RECENT PROGRESS WITH THE J-PARC RFQs

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Abstract

In this paper, we will report recent topics about J-PARC RFQs. First, the user operation of the existing RFQ (RFQ I) has been resumed from the long shutdown due to the earthquake. This RFQ has been suffered from a breakdown problem since 2008, therefore we have been developing a back-up RFQ (RFQ II). In April and May 2012, the high power test was successfully performed. Finally, we are fabricating a new RFQ for the beam-current upgrade of the J-PARC linac (RFQ III).

INTRODUCTION

At present, three radio frequency quadrupoles (RFQs) are under operation or development in Japan proton accelerator research complex (J-PARC). The original design energy and peak beam current of the J-PARC linac is 400 MeV and 50 mA, though, at the initial phase, the operation was started with a energy of 181 MeV omitting annular-ring coupled structures[1]. An RFQ built for the Japan hadron facility (JHF) project is used for the initial-phase linac; the design peak beam current of this RFQ is 30 mA[2]. This RFQ is called RFQ I. Because a sparking problem of this RFQ I occurred[3], an RFQ is fabricated as a spare of RFQ I[4]. This is called RFQ II. Moreover, to achieve the original design power of 1 MW (at the neutron target), it is planned to upgrade the linac to the original 400 MeV and 50 mA[5]. To upgrade the beam-current, another RFQ with a design current of 50 mA is newly fabricated and will replace the old one. This 50-mA RFQ is called RFQ III. In Table 1, parameters for each RFQ are listed.

In this paper, the status of each RFQ is described.

RFQ I

Fortunately, there was no damage to the RFQ I due to the Tohoku earthquake. During the period of the linac recovery[6] in 2011, a baking process was applied to desorb the absorbed gases on the surfaces during the operation after the improvement of the vacuum system in 2009[3].

Just after the restart of beam operation, the trip rate was rather high, but it became to be same level (∼20 times / day) as that of just before the earthquake. Figure 1 shows the history of the trip rate from just after the vacuum improvement to the run end before the long shut down of this summer.

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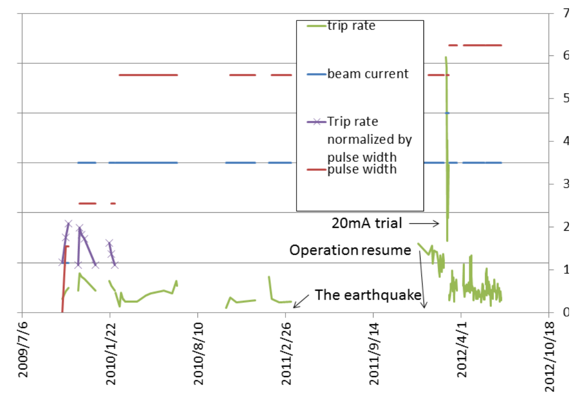

Figure 1: History of the trip rate of RFQ I from just after the vacuum improvement to the last run.

RFQ II

The high-power test of the RFQ II was planed to be completed in March 2011, but it was postponed due to the earthquake till the recovery of the accelerator from the damage of the disaster. After the user operation of the J-PARC was resumed, the high-power test of RFQ II was finally carried out from April to May 2012. Figure 2 is a photograph of RFQ II under high-power test.

Figure 2: High-power testing RFQ II.

After the assembling of high-power tuners, a coupler, and end plates, the measured unloaded Q-value was 9436. This corresponds to the value of 87 % of the SUPERFISH[7] calculation. The coupling factor of the high-power RF-coupler was set to be 1.7. The RFQ II was pumped with one 1700 l/s (for N_2) cryopump and two 400 l/s ion pumps during the high-power test.

In Figure 3, the conditioning history of RFQ II is shown. At first, the pulse height and repetition rate were set to be 30 μs and 25 Hz. After 15 hours conditioning, the peak

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Table 1: Design parameters of the J-PARC RFQs.

	RFQ I	RFQ III	RFQ III
Cavity structure	four vane	←	←
	(monolithic)	(consist of three units)	←
Vane length (mm)	3115	3172	3623
Number of the cells	294	294	317
Inter-vane voltage (kV)	82.9	←	81.0
Maximum surface field (MV/m) (Kilpatrick)	31.6 (1.77)	←	30.7 (1.72)
Average bore radius r_0 (mm)	3.70	3.69	3.49
Vane-tip curvature (mm)	$0.89r_0$ (3.29)	$0.89r_0$ (3.28)	$0.75r_0$ (2.62)
Maximum synchronous phase (deg)	-30	←	-30.6
Transmission (%)	97.7 [1]	← [1]	98.5 [2]
Transverse emittance (π mm mrad, normalized, r.m.s.)	0.18 [1]	← [1]	0.21 [2]
Longitudinal emittance (π MeV deg, normalized, r.m.s.)	0.083 [1]	0.084 [1]	0.11 [2]

[1]PARMTEQM calculation, 1.0 π mm mrad. (100%, normalized, water-bag), 36 mA injection
[2]LINACSrfqSIM calculation, 1.2 π mm mrad. (100%, normalized, water-bag), 60 mA injection

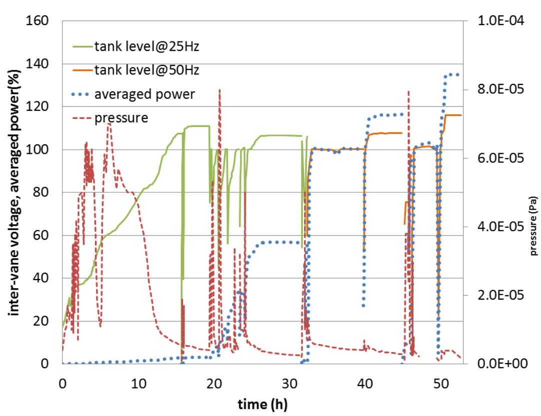

Figure 3: History of the RFQ II aging.

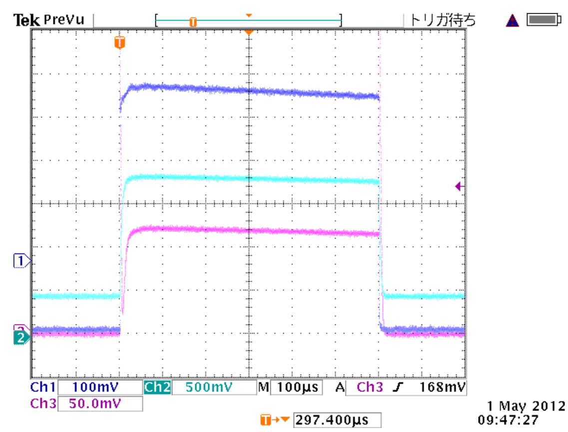

Figure 4: RF waveform of RFQ II. Blue: tank level, Cyan: inputted RF, Magenta: reflected RF.

voltage reached to be 107 % of nominal voltage; nominal voltage corresponds to a power of 333 kW. Next, the pulse width was gradually broaden, then the repetition rate was increased to be 50 Hz. Figure 4 shows the RF-waveform inputted to and reflected from the RFQ II. During a 24-hours operation, the trip occurred only three times.

RFQ III

For the beam-dynamics design of RFQ III, LINACSrfqDES[8][9] was used[10]. LINACSrfqDES is a Mathematica[11] based quite flexible tool. Figure 5 shows the obtained cell parameters as functions of cell number.

The particle simulations were performed by using LINACSrfqSIM[8][9]. LINACSrfqSIM is a time-domain code to treat the space-charge effect correctly. In addition to the conventional multipole-expansion method (mpole mode), a multigrid Poisson solver is implemented in LINACSrfqSIM (Poisson mode). The Poisson solver

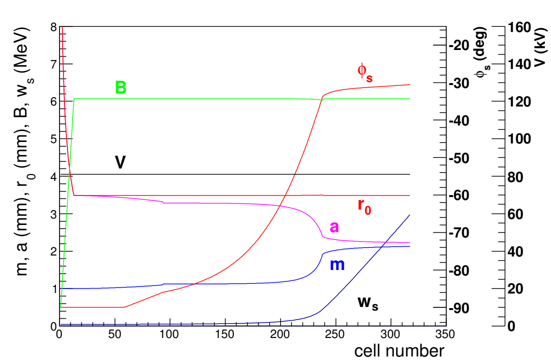

Figure 5: Cell parameters of RFQ III.

calculates the electro-magnetic field more accurately than the mpole method, especially, in the vicinity of the vane tips, and automatically correctly includes the image-charge

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effect. This feature is important for simulating high intensity RFQs.

In the simulation of RFQ III, the peak current of the input beam is 60 mA, the normalized rms transverse emittance is 0.20π mm mrad, the transverse distribution is water bag, input energy is 50 keV, and the phase distribution is uniform. Figure 6 shows emittance evolution as functions of cell number. The solid line represents the transverse emittance and the dashed line is longitudinal one. The transverse emittance growth to the input emittance is 7 %; this is sufficiently small for the J-PARC purpose.

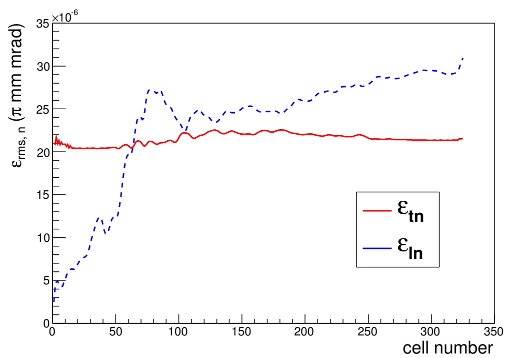

Figure 6: Emittance evolution as functions of cell number. The solid line represents the transverse normalized rms emittance, and the dashed line is the longitudinal one.

Machining of the vanes of the first and second unit cavities has been finished by the end of March 2012[12]. The dimensions of the vane tips were measured on the milling machine with newly developed laser displacement sensor based measuring system[13]. The brazing of the first unit is carried out in September 2012. Figure 7 shows the assembled unit 1 of RFQ III.

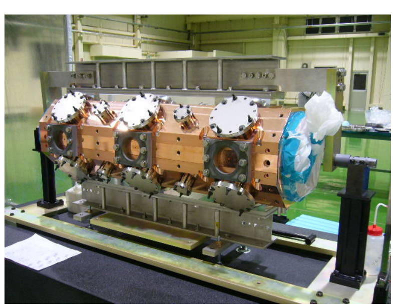

Figure 7: Assembling the RFQ III unit 1.

SCHEDULE

RFQ I will be used until July 2013. A high-power test of RFQ III will be done by the end of March 2013. Beam test will be carried out in the beginning of JPY2013 before the installation to the accelerator tunnel of the linac. RFQ III will replace RFQ I in August 2013.

RFQ II will be re-installed in the test-stand and will be used for various tests of accelerator components, such as ion source and diagnostics.

CONCLUSION

In these few years, remarkable progress has been made with J-PARC RFQs. RFQ I is under user operation with an acceptable trip rate of ∼20 times / day. The high-power test of RFQ II was successfully carried out in the beginning of JPY 2012. The beam dynamics design of RFQ III has been finished and it is now being fabricated. RFQ III will be installed into the accelerator tunnel in August 2013.

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