Upgrade of rf control system for RILAC injector

K. Yamada,*[1] K. Suda,*[1] T. Ohki,*[2] H. Yamauchi,*[2] K. Oyamada,*[2] M. Tamura,*[2] A. Yusa,*[2] K. Kaneko,*[2] and N. Sakamoto*[1]

The RIKEN linear accelerator (RILAC)[1,2] and its downstream superconducting linac (SRILAC)[3] actively supply beams for research studies involving super heavy element. The injection section of the RILAC was constructed in the 1990s and consists of three main instruments: a buncher, a folded-coaxial-type radio-frequency (rf) quadrupole linac (FCRFQ),[4] and a re-buncher.

The old rf control systems at RIKEN were very poor in terms of reproducibility and operability, and their old analog low-level circuits caused a lack of rf voltage and phase stability. One of the major reasons is that they are aging, having been manufactured nearly 30 years ago; another reason is that the resolution is insufficient because the set values are specified using analog voltages. In addition, the feedback parameter settings must be adjusted in the circuit itself and cannot be changed easily during operation. Therefore, we decided to improve the controllability and the resulting rf stability by upgrading the control system with a programmable logic controller (PLC) and a new digital low-level (LL) circuit.

The old control system and wiring were removed and the new system was installed from July to August 2022, and the wiring to each control target such as the resonators, amplifiers, and DC power supply was connected in September. Figure 1 depicts the front view of the new control system. The left half depicts the cabinet with the PLC and motor drivers, and the right side depicts the cabinet with digital LL circuits and oscilloscopes. All the 12 motors, three for the RFQ resonator, four for the RFQ amplifier, and five for the re-buncher resonator, were updated to new stepping motors. All devices are controlled by a single PLC, similar to other rf control systems in RIBF. The new control system allows for better reproducible positioning of each drive mechanism, and the frequency tuner, which was previously operated manually, is now controlled automatically. The rf system is interfaced by EPICS for remote operation and monitoring, which is connected to the PLC through a TCP/IP connection.

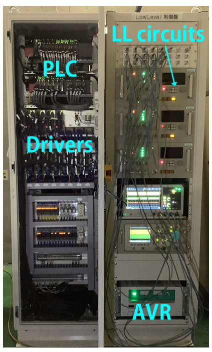

Fig. 1. New rf control system for the RILAC injector. The PLC and motor drivers are visible inside the door.

The digital LL circuit is an original one based on the circuit for SRILAC,[5] and it supports a frequency range of 17–40 MHz. The circuit integrates automatic gain control, phase-lock loop, and phase difference detection for automatic tuning. These signals acquired by on-board 16-bit ADCs are I/Q demodulated using a field programmable gate array, and a direct digital synthesizer output is I/Q modulated and output as an rf signal. Similar to the SRILAC, various parameters such as the voltage set value, phase set value, and internal status are read and written by the PLC in parallel communication with the digital LL circuit. As all communication with the circuit is done digitally, all setting parameters such as the feedback parameters and thresholds can be set reliably, and the settings can be changed remotely.

Figure 2 presents a one-day trend graph depicting the rf voltage and phase stability of the RFQ. It is clear that the new system has significantly improved the rf stability. We plan to replace the analog LL system of the RILAC and RRC with an equivalent digital LL system next fiscal year.

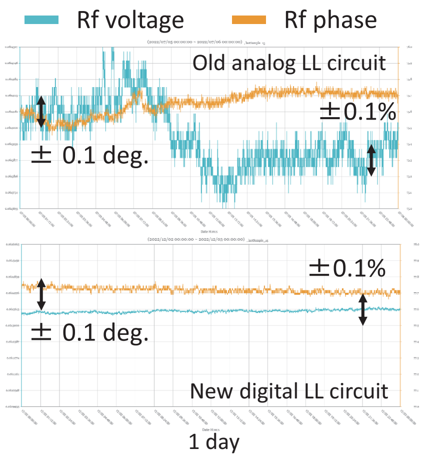

Fig. 2. Trend graph for rf voltage and phase of the RFQ before (upper panel) and after (lower panel) the upgrade.

*[1] RIKEN Nishina Center
*[2] SHI Accelerator Service Ltd.

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