Current status of the RIKEN 18-GHz superconducting ECR ion source

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The RIKEN 18-GHz superconducting electron cyclotron resonance ion source (18-GHz SC-ECRIS) provides comparatively light ions to the RIKEN AVF cyclotron[1)], which is used as an injector at the RI Beam Factory (RIBF) as well as for investigations in low-energy nuclear physics, material sciences, and biological irradiations and RI productions for commercial use. The 18-GHz SC-ECRIS was designed as a liquid-He-free system, and similar ion sources were constructed at the end of the 1990s[2)]. The SC-ECRIS consists of four superconducting solenoid coils and a permanent Nd-B-Fe hexapole magnet, which generate the so-called minimum-B magnetic mirror geometry. A high-power 18-GHz microwave ($\sim$ 500 W) is used to heat up the electrons in the plasma, so that highly charged heavy ions can be produced. The superconducting solenoid coils whose filaments are made of Nb-Ti alloy are cooled with a 4.2-K Gifford-McMahon (GM) refrigerator (0.7 W). In addition, the high-T_c superconducting current leads are cooled with another 20-K GM (4 W).

Last summer, these coils could not be cooled below 100 K after 21 days of cooling. This happened just after the annual maintenance of the cryostat systems, and so, we suspected that the thermal insulation surrounding the solenoid coils might be degraded. That is why the whole set of the solenoid coils and the vacuum insulation including the cryostat systems have been replaced with another set that was used in the past and was held in reserve. The replacement was carried out last October, following which the super-conducting coils could successfully be cooled to 4 K.

The permanent hexapole magnet had a length of 350 mm and an outer diameter of 199 mm. The hexapole magnet has been replaced with a larger one with an outer diameter of 210 mm so that the radial magnetic field increases from 1.0 T to 1.1 T at the magnet pole face to enhance the plasma confinement for the 18-GHz operation.

The klystron power amplifier (KPA), which was used to generate the high-power 18-GHz microwave, also showed degradation over time. Moreover, the output power was unstable, which directly led to fluctuation of the extracted beam intensity. That is why we have introduced a traveling-wave tube amplifier (TWTA) instead of the KPA even though the maximum output power of the TWTA (750 W) is half of that of the KPA. As a result of this replacement, new remote control functions and additional interlocks to protect the ion source were appended to the existing remote operating system.

The beam emittance extracted from the 18-GHz SC-ECRIS does not seem to be well matched with the acceptance of the low energy beam transport (LEBT) system of the AVF cyclotron. Transverse emittances are crucial parameters and can be optimized by matching the emittance with the acceptance of the LEBT. Moreover, decoupling any inter-plane correlation in the transverse 4D emittance is important to increase the beam brightness[3)]. At present, no device to measure the emittance is installed in the beam line following the 18-GHz SC-ECRIS. Because of a spatial limitation to install a new device, we have started to develop a compact emittance meter based on the pepper-pot method[4)]. The prototype emittance meter was installed behind the analyzing magnet. As the first step, we have obtained an image of beam spots of 6.52-keV p^+ ($\sim$ 80 $e\mu$A) as shown in Fig. 1. The transverse r.m.s emittances were measured to be about 40 mm mrad. Further developments and investigations are in progress to establish the emittance meter which can be applied for diagnostics of the low-energy highly charged heavy-ion beam extracted from ECR ion sources.

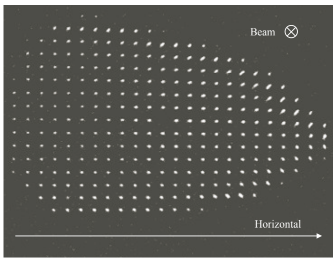

Fig. 1. An image of beam spots obtained using the prototype pepper-pot emittance meter.

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