UPGRADE OF POWER SUPPLY SYSTEM FOR RF-CHOPPER AT J-PARC LINAC

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Abstract

In the J-PARC linac, a radio frequency deflector (RFD) as a chopper was located in MEBT (Medium Energy Beam Transport) line between a RFQ and a 50-MeV DTL [1]. It consists of two cavities, RFD_U (upstream) and RFD_D (downstream). It is used to generate an intermediate-pulse due to the injection to RCS (Rapid Cycle Synchrotron). The fast rise and fall times are strongly required to decrease the beam loss for the half-kick [2]. However, the fall time indicated a poor result to affect the ringing into each cavity at that time [3]. It was caused that the output port of RFD_U was coupled to the input port of RFD_D through a coaxial line (series-connection) in the previous system [4, 5]. Therefore, the connection was improved to the parallel system from the series using independent two RF sources in the summer of 2012 (parallel-connection). As the results, the ringing vanished and the rise and fall times of the chopped beam were obtained to about 20 nsec. Although the connection was turned back to the series because of the breakdown of the solid-state amplifier, we would like to introduce the performance of the RF-chopper with the parallel-connected system.

INTRODUCTION

A RF deflector (RFD) was installed as a chopper in MEBT line between a RFQ and a 50-MeV DTL in the J-PARC linac. RFD plays an important role in the generation of an intermediate-pulse structure by the repetition of the RF-on period (about 500 nsec) and off (about 500 nsec). During the transient time of the RF rising and the falling, the beam is half-kicked and can cause a beam loss on the downstream. Therefore, a very low loaded-Q cavity and a RF source with the high-speed response are required as the RFD system.

RFD is composed of two cavities, RFD_U (upstream) and RFD_D (downstream). Each cavity has the loaded-Q of about 11 on the low-level measurement. A coupled RFD system, the output port of RFD_U was coupled to the input port of RFD_D through a coaxial line (series-connection), was adopted for saving the cost of the RF power source. The solid-state amplifier (HA-1241, NEC), which has under 15 nsec (10%-90%) at the rise and fall times and 36 kW at the peak driving power, was proposed as the RF power source.

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RINGING OF COUPLED RFD SYSTEM

Figure 1 shows the RF pickup signals of (a) RFD_U and (b) RFD_D. The large and long ringing after the RF falling of RFDs, especially RFD_U, was observed. Its period was longer than 100 nsec and its field in the maximum point reached about 25% (around 13.33 μsec of RFD_U in Fig. 1(a)) in comparison with the nominal RF driving field. The simulation result of Transient Solver on HFSS replicated the tendency of the measured ringing. It is thought to come from the effect of the wave reflection, of 0 and π mode components. Additionally, the timing of the RF rising on RFD_D was observed to 6 RF cycles later than that on RFD_U under the low-level measurement [3] [1].

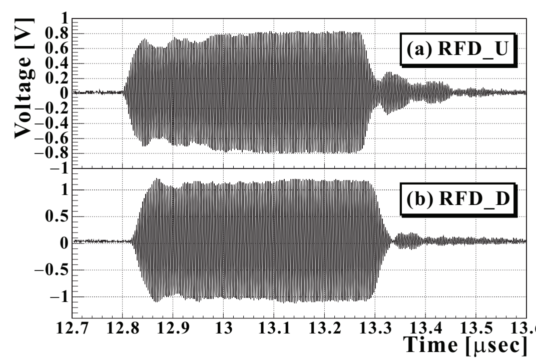

Figure 1: RF pickup signals of (a) RFD_U and (b) RFD_D in the series-connected system. The large and long ringing on the RF falling of RFDs, especially RFD_U, was observed.

The intermediate-pulse at the peak beam-current of 15 mA was measured using a fast current transformer (FCT) in the downstream of RFD as shown in Fig. 2. The dent on the head of the intermediate-pulse beam could be seen over a range of 50 nsec. It was almost corresponding to the maximum point of the RF ringing on RFD_U [2]. Therefore it was thought as the cause of the ringing on the RF falling period. In this condition of the driving power of 36 kW, the full field of RFD is estimated to be about 2.0 MV/m. The ringing (0.5 MV/m) can be a cause that some fraction of the beam particles is stopped according to the PARMILA multiparticle simulations [4].

[1] In Fig. 1, the timing and the attenuation (voltage) of (a) could not be compared with those of (b) due to the lack of the correction.

[2] The head of the intermediate-pulse corresponds to the RF falling on RFD because the beam is horizontally deflected by RFD in the beam-off period.

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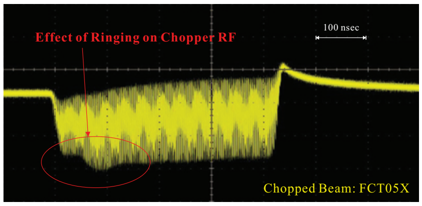

Figure 2: Chopped beam (FCT05) in the series-connected system. The dent on the beam head was observed. It was thought as the cause of the ringing on the period of the RF falling.

PARALLEL-CONNECTED SYSTEM

To suppress the RF ringing, the RF system of the chopper was improved to the parallel connection from the series in the summer of 2012 (parallel-connection). The other set of a low level RF system (LLRF) of 324 MHz, a chopper controller (CANDOX Systems Inc.), and a solid-state amplifier with the 30 kW driving power (TOMCO Technologies [6]) was installed as shown in Fig. 3.

The system makes possible the individual phase tune by each LLRF system of RFD. In addition, a variable delay (KN330, Kaizu Works Corp.) and a trombone were arranged as a knob of the relative timing tune on the logic-pulse line from RCS to the RFD_D chopper controller [3]. In this system, the phase and the relative timing can be independently tuned.

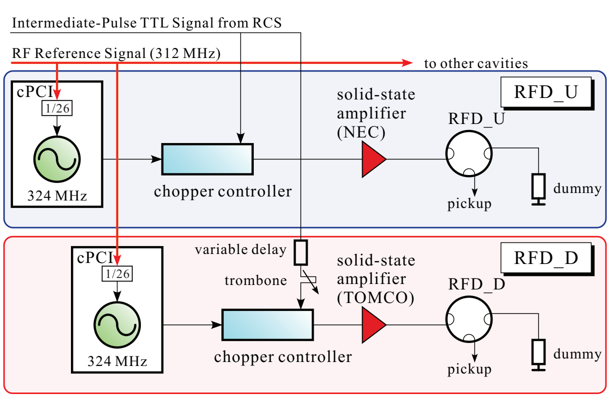

Figure 3: Schematic diagram of the parallel-connected system. There are two RF sources by each RFD.

The rise and fall times of the RF output signals on the new amplifier (TOMCO) were obtained to 12.5 nsec and 7.9 nsec, respectively. It were faster than those on the old.

Figure 4 shows the RFD pickup signals in the parallel-connected system. The ringing was smaller than that of the previous system (Fig. 1). The rise and fall times on the RF pickup signals achieved from 22 nsec to 35 nsec, except for the fall time of RFD_D. The long tail of the RF falling on RFD_D is the reason of the later response. Although the mismatch in the dummy load or the RFD_D cavity is a major candidate for the cause, it is not clear.

[3] The chopper controller generates the intermediate-pulse based on the signal from RCS.

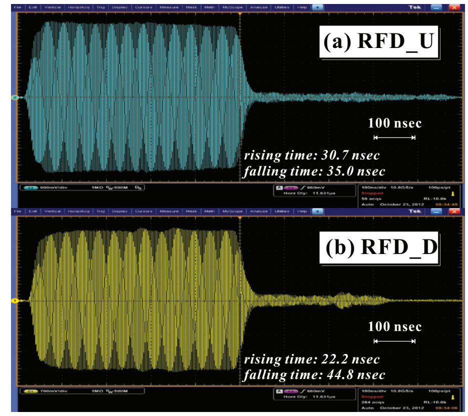

Figure 4: RF pickup signals of (a) RFD_U and (b) RFD_D in the parallel-connected system. The ringing on the RF falling of RFDs was suppressed in comparison with Fig. 1.

BEAM TEST OF PARALLEL-CONNECTED SYSTEM

Phase Tune

Figure 5 shows the results of the phase tune. The optimized phase was determined from the deflection angle with a beam profile monitor (BPM). It is a different procedure from the previous method [7].

Firstly, the horizontal beam position was measured using BPM05 by changing the phase of RFD_U when the RF driving power of RFD_D was off. Then the RF field of RFD_U was set to half against the operating amplitude. Secondary, the correlation between the phase and the horizontal beam position was fitted using a quadratic function as shown in Fig. 5 (a). The reference phase with the maximum deflection angle could be obtained against RFD_U. When interchanging RFD_U and RFD_D, the optimized phase for RFD_D could be determined (b). Finally, it was confirmed in the condition of the determined phase that the residual beam was under the measuring limitation using a wire scanner monitor (WSM) as Ref. [7].

Relative Timing Tune

The results of the relative timing tune are shown in Fig. 6. The relative timing between RFD_U and RFD_D was determined using the rise and fall times of the beam measured by BPM06.

After the phase tuning, both RFDs were driven as the half amplitude with the determined phases. There, the relative timing was changed using the variable delay setting and the BPM data in a oscilloscope, like Fig. 7 (a), were saved. The rise (20%-80%) and fall (80%-20%) times were obtained from the analysis of raw data. The correlations were fitted using a quadratic function as shown in Fig. 6. The optimized delay value with the fastest rise and fall

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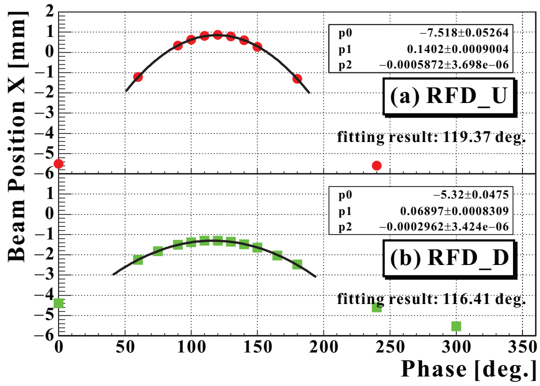

Figure 5: Results of the phase tuning for (a) RFD_U and (b) RFD_D. Each phase was adjusted to be the largest deflecting angle.

times was determined. Although the fluctuation was not small, the obtained delay value corresponded to the result of the low level measurement without the beam.

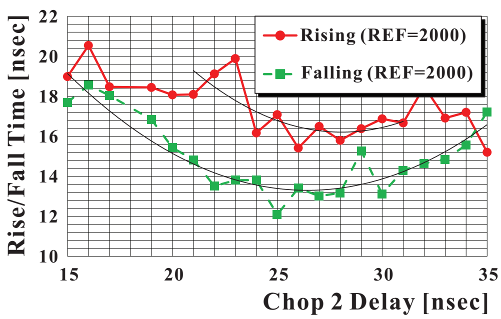

Figure 6: Results of the relative timing tuning. The red circles and the green squares show that for the rising and the falling, respectively.

Chopped Beam

Figure 7 shows the chopped beam measured by (a) BPM and (b) FCT in the parallel-connected system at the peak beam-current of 15 mA.

When the FCT data of the parallel-connected system in Fig. 7 (b) are comparing with those with the series-connected system of Fig. 2, the dent on the beam head could not be observed. It is suggested that the amount of the half-kicked particles was suppressed because the RF ringing decreased in the parallel-connected system.

The rise time (10%-90%) and the fall time (90%-10%) obtained by BPM data were estimated to 23.0 nsec and 15 nsec, respectively. The fall time with FCT in the parallel-connected system was almost same as that in the series-connected system.

TROUBLE OF SOLID STATE AMPLIFIER

The output power of the solid-state amplifier for RFD_D (TOMCO), which was installed in the summer shutdown of 2012, resulted in a sudden drop in 16th

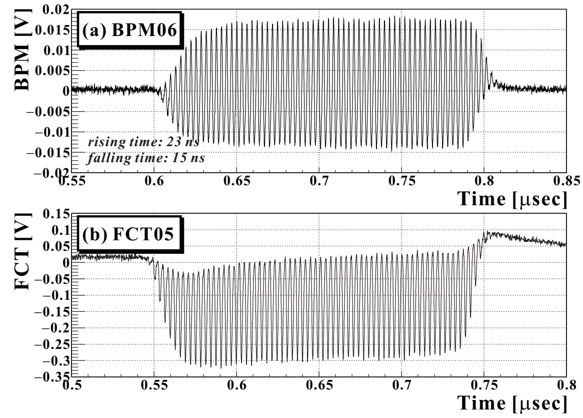

Figure 7: Chopped beam in the system of the parallel-connected system with (a) BPM06 and (b) FCT05. It could be confirmed that the effect of the ringing decreased.

November, 2012. The connection was turned back to the precious system having only one amplifier from the parallel-connected system needing two ones.

The broken amplifier was sipped back to TOMCO and the cause of the broken trouble has been investigated.

SUMMARY

In the summer of 2012, we installed the other set of a LLRF system, a chopper controller, and a solid-state amplifier in the RF-chopper due to changing to the parallel-connected system. The procedures for the phase tune and the relative timing tune were well-established. The ringing on the RF falling decreased and the dent of the beam head on the intermediate-pulse vanished. It predicts that the parallel-connected system has a tremendous amount of potential though the connection was turned back to the previous system due to the trouble of the amplifier.

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