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Texas A&M 14.5GHz ECRIS

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Abstract A new plasma chamber for the Texas A&M 14.5GHz ECR ion source ECR2 has been recently installed and the beam analysis line has been recently upgraded with the replacement of the solenoid with a shorter Glaser lens. The source is now used along with the 6.4GHz ECR1 for injection of beams into the K500 cyclotron. The new plasma chamber incorporates water-carrying copper tubes, each with an inner diameter of 0.7mm and an outer diameter of 1.8mm, interposed between the NbFeB permanent magnets and the aluminum plasma-chamber wall. The design allows for a much higher water flow and thus better cooling than the previous design, which used a thin, water-cooled liner. The source commissioning and operation is described.

Key words electron-cyclotron-resonance ion source

1 Introduction

Recently, a new aluminum plasma chamber was designed, machined and installed in the Texas A&M 14.5GHz ECR2 ion source. After ECR2 went through a short commissioning period, the first focusing solenoid in the beam analysis section was replaced with a Glaser lens having about one-half the effective length and twice the effective field strength.

Also, the source is in an open area, so recently thick lead shielding was positioned around the source to protect personnel from X-rays. This permitted more use of high microwave power and continuous running for injection of ECR2 beams into the K500 cyclotron.

2 New plasma chamber

Due to failure-prone water-to-vacuum seals in the old plasma chamber, a new one was built using a totally different scheme for water-cooling. This new design was presented in detail in Ref. [1]. Fig. 1 shows a cross-section through the chamber and one magnet pole. Eighteen copper tubes, each with an inner diameter of 0.7mm and an outer diameter of 1.8mm, lie between the aluminum of the plasma chamber wall and each of the six magnet bars. All eighteen tubes were soldered into a copper fitting for connection to the water supply. The tubes were positioned into parallel grooves in the aluminum along the face of the bars (Fig. 2). They were flow tested and then potted in place using a thermal epoxy. A sheet of 0.25mm stainless steel was positioned over the tubes and then the Nd-B-Fe bars were inserted into their channels.

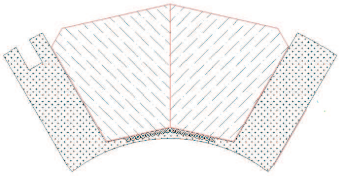

Fig. 1. Cross-section through one of the six slots for the permanent-magnet hexapole showing water-cooling tubes.

Before the design was finalized the concept was tested using a flat array of 18 tubes sandwiched between a thin aluminum plate and a 0.25mm thick,

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stainless-steel plate. First, flow tests determined that 36cc/s of water would flow through the 18 bundled tubes with a water pressure of 90psi. Then with this flow, a 300W electrical strip heater was attached to the center of the aluminum plate on the side opposite the tubes. The contact area for the heater was rectangular, measuring 2.2cm by 14.6cm. The temperature of the stainless steel directly opposite the heater was measured with water flowing as the heater power was increased. At 300W the temperature rise at this point was measured to be 13℃. This corresponds to small area heating of the plasma chamber using well over 1.8kW of microwave power dissipation.

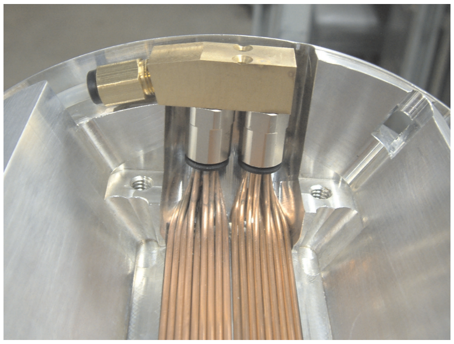

Fig. 2. The copper water-cooling tubes in position before the insertion of the hexapole-magnet bar.

The water flow through the new plasma chamber is approximately three times the flow through the old chamber. So far the power from the 14.5GHz microwave transmitter into the source has reached 1.5kW on a continuous basis with no sign of excess heating to the chamber.

3 Glaser lens

Replacing the first solenoid focusing lens with a Glaser lens has resulted in a significantly more sharply focused beam at the image point and higher transmission of beam through the defining slits. Fig. 3 illustrates the focus of the beam at the analysis point with one charge-state spectrum of oxygen taken at 10kV extraction through 13mm x-collimation and one spectrum taken with the collimation at 38mm (fully open). The older solenoid lens was capable of focusing only about 57% of a high intensity $^{16}O^{7+}$ beam through 13mm x-collimation.

4 Vacuum improvements

Even after the source was operated at high power for extended periods, the vacuum pressure, as measured with an ion gauge on a port external to the plasma chamber, has not decreased to the low values common in other ECR ion sources. With no gas flow and no microwave injection, it was common to see this pressure in the mid 10^{-7} torr range.

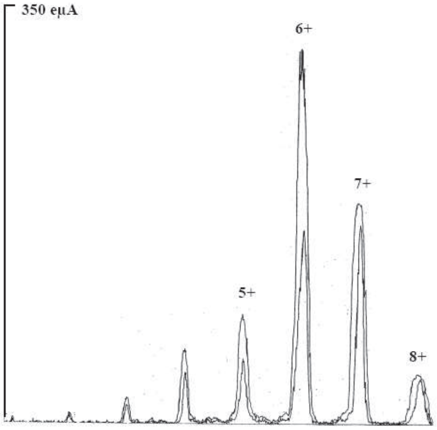

Fig. 3. Oxygen charge-state spectrum showing the intensity of beam transmitted through 13mm and 38mm collimation.

Since the beam coming from the ion source with no gas flow is predominantly oxygen, it is assumed that the background arises mainly from water vapor. A residual-gas analyzer confirmed this. The vacuum also is sensitive to the temperature of the low-conductivity water used to cool the plasma chamber. This water temperature varies slowly between 22℃ and 27℃ between seasons, and by about 1℃ through the day. The plasma chamber of ECR2 has a surface area of 0.2m^2, much larger than typical sources, and it is supposed that the pumping speed to the vacuum pumps and to the extracted beam is insufficient to handle the outgassing load. Several approaches are being explored to solve this problem.

4.1 Slotted extraction plate

In order to achieve more pumping speed into the plasma chamber, a slotted extraction plate was substituted for the original solid one. The three slots are 13mm wide, at an outer radius and angled so that there is no direct line of sight from the interior of the plasma chamber to the puller (Fig. 4). Initially this plate seemed to be more prone to a PIG discharge in the extraction region, but after a short conditioning period source performance improved to the point where a source record of $^{16}O^{7+}$ beam was achieved.

4.2 Temperature of cooling water

Since both the vacuum and the performance of the source were observed to be sensitive to the temperature of the plasma-chamber cooling water, an effort was made to lower this temperature. The low-conductivity water supply for the plasma chamber was plumbed through a heat exchanger with a supply of chilled water. This system immediately lowered the temperature of the plasma-chamber water from 27℃ to 22℃. The background pressure was observed to drop from 4.0×10^{-7} torr to 3.0×10^{-7}torr. Fig. 5 shows a comparison of charge-state spectra of argon taken with the chilled water on and off.

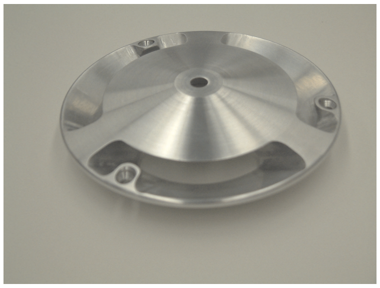

Fig. 4. Slotted extraction plate, plasma side up, showing slots.

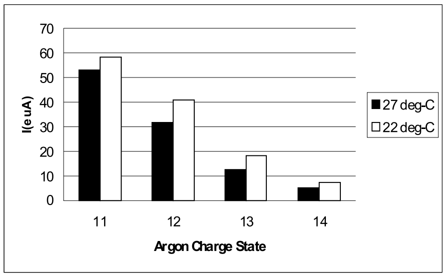

Fig. 5. Chart of argon charge states acquired with chilled water off (27^oC) and on (22^oC).

5 Performance

Figure 6 shows a recently acquired argon charge-state spectrum. The extraction voltage was 10kV and currents are measured on a faraday cup immediately downstream of a 13mm x-collimator biased at −120 volts for suppression of scattered electrons. ECR2 has produced 254eμA of 6+ oxygen and 162eμA of 7+ under the same conditions. The microwave power level was 1.3 to 1.4kW. Also at this power level the source has produced 111eμA of $^{40}Ar^{11+}$, 66eμA of $^{40}Ar^{12+}$, 27eμA of $^{40}Ar^{13+}$, 16eμA of $^{40}Ar^{14+}$ and 33eμA of $^{84}Kr^{17+}$ (from non-isotopic gas).

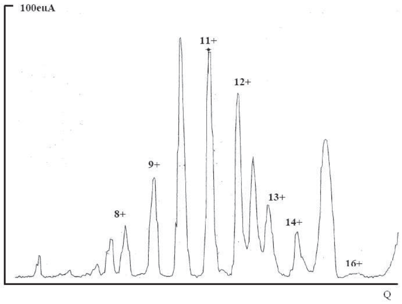

Fig. 6. Argon charge-state spectrum at 10kV and 13mm x-collimation. Microwave power was 1.4kW.

6 Conclusion

There are several paths for improvement. First, vacuum improvements via rebuilding the pumping manifold with higher pumping speed and less surface area as well as nickel-plating the steel in the extraction region will be attempted. The source will not reach optimum performance until the plasma-chamber vacuum approaches 1×10^{-7} torr. Meanwhile, a second transmitter will be added at 11GHz. A TWT with maximum power of over 400W has been acquired for this purpose. Overall, however, the ECR2 ion source has improved in stability, reliability and intensity of beams.

References

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