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Construction of New 28-GHz ECR ion source for RILAC

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Since 2017, we have been upgrading the RIKEN linear accelerator RILAC for the RIBF project[1)] and to synthesize new super-heavy elements (SHEs) with atomic number $Z \geq 119$. In the upgrade,[2)] some of the latter acceleration cavities of RILAC were planned to be replaced with superconducting quarter-wavelength resonators (SC-QWRs) to increase the energy of the beam with $M/Q = 6$ from 5 MeV/nucleon to 6 MeV/nucleon for the synthesis of SHEs. In the SHE project, the high intense metallic ion beams, such as Va and Cr ($>$ 10 particle μA), are required from the ion source. In addition, because the SC-QWRs are driven by the fixed frequency, these SC-QWRs are skipped in the variable frequency operation especially for the RIBF project. Thus, high-intensity ion beams with a higher charge than before. For example, Ca^{16+} beam of $\sim$ 100 electric μA is required to achieve enough energy without the SC-QWRs to meet the variable frequency acceleration scheme of RIBF. To meet these requirements, we decided to construct a new electron cyclotron resonance ion source that consists of fully superconducting mirror magnets (SC-ECRIS) with a high-power 28 GHz gyrotron microwave generator.

Figure 1 shows the current status of the new 28 GHz SC-ECRIS and gyrotron microwave generator with low energy beam transport (LEBT) constructed in the injection room of the RILAC accelerator building. The SC-ECRIS and microwave generator are the same models as the uranium ion source of RILAC II, which is predominantly used for RIBF project (for details, please see the references).[3–5)] The new SC-ECRIS is designed to be operated with 18 and 28 GHz microwaves. In Fig. 1, the LEBT following the ECRIS consists of a solenoidal lens, an analyzing magnet sandwiched by two steering magnets, a diagnostics chamber, and another solenoidal lens. In the diagnostics chamber, a Faraday cup and a pepper-pot type emittance meter (PPEM) were installed. The $^{40}Ar^{11+}$ beam of $\sim$ 90 electric μA was successfully extracted from the new SC-ECRIS as the first beam with the 18 GHz microwave because the 28 GHz microwave generator was not ready at that time. Figure 2 shows the beam profile (x-y plot) and horizontal emittance (x-x' plot) of $^{40}Ar^{11+}$ beam with the 18 GHz microwave of 700 W using the PPEM. In Fig. 2, the beam has a characteristic triangular hollow shape with widely spread emittance along the horizontal. The triangular shape is formed by the hexapolar magnetic field of the mirror field of ECRIS and the ions are localized into three peripheral regions in the beam. By selecting one of the three intense regions in the x-y space as a red rectangle in the left of Fig. 2, it is found that the localization in the emittance space also appears as shown in the right of Fig. 2. From the result, we can effectively increase the beam brightness, which is defined as the beam intensity per unit emittance, by suitable spatial selection of the localized beam using a combination of slits and steering magnets.

We plan to finish the preparations for the 28 GHz microwave generator and high temperature oven to generate metallic vapor in the first half of 2019.

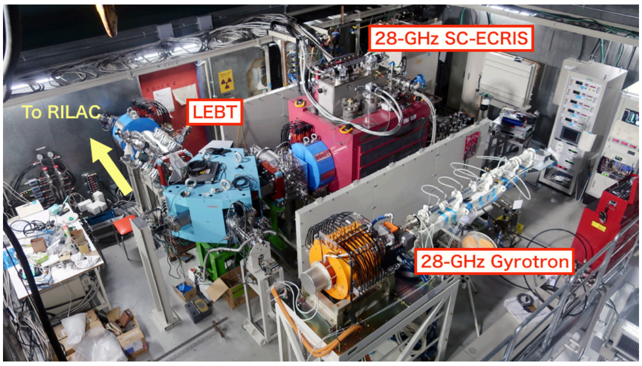

Fig. 1. New 28 GHz SC-ECRIS and LEBT.

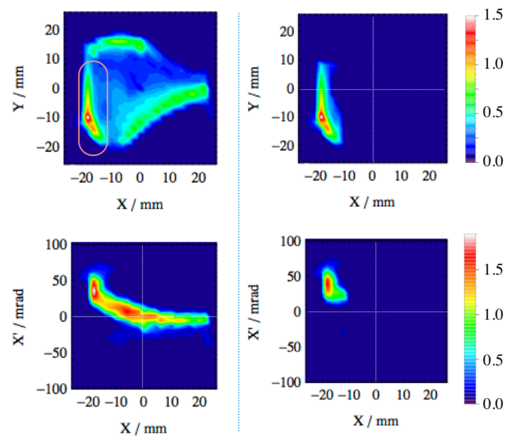

Fig. 2. Obtained beam profile (upper) and horizontal emittance (lower) of $^{40}Ar^{11+}$ beam using PPEM. Color indicates the beam intensity in the arbitrary unit.

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