Improvement of beam stability by stabilizing the cooling-water temperature for the main and trim coils of IRC

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Thermal stability is highly important for the stable operation of RIBF with a high-intensity beam. It makes the beam trajectory in a cyclotron stable and thereby reduces the heat load due to beam loss on the septum of the electrostatic deflection channel (EDC), especially of SRC. Consequently, the beam-tuning for obtaining a high-intensity beam is facilitated.

The periodic fluctuation of the heat load on SRC-EDC has been observed with high-intensity beams such as 345 MeV/nucleon ^{238}U since 2017. It has been the fastest and most effective method to adjust the rf voltage and/or phase of RRC and/or fRC to suppress the increase in heat load, but such an adjustment has a negative impact on the improvement of overall beam-transmission efficiency.

An investigation performed at the end of 2018 clarified that the period of such heat-load fluctuations is synchronized with the fluctuation period of the cooling-water temperature for the main and trim coils of IRC (upstream cyclotron of SRC). This synchronization is caused by the periodic movement of the temperature-regulating valves for the secondary cooling water of these coils with 0–100% opening, which results from some kind of failure of the temperature control system.

In a 2019 operation of a 345 MeV/nucleon ^{238}U, the temperature of both the primary and secondary cooling water of the main and trim coils of IRC were drastically stabilized by fixing the valve openings to 50%, and the resulting extraction beam from IRC was stabilized.

The correlation between the values before and after improvement are shown in the left and right part of Fig. 1, respectively, where the details are as follows (the itemization corresponds to that in Fig. 1):

- a) Temperature of the primary cooling water for the main and trim coils of IRC. The fluctuation ranges of both were improved from ∼6°C to 0.2°C.
- b) Rising temperature of SRC-EDC due to the beam loss. It was improved from 8 ± 1°C to 6 ± 0.5°C.
- c) Opening of temperature-regulating valves for the secondary cooling water of the main and trim coils of IRC. They were fixed to 50% for stabilization.
- d, e) Stability of the beam intensity and phase observed by the phase probe K01 (∼5 m downstream from IRC). The fluctuation range of beam intensity is improved from 8% to 3% and that of beam phase is improved from 0.1 ns to 0.01 ns.

The improvement of the thermal stability of IRC made the extraction beam from IRC and the beam trajectory in SRC stable, and thereby, a tuning procedure for the suppression of heat load on SRC-EDC consistent with the overall beam-transmission efficiency has been facilitated. Consequently, we achieved the highest intensity thus far of 94 particle nA for 345 MeV/nucleon ^{238}U which is also attributed to other continuous efforts.

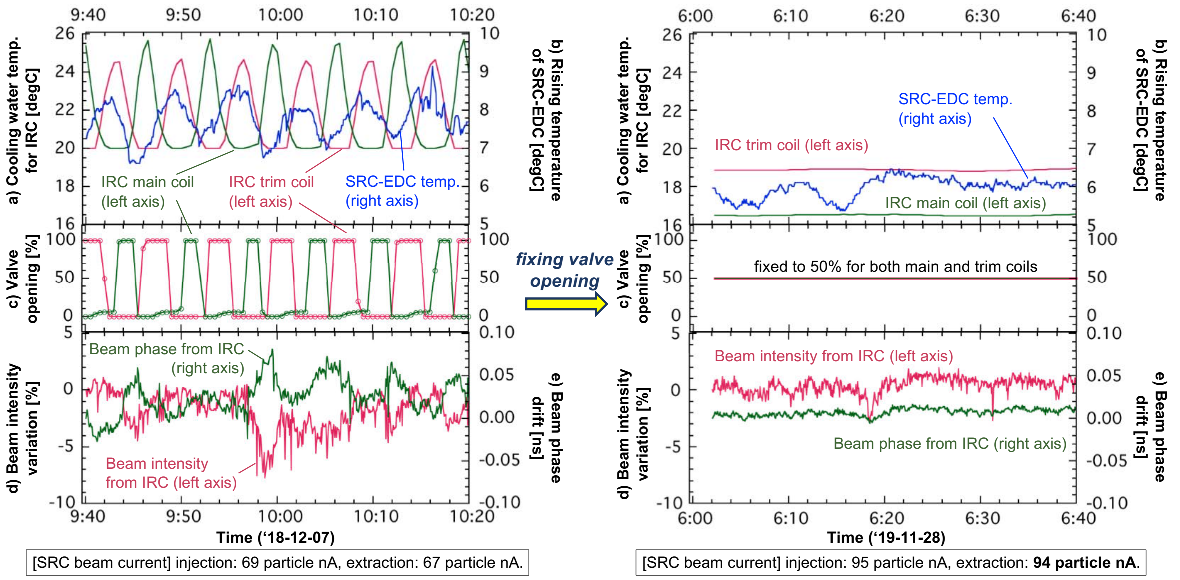

Fig. 1. Stabilizing effect of cooling-water temperature for the main and trim coils of IRC in a 345 MeV/nucleon ^{238}U operation. The data acquired before and after stabilization are indicated on the left and right part, respectively.

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