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Abstract:

A new compact ECR ion source working at Ku-Band is designed and in manufacture. Remarkable features of the source are as follows: (1) ordinal ECR zone and second Bernstein zone can be formed in the plasma chamber, (2) basic B-minimum field is produced by permanent magnets and axial Bmin field is adjusted by a small auxially solenoid, (3) both an axial and radial microwave ports are placed at a plasma chamber, and (4) microwave frequency is variable in the range of 12-14.5GHz. The outer size of the chamber is $\phi 180\times 230$ mm^3 and its total weight is about 30 kg.

1. Introduction

Recently with various progress of ECRIS development, an ion source with low or medium charge state has been distincted to a more highly charged source and its development has been recognized as a necessary task. Although these kinds of source are commonly configulated of a "B-minimum" field, for an extraction of ions, the optimized working condition are not always in both kinds[1]. In addition, a more smaller size and lighter weight are expected for the utility.

At the 12th ECRIS workshop, some new attempts were reported for these purposes. For compactness of the source, very small and light sources working at 10 and 14 GHz were presented from several institutes. In other side, for extentions of the ECR principle, some attempts and proposals were also reported such as a use of a second Bernstein (B2) mode by K. S. Golovanivsky[2] and a double frequency heating experiment by LBL group[3].

Combining these attempts, a new compact ECR ion source is designed and now in manufacture in our institute. In this new source the effectiveness and practicability on setting of B2 mode are to be tested and double frequency heating is also scheduled. Our works are summarized in this report.

2. Design principles

Combining with three guidlines, compactness, extention of ECR principle and conformability for production of low and multiplied charge state ion, the new ion source is designed, taking account of following points:

1) Basic confining B-minimum field structure is configurated by permanent magnets (two ring magnets for axial mirror and six rectangular magnets for radial mirror) and an additional variation of the axial mirror is given by an auxiliary small solenoid mounted on the B-minimum point.

2) As a remarkable points, in addition to the ordinary ECR zone, a B2 zone with 1/2 Becr field can be formed in central region of the plasma chamber. It can be considered that the B2 mode works actively when gaseus flow rate is to some degree higher than that of usual case of production of multiplied charge ions. Such a case may be corresponded to an extraction of low charge state ions.

3) In this kind of source a high microwave power, such as kW class is not necessary. The microwave system is designed 200W with effective output power and an operating frequency range of 12-14.5 GHz. It is also

desireble to operate the power in a variable pulse mode. The microwave system is composed of a YIG oscillator, a PIN diode and a TWTA in order to satisfy these requirements.

4) Microwave power can be injected from both axial (R-wave mode) and radial (X-wave mode) ports. Thus a double port heating or a double frequency heating is also possible, if necessary.

As for the extraction of low charge state ion, both basic ECR and B2 zone are used actively by increase of gaseus flow rate. In this case, if the B-minimum field is increased slightly by the solenoid current and the B2 zone is taken off, it can be distinguished whether the B2 mode contributes the increase of the extracted ion current or not. For medium or multiplied charge state ions, the basic ECR mode will be worked dominantly by a relatively smaller rate of gaseus flow and increase of the axial B-minimum field stren-gth.

The extracted beam is optimized with adjustments of the ECR zone and Bmin by tuning of the operating frequency and Bmin intensity respectively.

3. Design Parameters

Main parameters of the source are shown in Table 1. The axial peak magnetic field are designed to 1.5 Becr (gas injection side) and 1.35 Becr (beam extraction side), respectively, when the microwave frequency is 14GHz, i.e., Becr=5.0 kG. The axial mirror ratio Bmax/Bmin is set to 3.0. The inner diameters and mutual distance between two ring magnets are decided from these limitations. Then the diameter and the axial length of the plasma chamber are also decided from these parameters. In the case of a 14 GHz operation, the transverse ECR surface is several mm inner from the chamber surface.

The maximum mirror ratio is also set to 3.0 as for the radial mirror field. The minimum longitudinal width of radial flat waveguide holes is limitted about 3.0. The distance of adjacent rectangular sectupole magnets is, thus, necessary to be larger than 5.0 mm. By this reason the size and mutual configuration of sectupole magnets are limittedvery severely.

The maximum acceleration voltage is designed to 30 kV. The distance between plasma and extractor electrodes are variable within 5-10 mm. Each diameter is $\phi 5.0$ and $\phi 6.0$, respectively.

The microwave frequency can be changed in the range of 12.0-14.5 GHz by using of a YIG oscillator. The effective output power of the final amplifier (TWTA) is 200 W for all over the frequency range. This microwave power is supplied to the plasma chamber by C.W. or variable pulse mode.

Effective microwave power		200			W
Variable microwave frequency	12 →	13 →	14 →	14.5	GHz
ECR magnetic field intensity	4.28	4.64	5.00	5.18	kG
ECR-zone	$\phi 25\times 56$	$\phi 26.5\times 62$	$\phi 28\times 68$		mm^3
Maximum variable axial field		500			G
Bmax ; Bmin		7.20, 6.75 ; 2.40			kG
Maximum beam voltage		30			kV
Inner dimension of plasma chamber		$\phi 37\times 110$			mm^3
Cross section of axial RF port		15.8×7.9			mm^2
Cross section of radial RF port		15.8×3.0			mm^2
Outer dimension of source		$\phi 180\times 230$			mm^3
Total weight		30			kg

Tab. 1 Design parameters of the source

4. Structure of the source

A cross sectional drawing of the source is shown in Fig.1. Two ring-shaped magnets for the axial mirror are combined with a cylindrical return yoke. The use of this yoke makes axial mirror field stronge by tens of % compared to that without it. A small auxiliary solenoid is mounted at the B-minimum position on the axis. A transverse microwave port is also placed at the same position.But another microwave port is usually used for the X-mode injection set at 20mm upstream of the B-minimum point. Each microwave window can be also used as a viewing port.Slots for sectupole magnets and cooling holes are prepared in the chamber block made of stainless steel.

The extractor electrode is made of mild steel in order to increase the axial mirror field strength and its position is adjustable within 5mm on the axis.

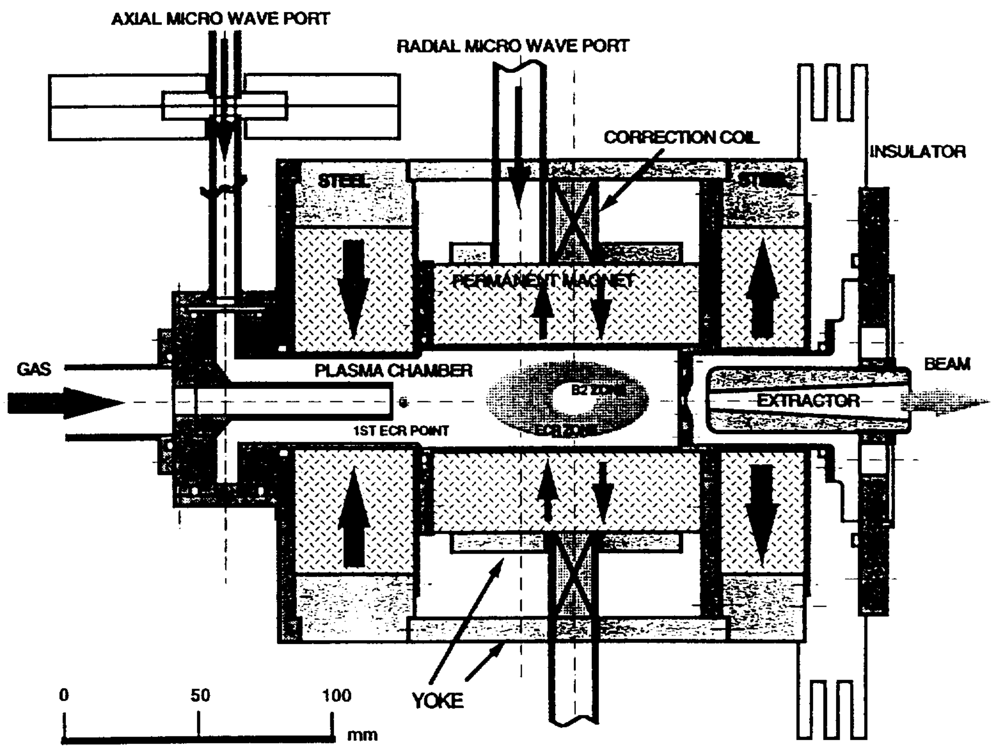

Fig. 1 Sectional view of the ion source

5. Magnetic field distribution

The axial and transverse field distributions are given in Fig. 2 and Fig. 3. Thease results are given by use of the MAFIA code. For the axial field Bz(z,r), the required distribution is formed inside the plasma chamber.But inverse magnetic fields are generated in both gas-inlet and beam-extraction sides, −6.5 and −4.5 kV respectively. But at the injection side of the chamber,the microwave power is transmitted from a rectangular guide to a coaxial one on the chamber axis, then an unstable ECR point cannot be formed by such an inverse field on the axis. At the extractor side, the inverse field intensity is reduced by some orders of magnitude by use of a thick cylindrical extractor made of a mild steel, but if its effect to the extracted beam is not negligible, it may be a matter to be solved hereafter.

For the transverse magnetic field, the maximum value of 7.25 kG by sectupole magnets is generated at the inner surface of the plasma chamber. Its total field intensity added to the axial field component is amount to 7.8 kG, so a strong enough field is well realized. The distance between wall of the chamber and ECR surface is 4.5 mm in the case of 14 GHz.

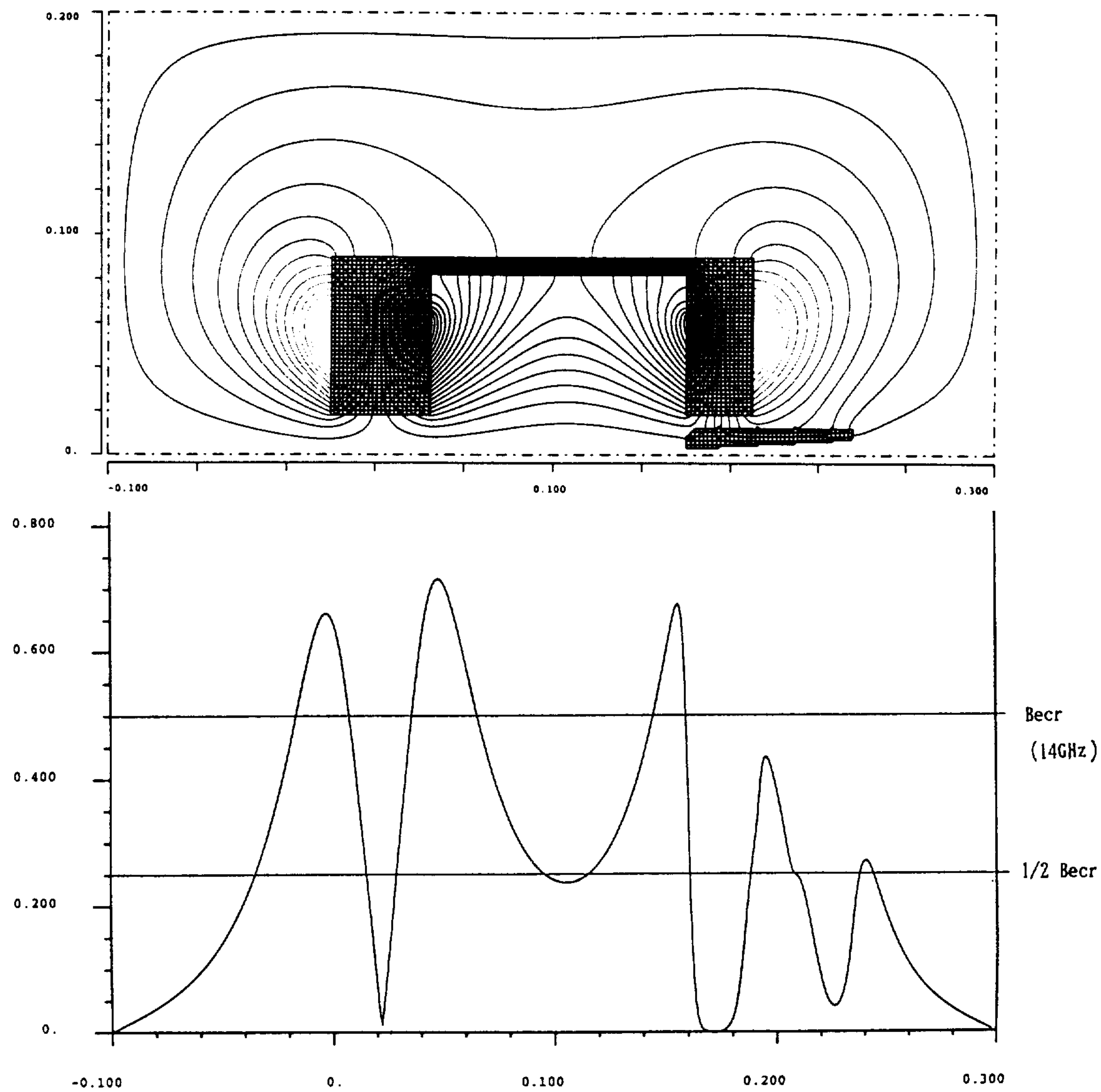

Fig.2 Axial field distrbution

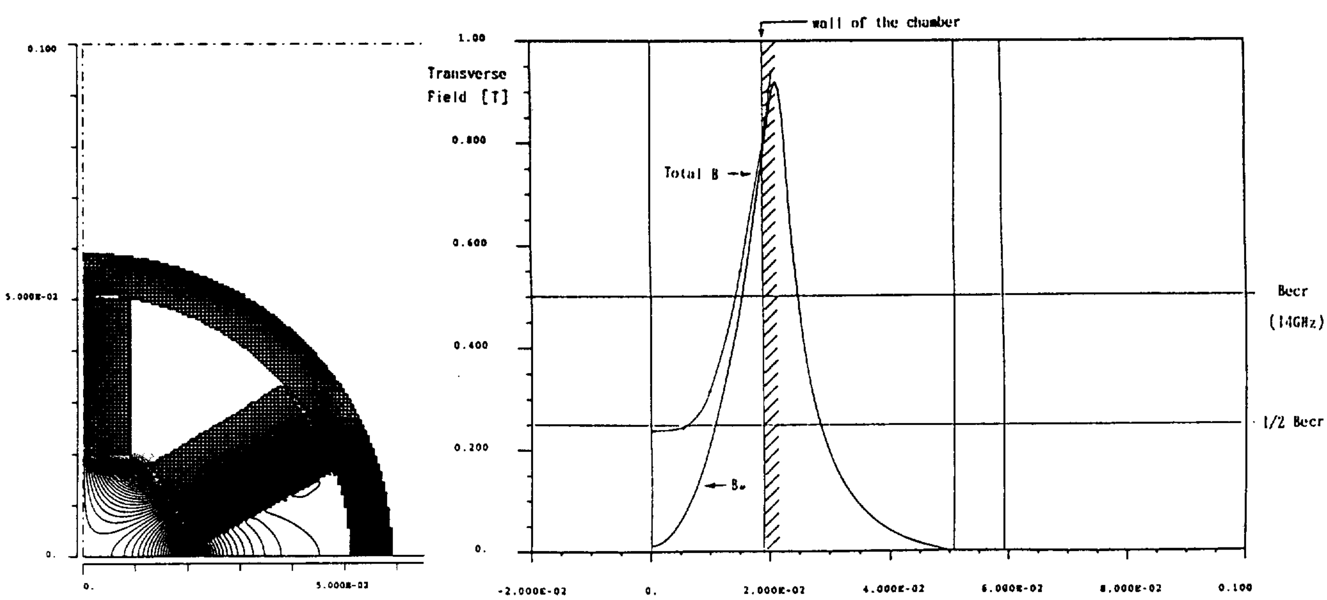

Fig.3 Transverse field distribution

6. Microwave system

Fig. 4 shows the blockdiagram of the microwave system. The operating frequency is set at the YIG oscillator with an accuracy of ±8MHz. Its output continuous wave power is converted to a pulse power with variable duty through a PIN modulator. The TWTA is constructed with two sections: a pre-amplifier(solid-state) and a travelling wave tube. Its final output power is transmitted to one or two microwave ports of the ion source according to demand through a variable power divider.

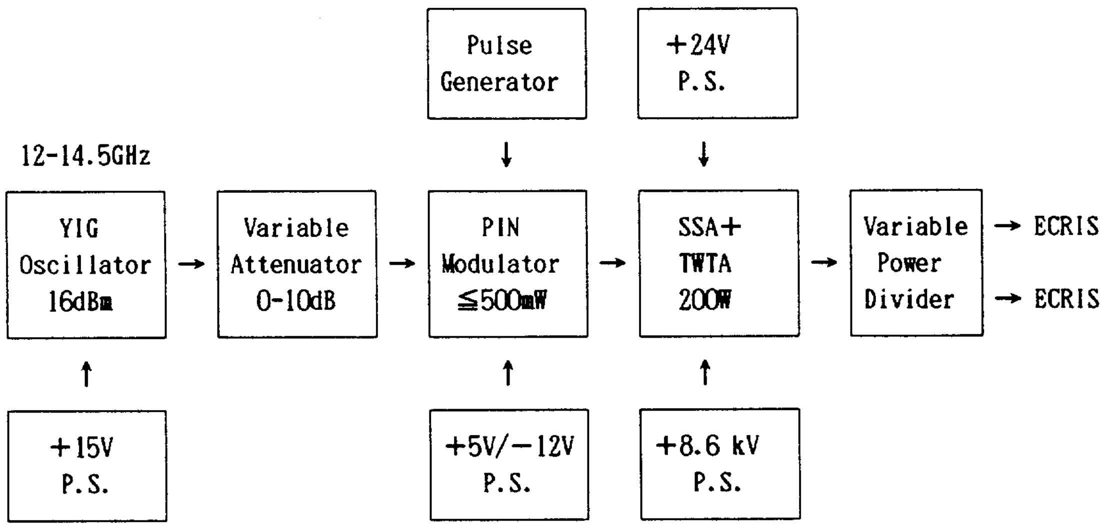

Fig.4 Blockdiagram of Ku-Band microwave system

7. Conclusion

A new compact ECR ion source working at Ku-Band is designed for production of both low and multiplied charge state ions. The body of the source and the microwave system are now in manufacture. The construction of the total system will be completed before the end of March, 1997.

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