the LaB_6 piece is very sensitive to plasma and beam stability,so it can be valiable for optimization.

Conclusion

With these design, each parts are in manifacture,and until the end of this year,assemble Hyper ECR Ion Source(see Fig.4). Hopefully,these frexibility help to produce ions and to study ionization mechanism.

References

1. T.Hattori,Proc. 13th Linear Accelerator Meeting in Japan (1988.9.7-9,KEK,Tsukuba) pp. 62 - 64
2. T.Hattori,Proc. 7th Symp. on Accelerator Science and Technology, 1989, Osaka, Japan, pp. 71 - 85

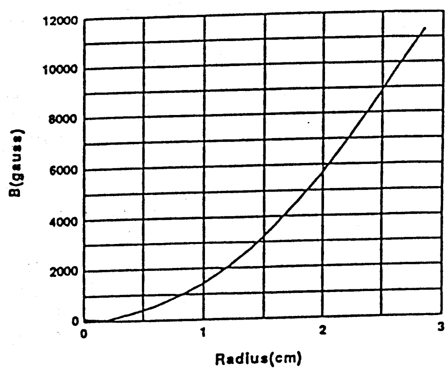

Fig.1 Sextupole magnetic field

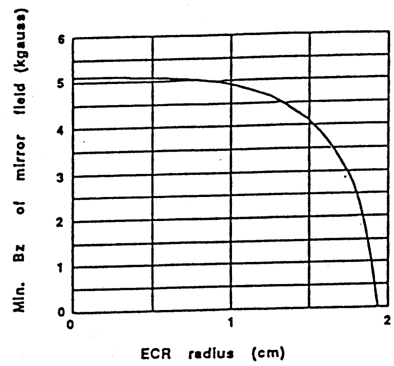

Fig.2 ECR shell radius to minimum Bz of mirror field.

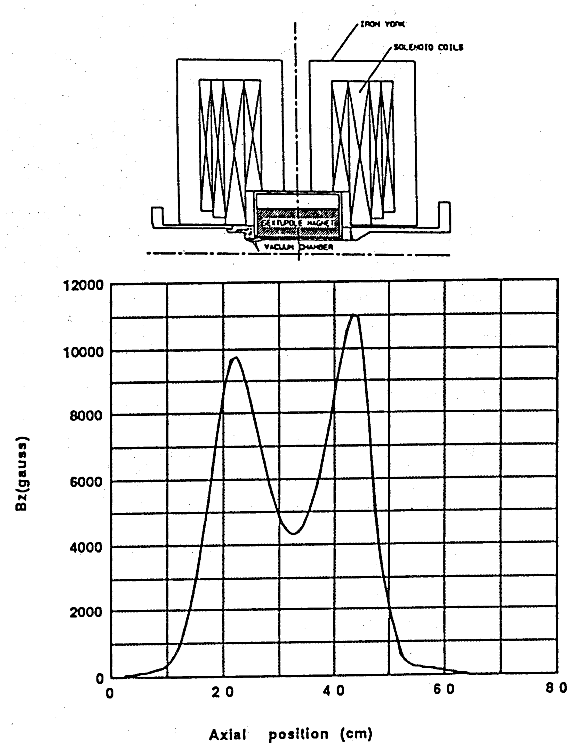

Fig.3 Mirror field distribution

Table 2. Design parameters for Hyper ECR ion source

Microwave Power Source	
Frequency	14.25GHz
Max.Power	2.0kW
Chamber Diameter	ϕ50mm
Length	190mm
Multipole Magnet	
Multipolarity	Sextupole
Field Strength	11kG on the surface
Material	Nd-Fe-B
Inner Diameter	57mm and 63mm
Length	150mm
Mirror Coil	
Max.field Strength on axis	11kG
Max.Current	600A
Max.Power	60kW
Turn Number	211T for each coil
Vacuum System	
pumps	Turbo-Molecular Pump 500l/s and 150l/s

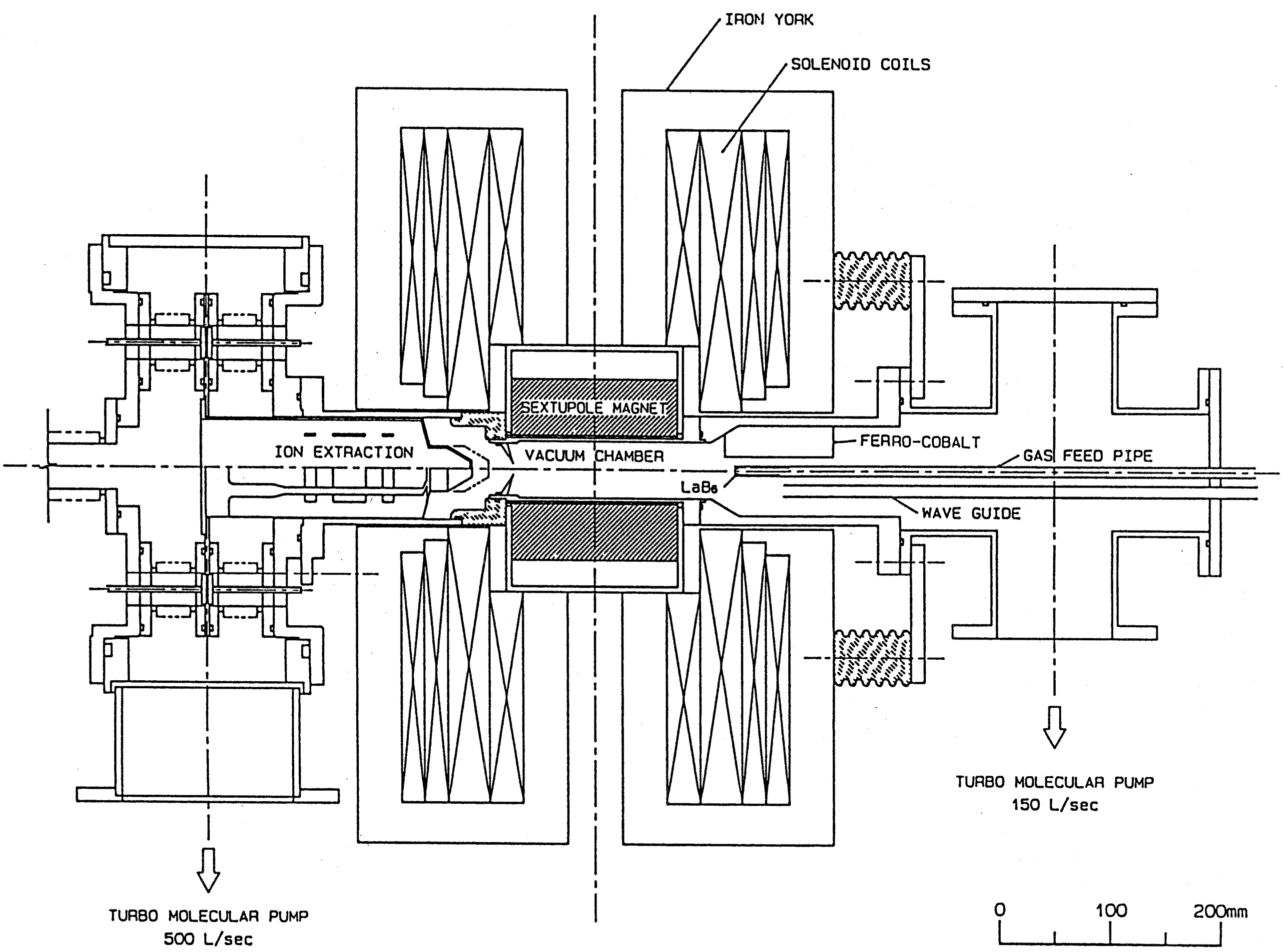

Fig 4. Schematic drawing of the Hyper ECR ion source