Improvement of the transmission efficiency of RILAC

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The performance of the RIKEN heavy-ion linac (RILAC) has been upgraded[1)] with a new superconducting electron cyclotron resonance ion source (SC-ECRIS)[2)] and a superconducting linac booster (SRILAC).[3)] Since July 2020, we have been successfully providing a high-intensity V^{13+} beam with an energy of 6 MeV/nucleon to the GARIS-III[4)] experiment.

The RILAC facility leaves room for further improvement of the transmission efficiency to provide higher-intensity beams. The beam from SC-ECRIS is transported through the low-energy beam transport (LEBT) system, which is equipped with a slit triplet that controls the beam emittance in RILAC. The beam is then bunched and accelerated by a radio frequency quadrupole (RFQ) and injected to the RILAC cavities, booster cavities, and SRILAC. The transmission from the entrance of the RFQ to the entrance of SRILAC was inadequate at about 50%.

One of the causes of the low transmission efficiency was the mismatch of beam optics between the RFQ and the first acceleration cavity of RILAC. The beam line consists of two quadrupole doublets (QDL15 and QDL16) and a re-buncher, as shown in Fig. 1. The beam envelope should be narrowed inside the re-buncher because the duct radius in the re-buncher is 20 mm, which is smaller than the 32 mm duct radius in the rest of the beam line. The problem was that the QDL15 magnets were relatively far from an edge of the vane of RFQ (515 mm) and close to the re-buncher. The beam spreading in the long drift space after the RFQ should be suppressed in short drift space by a strong magnetic field for it to pass through the re-buncher. In contrast, the magnetic field of QDL15a, which is a horizontally focussing magnet, was limited to suppress the enhancement of the beam size in the vertical direction. Consequently, the optics lost flexibility and could not realize the emittance matching and good transmission efficiency simultaneously.

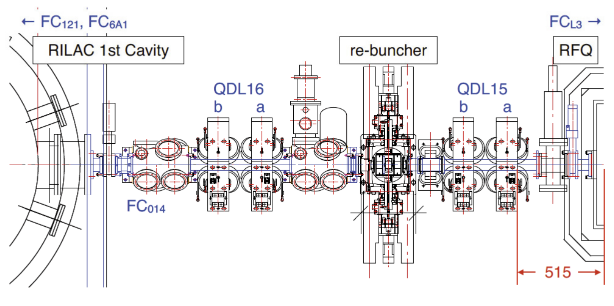

Fig. 1. Top view of the beam line from the RFQ to the 1st cavity of RILAC before the rearrangement.

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Therefore, we rearranged the QDL15 quadrupole magnets together with the other devices (a steerer, a gate valve, and a profile monitor) in September 2021. The cooling pipes of the RFQ were also relocated to avoid interference with the magnets. The improved transmission efficiency and the current applied to the magnets are summarized in Table 1. These values were measured when the beam was delivered to GARIS-III after the transmission optimization by RILAC operators. The transmission efficiency was measured by Faraday cups in the beam lines. L31, 014, 121, and 6A1 are the names of the locations where the Faraday cups are installed, representing the entrance to the RFQ, the entrance of the first cavity of RILAC, the middle point of 1st and 2nd cavities, and downstream of the last cavity of RILAC, respectively. As presented in Table 1, a larger current can be applied to QDL15a as expected. The transmission efficiency is improved by 5% upto 014 and 121 and by 10% upto 6A1. The simultaneous improvement in transmission from L31 to 014 and L31 to 121 is expected to be the result of increased flexibility of the optics downstream of the RFQ. For further increase in the transmission efficiency, we plan to measure the phase ellipse with the profile monitors installed between the RFQ and RILAC and to optimize the optics by realizing emittance matching to the acceptance of the first cavity of RILAC.

Table 1. Quadrupole magnet currents and transmission of RILAC after optimization.

		Jul. 2021	Dec. 2021
Current [A]	QDL15a (H)	38.0	46.8
	QDL15b (V)	36.8	40.8
	QDL16a (H)	21.5	29.2
	QDL16b (V)	13.0	30.1
Transmission efficiency from L31 [%]	014	80–85	90
	121	65	70
	6A1	50–55	60–65

In conclusion, the beam transmission from the RFQ was successfully improved. The upgrade of the aged beam line upstream of RILAC is essential to improve the transmission further.

References

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