Performance test of kicker system for Rare-RI Ring

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In the Rare-RI ring (R3) facility, charging capacitors of the kicker system repeatedly malfunctioned during the 2021 experiments, and repairs have been ongoing since then. Last year, we confirmed that the new capacitor allows the kicker system to operate more stably than the previous capacitor.[1)] Based on the results, all charging capacitors were replaced with new ones. We have recently conducted 4.5-day continuous operation test and reported the results. In addition, we report on the aging deterioration and adaptive measures for the thyratron, which is a high-power switching device.

There are four twin-type kicker magnets in R3, and each kicker magnet has two charging units. A total of 512 capacitors were used for the eight charging units. In the continuous operation test, the charging voltage could be maintained above 50 kV, as shown in Fig. 1. This will lead to the resumption of mass measurement experiments. Stable operation was possible up to a charging voltage of 55 kV, but when the voltage was increased above 55 kV, thyratron misfire occurred frequently. Each unit is designed to operate with a minimum time interval of 700 μs between injection and extraction, but when it was extended to 5 ms, the thyratron stabilized and the charging voltage was increased up to 60 kV.

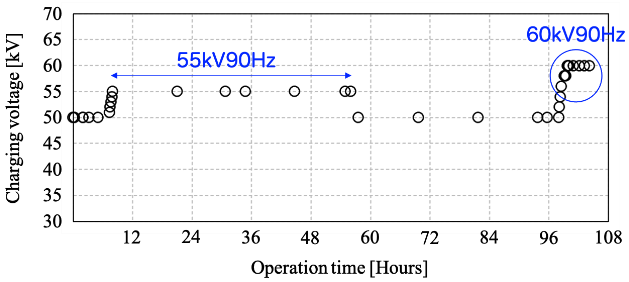

Fig. 1. Trend of setting value of charging voltage during operation test. The frequency of one-set is 90 Hz. One-set means for injection and extraction.

For instance, even when a long extraction duration is required,[2)] a charging voltage of 60 kV can handle particles up to $B\rho = 5.1$ Tm in the time interval of 5 ms between injection and extraction. For experiments that do not require long extraction durations, three or four kicker magnets can be used simultaneously to suppress the charging voltage, thus minimizing the time interval between injection and extraction. In any case, four kicker magnets will be used appropriately for upcoming experiments.

Before the continuous operation test, aging deterioration of the thyratron (CX1171, e2v technologies) was found for the first time. This was confirmed as a jitter of output current waveform, as shown in Fig. 2. These signals were obtained using current monitors. In this time, the charging voltage was 50 kV and repetition frequency was 90 Hz. The jitter is caused by the instability in the gas pressure of the deuterium filled in the thyratron CX1171. This thyratron is equipped with a titanium deuteride reservoir to adjust the gas pressure. The gas pressure can be adjusted by changing the heater voltage of the reservoir. The adjustment range of the reservoir-heater voltage is 4.5 V to 6.5 V. Figure 2 shows the results after increasing the voltage from 4.8 V to 5.2 V. It can be seen that jitter has been eliminated and the response time of the thyratron was faster. The rise timing of units (a) and (b) was adjusted using an external delay during the continuous operation test. The reservoir-heater voltage, when significantly high, increases the frequency of the thyratron misfires, but this dit not occurr during the continuous operation test. The optimal reservoir-heater voltage gradually increases with the thyratron operation time. It is currently set at a relatively low of the adjustable range, but it will eventually no longer be adjustable. High-power thyratrons are expensive and difficult to obtain. Therefore, it is necessary to consider changing to the charging method using linear transformer drivers[3)] equipped with the next-generation semiconductor SiC-MOSFETs.[4)]

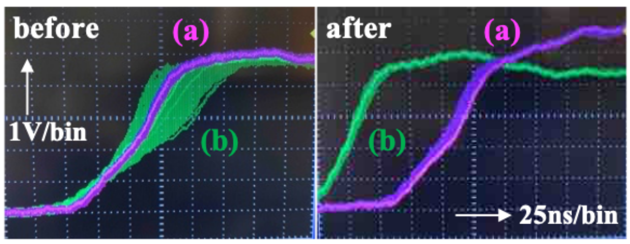

Fig. 2. Output current waveforms of charging units (a) and (b) for one kicker magnet. Unit (b) had jitter, which was improved by adjusting reservoir-heater voltage.

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