HIGH-POWER TEST RESULTS OF THE RFQ III IN J-PARC LINAC

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Abstract

The RFQ III, which is designed for 50mA beam acceleration from 0.05MeV to 3MeV, has been fabricated and the high-power test has started at April 2013 at the test station in the J-PARC. The high-power conditioning reached to the 120% of the nominal peak power with 1.5% (600μs, 25Hz) RF duty. Then, the beam acceleration test has started. In Jun. 2014, continuous beam operation for one month has been demonstrated.

INTRODUCTION

The J-PARC accelerator comprises an injector linac, a 3-GeV Rapid-Cycling Synchrotron (RCS) and a 50-GeV Main Ring. The beam energy of the linac has been upgraded from 181MeV to 400MeV in 2013. For the beam current upgrade, the new frontend (RF ion source, RFQ, chopping system) installation is scheduled in summer 2014 for 1MW operation at RCS. We performed the beam operation at the test station and measured parameters of the beam accelerated by the RFQ III. The results of the high-power conditioning and the stability of the RFQ with beam are described.

RFQ III AND TEST STATION

The beam dynamics design is described in Ref. [1]. The RFQ III is a Four-vane type cavity. To reduce the dipole mode mixing, the dipole stabilization rods (DSRs) are inserted from the endplates. The frequency separation from the nearest dipole mode is 4.6MHz. The mechanical and the RF properties of the RFQ III cavity are in Refs. [2, 3].

The nominal RF power and RF duty of the RFQ III are 400kW and 3%, respectively. The cavity is driven by one loop-type input coupler, of which coupling is adjusted to 1.8 for the beam loading. Vacuum system for the RFQ cavity consists of three cryogenic pumps (2700L/s for hydrogen), three ion pumps (400L/s for nitrogen), a B-A gauge, a cold cathode gauge, and a residual gas analyzer at the test station.

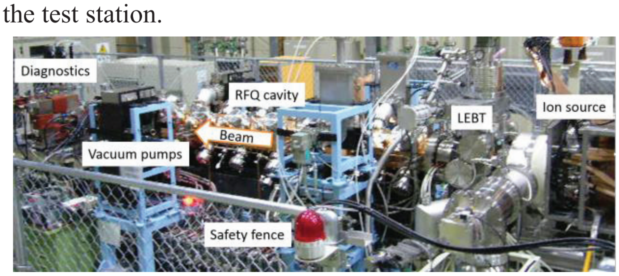

Figure 1: Photograph of the test station.

The test station (Fig. 1) consists of the ion source, two solenoids in the low-energy beam transport (LEBT), the RFQ, and the diagnostics with beam dump. The ion source is RF driven cesium seeded type, which can extract more than 60 mA, 50keV negative hydrogen beam with the pulse width of 1ms and the repetition rate of 25Hz. The diagnostics section has two quads, a bending magnet, and an emittance measurement system. After the accelerated beam parameter measurement, the emittance measurement system was replaced to the scraper irradiation test chamber. Then, the RFQ conditioning with beam was performed in parallel with the scraper irradiation test for one month.

HIGH-POWER TEST RESULTS

Conditioning

Before the beam operation, the high-power conditioning has performed at the test station in Apr. 2013. The vacuum pressure reached to 6e-6Pa before the high-power conditioning. At the beginning of the high-power conditioning, the RF pulse width was taken as 30μs with 25Hz repetition. Figure 2 shows the history of the high-power conditioning. The tank level was gradually increased and reached to the 110% of the design tank level after ten hours conditioning. Then, the RF pulse width was extended to 50μs. After 20 hours conditioning, the tank level reached to 110% of the design level with RF width of 600μs. At that time, the RF trips (mainly due to the abnormal RF reflection from the cavity) occurred a few times per hour, however, it was improved to a few times per day. Then, we started the beam acceleration test [4].

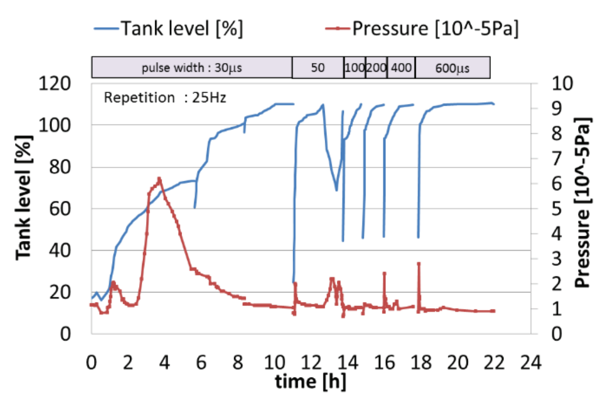

Figure 2: History of the high power conditioning. The blue and red curves show the tank RF level and vacuum pressure in the RFQ cavity, respectively.

The vacuum pressure was less than 1e-5Pa with high-power RF. At the beginning of this conditioning, there were two outgassing region near the RF tank level of 30% and 70% as shown in Fig.2. After this conditioning, vacuum pumping continued and the beam test has

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conducted for half year. Currently, outgas at 70% of the RF level of the tank has dried up, and the other remains slightly.

Uniformity of the Field Distribution with High-Power RF

The RF field distribution is measured by the pickup monitors distributed along the beam axis in all quadrants. The distribution of the pickup monitors are in Ref. [2]. The cooling water temperature is controlled for the frequency tuning of the RFQ cavity in the high-power operation [5]. Figure 3a shows the difference of the pickup voltage distribution between low-level measurement and high-power RF operation. Figure 3b is difference by changing the cooling water temperature from 27.0degree to 26.8degree. The abscissa shows the position of the pickups along the beam axis from the injection part to the downstream.

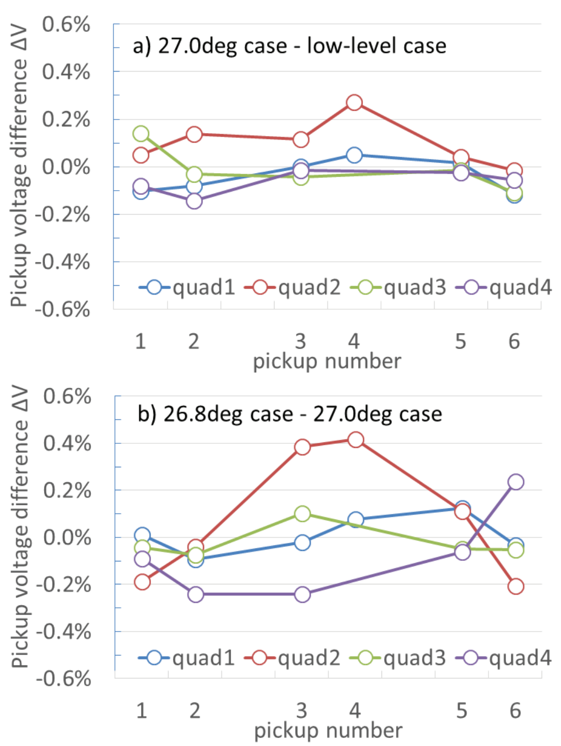

Figure 3: Difference of the pickup voltage between a): low-level and high-power, b): the water temperature of 26.8degree and 27.0degree.

As shown in Fig. 3a, the deviation of the field uniformity by applying high-power RF was less than 0.3%, where the error of this measurement is less than 0.15 %. The heat load by the high-power RF does not affect the flatness and the balance of the quadrupole field. Then, we investigated the influence due to the fluctuation of the cooling water temperature. By changing the water temperature from 27.0degree to 26.8degree, the field flatness in quadrants 2 and 4 affected about 0.4% as shown in Fig. 3b, where the VSWR changed from 1.79 to 1.84. This non-uniformity by 0.2degree fluctuation might not affect the beam quality seriously. In addition, the temperature control system of the cooling water is designed as +/- 0.1degree stability.

STABILITY WITH 50 mA BEAM OPERATION

After the high-power conditioning, properties of the accelerated beam were measured. Then, we demonstrated the continuous beam operation for one month in Jun. 2014. During this operation, the beam current at the exit of the RFQ and the tank level were kept at 50mA and 100% respectively. The beam operation parameters such as the beam width, the repetition, and the ion source duty factor were adjusted several times to change the scraper irradiation condition. Figure 4 shows the history of the trip rate (number of trips per hour), the 3MeV beam duty factor, and the vacuum pressure for one month. The trip rate is high, typically eight times per hour. Also, the trip rate is related to the beam operation setting.

The trip rate rapidly decreased at 11th day, where the 3MeV beam duty (250μs, 5Hz) was not changed but the ion source discharge repetition was changed from 25Hz to 5Hz. The hydrogen gas flow rate into the ion source was not changed at that day. Therefore, the rapid decrease in the vacuum pressure at 11th day corresponds to the decrease of the gas from the 50keV beam loss (about 50mA, 20Hz, 1ms) and induced outgassing in the cavity. The same tendency can be seen at 17th day, where the discharge width of the ion source is decreased from 1ms to 0.6ms. The beam duty was increased at 14th and 28th, however, the trip rate is not almost affected by the 3MeV beam duty.

RESIDUAL GAS

This RFQ cavity has been pumped since Apr. 2013. The mass analyzer signal without high-power RF is shown in Fig. 5. One scan of the mass analyzer takes 40 seconds and plotted data is averaged over one hour. Almost of all carbon related components are still decreasing gradually. The water level seems to saturate. Figure 6 shows the comparison among with and without high-power RF, and beam. There is no difference between the data with and without high-power RF input, however, the hydro-carbon related components appear when beams are in RFQ cavity. The lost beam in the cavity induces outgassing from the surface. We consider that the impurities in the cavity space are re-adsorbed on the vane tip, then, the RF trip is induced at the contaminated surface by the beam impact. The residual gas signals during one month beam operation are shown in Fig. 7. The main component is the hydrogen, which was almost constant if the ion source duty is the same. The water and the carbon oxide related components are in second and third places. These components decreased in the first two weeks, also, the decrease in vacuum pressure was observed as shown in Fig. 4. The hydro-carbon related components continue to decrease. Therefore, the conditioning with beam is insufficient at this moment.

CONCLUSION

The J-PARC RFQ III has high-power conditioned and the one month beam acceleration test has conducted. The soundness of the RF field with high-power RF is confirmed. However, the operation stability with beam is not enough at this moment. We will improve the vacuum system and continue the conditioning with beam for the stable beam operation.

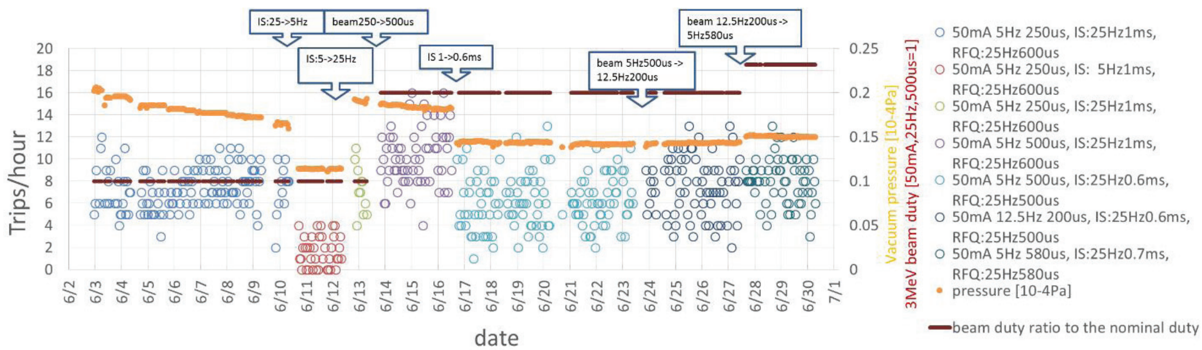

Figure 4: Trip rate, vacuum pressure, and the beam duty at the continuous beam acceleration test in Jun. 2014.

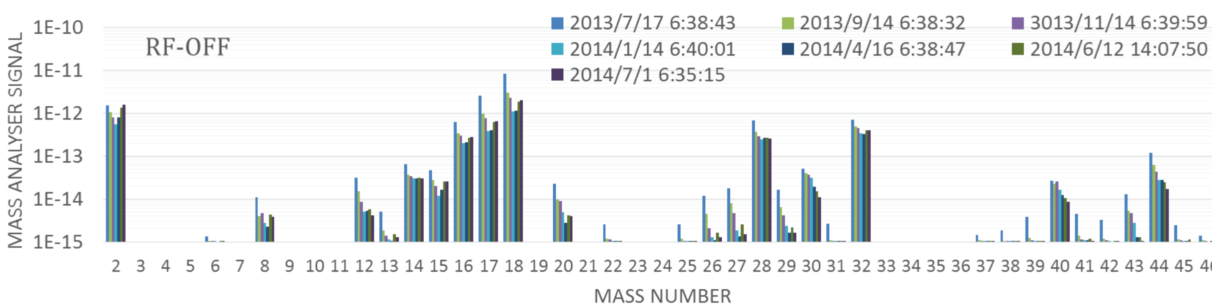

Figure 5: Residual gas signals without high-power RF for one year.

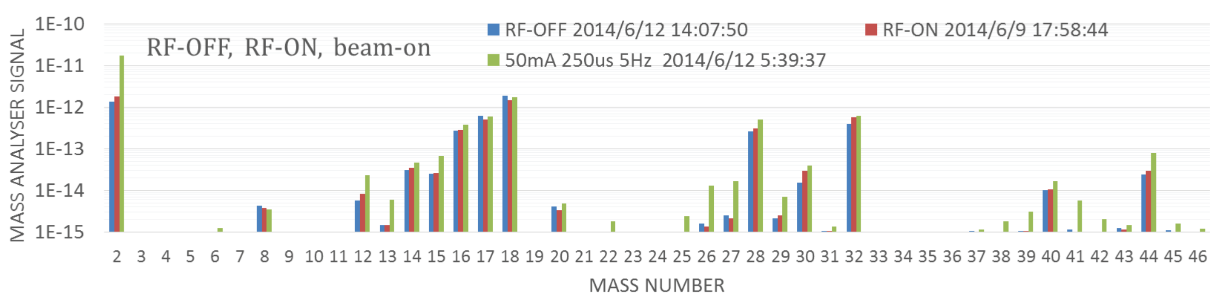

Figure 6: Comparison of the residual gas signal for RF-off, RF-on, and beam-on.

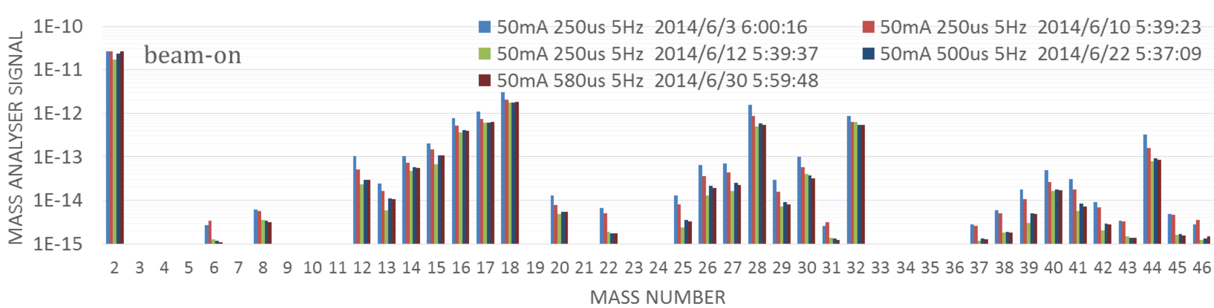

Figure 7: Residual gas signals during one month continuous beam test.

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REFERENCES

[1] Y. Kondo et al., Phys. Rev. ST Accel. Beams 15, 080101 (2012).
[2] T. Morishita et al., "Progress on RFQIII Fabrication in J-PARC Linac," Procs. of LINAC 2012, Tel Aviv, Israel (2012).
[3] T. Morishita et al., "Fabrication of the RFQ III for the J-PARC Linac Current UpgradeE," Procs. of IPAC 2013, Shanghai, China (2013).
[4] Y. Kondo et al., "Beamtest of a new RFQ for the J-PARC linac", MOPP091, Procs. of LINAC 2014.
[5] Y. Kondo et al., Phys. Rev. ST Accel. Beams 16, 040102 (2013).