Air stripper for high-intensity xenon beam

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Intensity upgrade of very heavy ions such as U and Xe beams is one of the main concerns at the RIKEN Radioactive Isotope Beam Factory (RIBF). A new injector, RILAC2, which includes a 28-GHz superconducting electron cyclotron resonance ion source[1)], has been successfully developed and became fully operational in the fiscal year 2011. In the acceleration with RILAC2, the possible output intensities have been principally limited by the lifetime problem of the carbon foil strippers. The recently developed recirculating helium gas stripper successfully solved the lifetime problem of the first-stage carbon foil stripper in the use with U beams at 11 MeV/u[2)]. However, the lifetime problem was an issue for the second-stage stripper as well. In the previous runs with Xe beams in 2012, it was necessary to replace the second-stage carbon-foil stripper every 8 h because of the decreasing thickness.

In the present study, we developed a very-thick air stripper as a second-stage stripper applicable for Xe beams at 51 MeV/u. We also tried Xe-beam acceleration only with gas strippers (the first-stage is N_2 gas and the second stage is air) for the first time in the RIBF user runs.

The thickness required to obtain the equilibrium charge state of the beams increases significantly at higher beam injection energies. In the present case, the second-stage stripper also functions as an energy degrader that changes the output energy of a fixed-frequency cyclotron (fRC) which is approximately 51 MeV/u, to the injection energy of the subsequent cyclotron IRC which is approximately 46 MeV/u. The required thickness of the second air stripper is about 30 times higher than the thickness for the first-stage helium stripper. Also, the required pressure at the target region is four times higher than that for the helium stripper.

The new charge stripping system was constructed in the E1 room after the fRC. The same technology of differential pumping for windowless gas confinement as the prototype He gas stripper[2)] was applied to the new system. The stripper consists of two tube-separated five-stage differential pumping systems with 17 pumps (Fig. 1). It is designed to achieve vacuum reduction from the target pressure of 25 kPa to 10^{-5} Pa within a length of 1 m while ensuring a 8.5-mm beam path.

We confined a very thick gas target, up to 20 mg/cm^2 of air, in a 51-cm target chamber. Air in the E1 room was continuously compressed and the inlet pressure of a pressure regulator was kept at 0.7 MPa with a relief valve. The regulator's secondary pressure was set to 0.4 MPa to deliver a steady flow to the target via a mass-flow controller. High-flow air up to 400 STL/min was introduced to the target chamber. Because we used air in the room, which could be inexhaustible, we did not need any recirculation system in the air stripper.

The stripper construction was completed in March 2013 and stably operated as the second-stage stripper in user runs performed in June 2013. We also used nitrogen gas (0.2 mg/cm^2), which is confined in the same system of the recirculating helium gas stripper as the first-stage stripper in the user runs. The availability (actual beam service time/scheduled beam service time) of Xe beams at 345 MeV/u in the user runs reached 91%[3)]. The maximum beam intensity reached 38 pnA, and the average intensity provided to users becomes approximately four times higher than it was in 2012. The new down time-free gas stripper contributed substantially to these improvements.

We note that this is the first observation of successful of the acceleration only with gas strippers at the RIBF, which is an important cornerstone for next-generation high-intensity heavy ion accelerators.

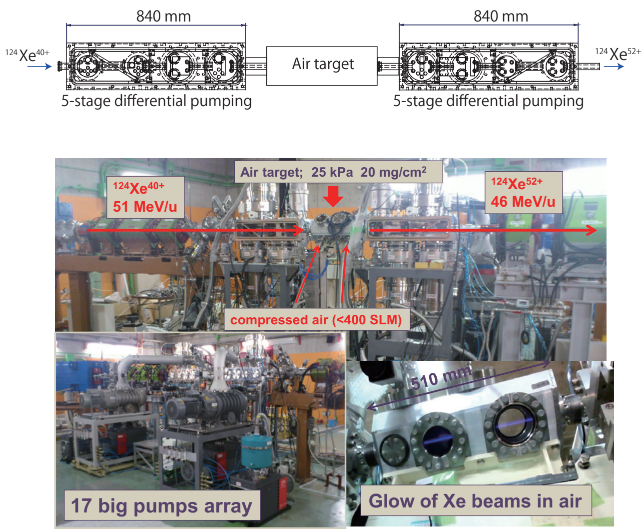

Fig. 1. A schematic view of the air stripper (upper). Pictures of the air stripper and glowing 100-pnA xenon beams (lower).

References
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