VACUUM IMPROVEMENT OF BUNCH SHAPE MONITOR FOR J-PARC LINAC*

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Abstract

Bunch shape monitors (BSMs) have been developed and installed in the summer of 2012 at the upstream part of new Annular-ring Coupled Structure Linac (ACS) section. Because a problem of the vacuum degradation was found during the BSM operations, BSMs were once dismounted from the beam line and the off-line baking operations with outgas analysis had been performed to reduce the vacuum pressure of BSM surrounding. The impacts of the bias voltage to the target wire and static lens, and the RF power to the deflector were examined in the vacuum test. Finally, we propose the additional vacuum system arrangement for the installation of BSM to the beam line. This paper describes the vacuum test results of BSMs and the additional vacuum system arrangement for the BSM installation.

INTRODUCTION

In the upgrade project in J-PARC to establish the 1 MW at the experimental laboratories connected to the upstream Linac and Rapid Cycling Synchrotron, we have two big projects as the energy upgrade from 181-MeV Linac to 400-MeV Linac and the front end improvement using new RF ion source and replacing of the upgraded Radio Frequency Quadrupole Linac (RFQ) cavity. To meet with the 400 MeV, 21 ACS cavities have been developed and installed in the beam line, and to meet with this installation, we have developed the beam monitors for the ACS cavity tuning. Because the acceleration frequency of ACS cavities is 972 MHz which is three-fold higher than that of upstream RF cavities, we need to take longitudinal matching at the upstream part of new ACS beam line.

We started the development of BSM for the J-PARC Linac in corroboration with the Institute of Nuclear Research, Russian Academy of Science (INR, RAS). After three years since the project started, three BSMs were completed to be fabricated. In the summer of 2012, prior to the installation of ACS cavities, we installed all three BSMs at the upstream of the new ACS section in order to conduct some test measurement using 181-MeV beams. During the BSM measurements, a problem of the degradation in vacuum conditions was found. One reason for this problem is the dark current resulting in desorption of absorbed gas molecules. And another reason is outgas released from materials when the high voltage and RF power were supplied for the electro-static lens and RF deflector, respectively. In order to evaluate and mitigate this problem, BSMs were once dismounted from the beam line and the off-line baking operations with outgas analysis had been performed to avoid the degradation of the vacuum in the summer of 2013. The impacts of the bias voltage to the target wire and static lens, and the RF power to the deflector were examined in the vacuum test.

Finally the improved arrangement of the vacuum system to install the BSM is also proposed. We will install a BSM in at the upstream of the ACS again in the summer of 2014 with additional vacuum arrangement. This paper describes the vacuum degradation of the BSMs, results of the vacuum test, and the proposed arrangement of vacuum system.

VACUUM DEGRADATION AT BEAM LINE

Longitudinal pulse width measurements were done with the beam energy of 181 MeV, the beam pulse current of 15 mA, the pulse duration of 100 μs, and the pulse repetition rate of 1 Hz [1]. During the measurement, several problems connected with the influence on the vacuum have been found. Before the BSM installation, vacuum pressure at the upstream part of ACS section is around 1.0e-6 Pa.

The first one was connected with too big excitation power of BSM power amplifier. It was observed that the vacuum degraded over 1.0e-4 Pa which is the machine protection level in J-PARC Linac immediately after supplying RF power to the deflector. Decreasing of the magnitude of the input RF signal immediately removed the influence on the vacuum.

The second problem was a vacuum degradation in the case of multipactoring in the RF deflector at the operating mode. This discharge occurred when the high voltage potential was not supplied to the deflector electrodes. The software had been modified to suppress this degradation. RF is switched on only during the measurements.

The third effect is an influence of a dark electron current from the target. The electrons are accelerated and bombard the surfaces resulting in desorption of the absorbed gas molecules. The effect was observed immediately after supplying high voltage potential. After conditioning for several days the effect almost decreased and it became possible to make measurement with the potential of -10 kV. After installation and beam line tuning, beam line pressure didn't recover the previous level because of the malfunction of the closest ion pump.

Above influences had been met at the beam line. We have examined the vacuum test for BSMs with additional pumps.

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STRUCTURE OF BSM

BSM consists of the body, RF deflector, steering magnet, actuator and electron detector in Fig. 1. An RF deflector and an actuator which holds a target wire are vertically installed against the beam axis on the body. Secondary electron past through the doubly installed collimators on the RF deflector travels to the pipe connected to the electron detector [2].

We supply the constant high voltage to focus the secondary electron trajectories from the feed-through set. There are ceramic spacers to support the electrodes

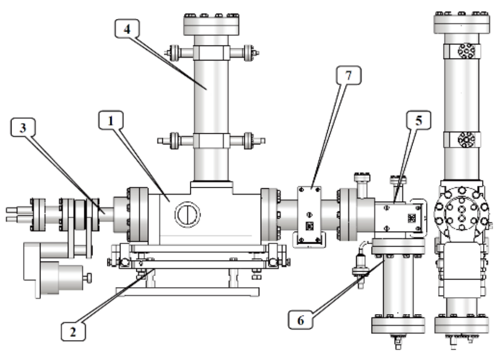

Figure 1: Over View of BSM (1- body, 2- support, 3- target actuator, 4- RF deflector, 5- bending magnet, 6- electron detector, 7- steering magnet).

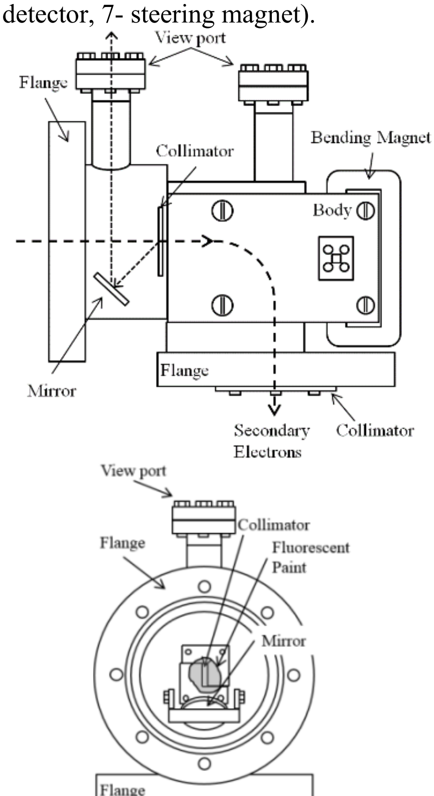

Figure 2: Schematic View of Bending Magnet. Dashed line in the side view shows the secondary electron trajectory.

spacing in the deflector pipe. These structural characteristics depend on the low conductance of pumping rate. For the coarse tuning of secondary electron trajectories, we can directory observe the electron trajectory from the two view port located at the bending magnet part in Fig. 2. We use the thermal electrons emitted from the target wire by supplying the electrical current. When the electron trajectory is out of double collimators, electrons hit the fluorescent paint to release the light of fluorescence. The path width inside the bending magnet is almost 10 mm with the collimators at the both sides. Finally, secondary electrons past through some collimators and bending magnet reach the electron multiplier.

As shown in Fig. 1 and 2, there are some collimators and structural parts which prevent from the gas flow. This is thought to cause a low pumping rate. The bias high voltage to the static lens and target wire, and RF power input are the main parameters of the BSM measurement, they are also key parameters for the vacuum degradation.

VACUUM TEST

Target Vacuum Pressure

Vacuum pressure around BSM should be around or under the pressure of the ACS cavities, because the vacuum degradation is a potential hazard of the cavity condition. Assuming the vacuum accident, pumping time to reach the normal vacuum pressure should be consistent to that of the cavities. We decided the target vacuum pressure under 5.0e-7 Pa and the pumping time to reach under 1.0e-6 Pa is faster than a week by referring the cavity records [3].

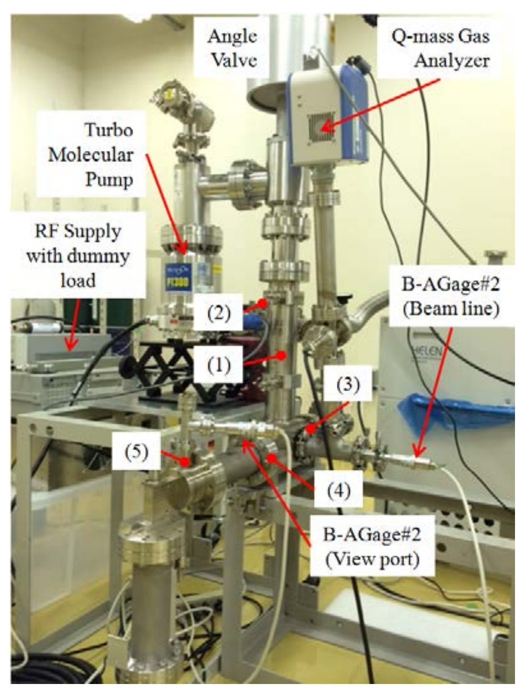

Figure 3: Set-up of vacuum test using BSM#1 in Test bench.

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Set-up of the Vacuum Test

We use an additional turbo molecular pump (TMP) for a BSM vacuum test. We assume the realistic beam line layout of the pump arrangement, the TMP is located above the quadrupole magnets. The vacuum test set-up consists of a turbo molecular pump (TMP), the heating devices, a Q-mass analyzer, two vacuum gage (B-A gage) which are set at the end of beam line and the view port, a high voltage supplier and an RF power supply with a dummy load. High voltage supplier can put a DC voltage and pulsed RF power can input the RF deflector. Numbers in brackets are the points for temperature measurement (Fig. 3).

Baking of BSM

Tape-shaped heaters are put on the surface of the RF deflector, nipples, pipe between the body and bending magnet, pipe of actuator, pipe of electron detector and around an angle valve. Baking temperature is carefully decided. Metallic and ceramic parts can be sustained up to 200 deg. C, but vacuum seal and cramps should be under 100 deg. C. Maximum baking temperature at six points are below. These numbers are corresponding in the numbers in Fig. 3.

(1) Surface of RF deflector: 175 ^{0}C
(2) SHV connector on RF deflector: 60 ^{0}C
(3) KF40 Flange (Beam line): 70 ^{0}C
(4) ICF114 Flange between body and pipe: 180 ^{0}C
(5) Surface of first view point: 150 ^{0}C

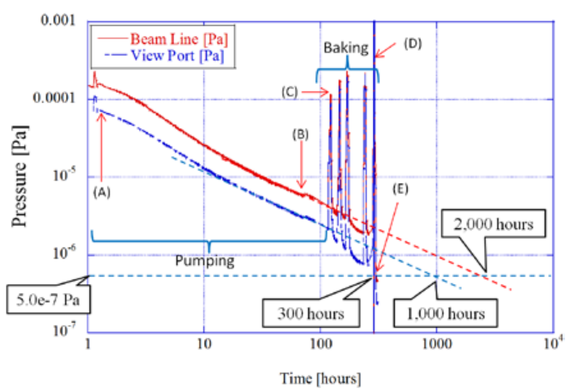

Figure 4: Initial pumping speed of BSM and acceleration of time for the target vacuum level.

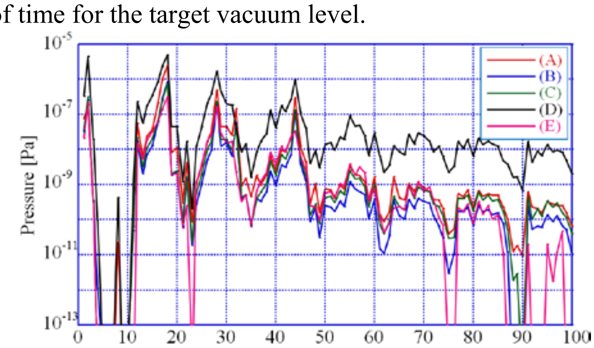

Figure 5: Gas components of at pumping and baking time. Heavier hydro carbons can be removed by baking. Symbols (A) to (E) are the timings of gas analysis, which are shown in Fig. 4.

Initial Pumping Rate and Baking Effect

Trend on the pumping speed of a BSM using a TMP is shown in Fig. 4. Estimated time to the target vacuum pressure is over 1,000 hours. The time can be accelerated to about 300 hours by baking five times. As the mass peak of the outgas components seen in Fig. 5, before the baking, the gas mainly consisted of the air components. During the high temperature, heavy hydrocarbons are removed. After baking, mass number 2, 18, 28, 32 and 44 are the conspicuously reduced.

Effect by Static Lens

After pumping, a lens high voltage was scanned from 0 to -10 kV. Usual setting value is -8.3 kV. Although the scan range covers with the higher voltage, no effect with the high voltage was found in Fig. 6. In the beam line measurement, no big pressure increase was found by supplying the lens high voltage. This result agreed with the experience at beam line.

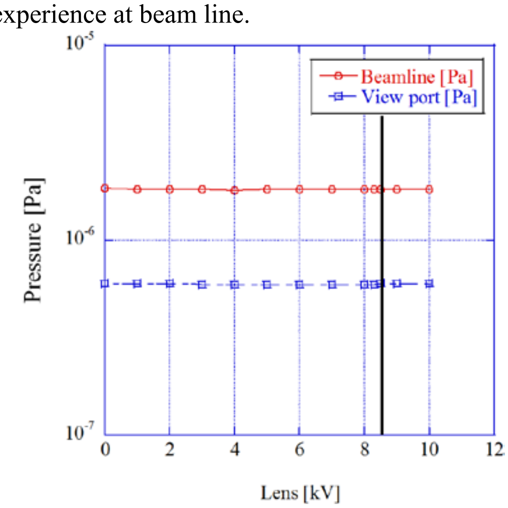

Figure 6: Lens HV Dependence on Gas Pressure. There is no dependence on the lens HV (DC). This lens DC is the negative potential.

Effect by RF Power for Deflector

Pulsed (100 µs) RF power was supplied from 0 to 13 W. Usual setting value is 10 W for BSM, but estimated input power is attenuated in the long transport cable to 6 - 7 W. The vacuum pressure increase was slightly observed from 2 W, but the dependence of the RF Power is not strongly connected on the vacuum pressure (Fig. 7). At the beam line test, we input too much power to the RF deflector and the vacuum degraded immediately. The RF amplitude was tuned to the half, we observed the immediate reduction of the vacuum pressure. This results didn't show a strong dependence, but we have already improved to suppress this degradation by the software modification. The software controls the RF input only during the measurements.

Effect by Target HV

The target high voltage was scanned from 0 to -13 kV. Usual setting value is -10.0 kV. The very big out gassing was observed from -7.0 kV (in Fig. 8). At the beam line

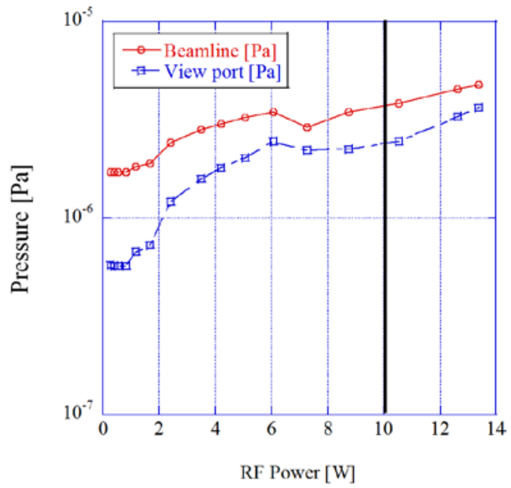

Figure 7: RF power dependence on gas pressure. There is small dependence on the RF power.

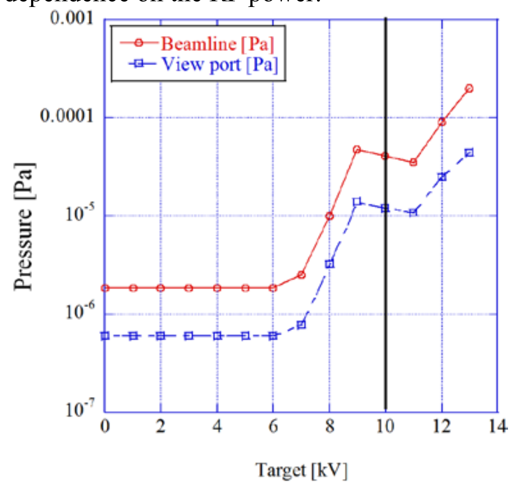

Figure 8: Target HV dependence on gas pressure. The effect strongly starts from -7 kV. This bias voltage is negative.

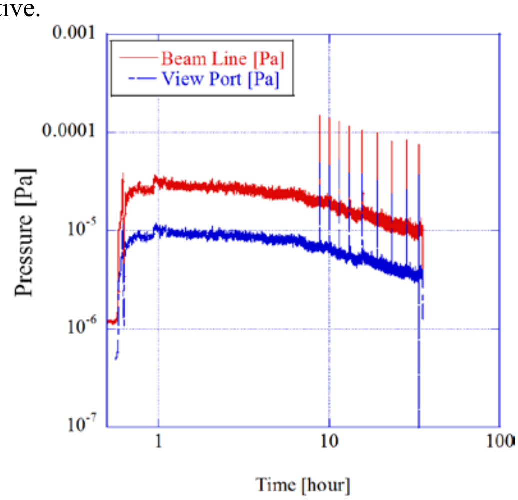

Figure 9: Target wire conditioning with HV supply. Pressure depends on the conditioning.

measurement, the intensity of the effect also depended on the value of the target potential and normally started at around -7 kV. This result is agreed with this result.

High voltage was supplied from 0 to -13 kV and the voltage was kept at -10 kV for over 35 hours for the wire conditioning. Vacuum pressure was decreased gradually with time (Fig. 9). About 10 hours has passed, electrical discharge is seen. After conditioning of the target wire, the dependence of high voltage supply to the target wire is improved to about one order in Fig. 10.

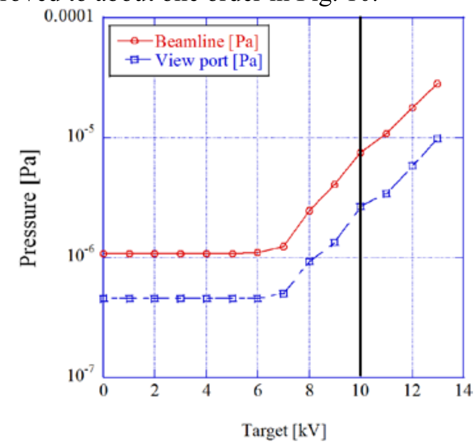

Figure 10: After conditioning of target wire. The effect is drastically improved. These data were taken with Q-mass analysis. Pressure with Q-mass analysis is usually higher than that without Q-mass analysis.

Improved Vacuum Pressure in the Test

After cooled from the finishing the baking and the target wire conditioning, we turned off the target HV and Q-mass analyzer to check the achieved pressure level. As the results, vacuum pressure reached 5.99e-7 at beam line and 3.08e-7 Pa at view port. High voltage to the target wire was supplied again from the lowest pressure, the pressure was recovered from the original level. Because the recovered pressure level after conditioning was already improved, impact of the pressure increasing is not so seriously high. After purging with dry nitrogen gas to confirm the pumping rate again (Fig. 11), the estimated time to 5.0e-7 Pa is almost half as initial condition in Fig. 4. After baking once, and turned off the target HV and Q-

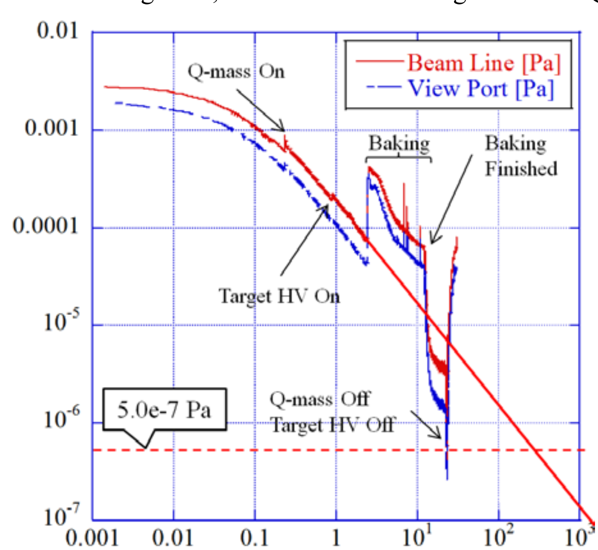

Figure 11: Pumping Speed after Baking. Once dry nitrogen gas was purged inside the BSM, pumping stated again.

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mass analysis, time to achieve 5.0e-7 Pa is about 30 hours. Actually the vacuum pressure reached 4.05e-7 at beam line and 2.74e-7 Pa at view port. This result is enough for the target level. But the target HV turned on again, the pressure level was recovered to the original level to the 3.50e-6 at beam line and 9.38e-7 Pa at view port. Because the HV impact still remained, further conditioning were required.

VACUUM SYSTEM IMPROVEMENT

Original BSM has no vacuum equipment, but the installation of BSM caused some vacuum degradation. We have examined the vacuum test with the high voltage supply and RF power input using additional vacuum pump. When the high voltage supply and RF power are off, the target vacuum level was almost achieved. But the vacuum level with high voltage was recovered to another pumps will be installed closer to the beam line to remove the impact of the high voltage supply.

CONCLUSION

Because there are some narrow slits inside the BSM, vacuum conductance is suppressed. Low conductance will require a quite long time to reach the operational vacuum condition. An additional pump and baking can accelerate the pumping speed. HV supply and RF supply have the impact of vacuum increasing. Baking with the target conditioning (supplying HV) is effective for the vacuum improvement. Further improvement will bring the better condition. Supplying period of RF power is limited only for the measurement by software improvement. Limitation of HV supplying is only for the pulse duration (supplying term is set for slightly longer than the macro pulse). Using the shorter pulse duration for the measurement.

We can successfully take various vacuum data for installation of BSM. But this is not enough for all three BSMs. We will continue to improve the vacuum system of BSM.

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REFERENCES

[1] A. Miura, et. al., “Bunch Shape Measurement of 181 MeV Beam in J-PARC Linac", Special Volume of Proceedings of J-PARC Symposium, Journal of the Physical Society of Japan (JPSJ), to be published in April, 2015,

[2] A. V. Feschenko, "Methods and Instrumentation for Bunch Shape Measurements", Proc. Part. Acc. Conf. PAC 2001, Chicago, p. 517 (2001).

[3] H. Ao, et. al., “Annular-ring Coupled Structure Linac for the J-PARC Linac Energy Upgrade”, Proceedings of IPAC13, THPWO036, Shanghai, China, 2013.