BEAM LOSS OCCURRED AT DTL CAVITY IN J-PARC LINAC*

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Abstract

We measured the residual radiation along the beam line during short operation intervals. Because the dependence on the operational condition of higher residual radiation was recognized at the surface of drift tube linac (DTL) cavity by radiation survey, we installed scintillation beam loss monitors at some points with particularly high radiation to investigate the cause of the radiation. Although the DTL section is low energy part of the linac, fine structure of the beam loss was observed by the scintillation BLM. We also measured the beam loss occurred at the DTL varying the beam orbit. In this paper, the result of the radiation measurement and beam loss signals obtained by the scintillation BLM's are presented.

INTRODUCTION

There was big damage in J-PARC caused by the Tohoku earthquake in March 2011[1-3]. And the beam operation of J-PARC linac was suspended. We resumed the beam operation and delivered to the laboratory from December. After resuming the operation, we measured the residual radiation along the beam line during short intervals. Because the dependence on the operation condition and history of higher residual radiation was recognized at the surface of drift tube linac (DTL) cavity by radiation survey, we installed scintillation beam loss monitors (BLM's) at some points with particularly high radiation to investigate the cause of the radiation. We also measured the beam loss occurred at the DTL varying the beam orbit.

RESIDUAL RADIATION IN DTL SECTION

DTL (Drift Tube Linac) in Linac

J-PARC linac consists of the IS (ion source), RFQ (Radiofrequency Quadrupole), DTL (Drift Tube Linac), SDTL (Separated type DTL) and the beam transport to downstream RCS (Rapid Cycling Synchrotron) as fig. 1. Negative hydrogen ion beam is accelerated up to 50 keV in the ion source chamber. After the beam is accelerated up to 3 MeV by RFQ and had matching by the quadrupole magnets in MEBT (middle energy beam transport) section, it is injected to DTL through SDTL to be accelerated.

J-PARC linac has three DTL cavities, and each cavity consists of connected 3 unit tanks. Length of a unit tank reaches 3 m, then a DTL cavity reaches about 9 m. The first DTL cavity consists of 75 drift tubes (DTs) and quadrupoles. All DTs are aligned within 50 μm to the center of the magnetic fields [4].

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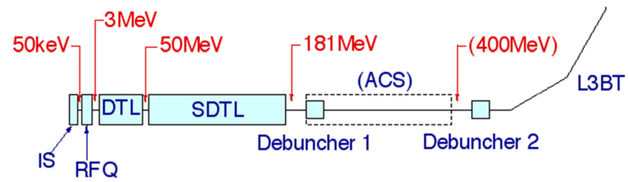

Figure 1: Configuration of J-PARC Linac. DTL section is located to the downstream of RFQ, the beam energy is accelerated from 3 to 50 MeV. (IS: Ion source, RFQ: Radio Frequency Quadrupole, DTL: Drift Tube Linac, SDTL: Sparated-type DTL)

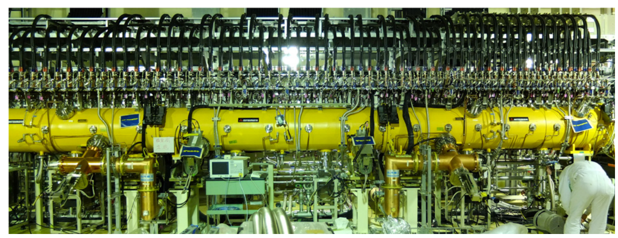

Figure 2: Overview of DTL Cavity. One DTL cavity consists of 3 unit tanks.

Residual Radiation in DTL Section

Intervals of the first operation after resuming the operation, residual radiation at the surface of DTL cavities was measured using Geiger-Muller counter. Most of all points are measured under 1.0 μSv/h, but higher residual radiation was recognized at DT25 (the 25th DT) and DT55 (the 55th DT) of 1st DTL cavity. Measured points are described in fig. 3 and measured values are listed in table 1.

Based on these results, we measured the residual radiation every interval of beam operation. As described in fig. 4, dependences on the operational conditions and

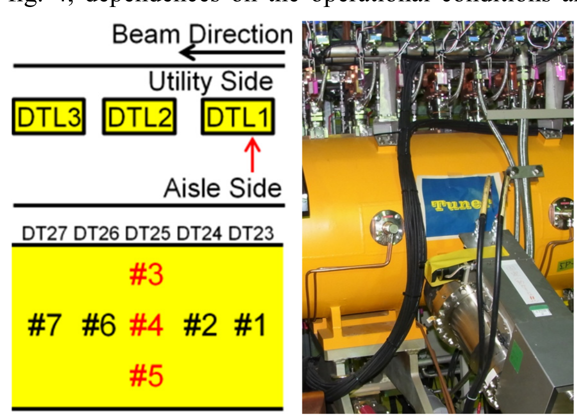

Figure 3. Measurement Points of 1st DTL1 Cavity. Axis is defined to the x-y-z coordination, +y as a top of vertical, +z as a beam direction, +x as a inevitably defined for aisle direction.

the operation history are recognized. Because the beam energy is not enough high to detect the gas-proportional BLM (beam loss monitor) and the installed position of them is not close to the surface of cavities, there was no difference of beam loss signals from gas-proportional BLM during the operation. Based on the less sensitivity of gas-proportional BLM, we employed scintillation BLMs to observe the beam loss carefully through an operation at the points where the higher residual radiation was detected.

Table 1: Residual Radiation around DT25 and DT55 of 1st DTL Cavity

Aisle Side(+x direction)		Utility Side(-x direction)	
Position	Dose value [μSv/h]	Position	Dose value [μSv/h]
# 1	4.2	# 1	5.30
# 2	4.58	# 2	8.87
# 3	8.7	# 3	9.04
# 4	6.59	# 4	6.98
# 5	6.7	# 5	8.78
# 6	5.50	# 6	5.17
# 7	2.49	# 7	2.51

BEAM LOSS DETECTION BY SCINTILLATION BLM

Plastic Scintillation Beam Loss Monitor

Plastic scintillation monitors with less X-ray sensitivity are employed and installed to measure the beam loss. We used photo-multipliers of Hamamatsu H3164-10 with the gain of 1.1 x 10^6, the peak wavelength of 420 nm, and the rise time of 0.8 nsec (Figure 4). The plastic scintillator is Saint-Gobain BC-408 with the peak emission wavelength

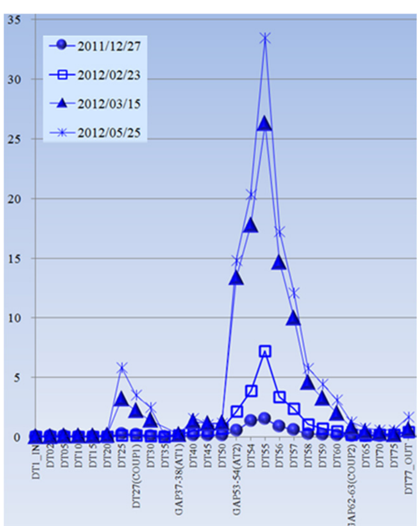

Figure 4: Residual Radiation at DTL1. Radiation depends on the operation history and beam outputs. Unit of longitudinal axis is in μSv/h and horizontal axis describes the position.

of 425 nm and rise time of 0.9 nsec, which matches the photomultiplier [5].

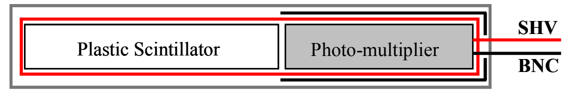

Figure 5: Configuration of Plastic Scintillation Beam Loss Monitor.

Beam Loss Measurement

In the first DTL section, beam energy is at least 10 to 20 MeV. Peak sensitivity of plastic scintillator (BC-408) is slightly sifted to higher energy, but it would have low sensitivity even the low beam energy. We employed the four scintillation BLMs to install +x side (aisle side) and –x side (utility side) at both DT25 and DT55 (fig. 6). In order to confirm the beam orbit dependence of beam loss at DT25 and DT55, we use the steering magnet installed at upstream part (MEBT1) to shift a beam orbit. In addition, high voltage supplied for the photo multiplier is suppressed under -800V to prevent from a saturation of signal responce. Waveform of the signal is obtained to observe the beam loss events using high speed sampling oscilloscope.

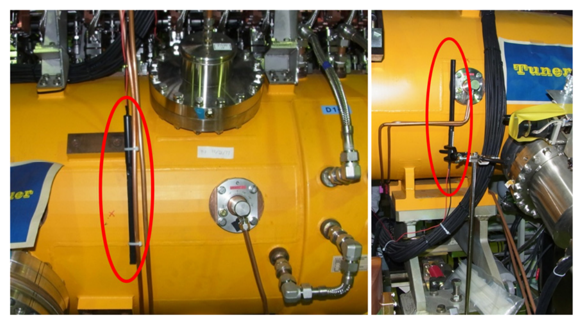

Figure 6: Scintillation BMLs Installed at the Surface of DTL Cavity. Installation situation of DT25 is on left side and it of DT55 is on right side.

Discussions of Beam Loss Measurement

Because beam loss signals are successfully obtained even in low beam energy and fine waveforms are obtained using scintillation BMLs, discussions can be useful.

Waveforms obtained at DT25 are shown in fig. 7 and fig.8. Figure 7 shows the waveform obtained after the beam orbit correction. The beam orbit is corrected with observing beam losses occurring from DTL to downstream section.

Figure 8 shows the waveform obtained after the slightly shift of beam orbit. In this case, beam loss events are recognized more at the corrected orbit than those at the shifted orbit.

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In case of DT55, characteristic beam loss events are shown in fig. 9 and 10. In fig. 9, the less beam loss occurs at the corrected orbit. If the beam orbit is misaligned, many beam loss events are observed in figure 10. In this case, a beam orbit dependence of beam loss events is recognized, but these patterns show a different contribution.

SUMMARY

Beam orbit dependence of beam loss at two point of DTL cavity is obtained by the measurement using scintillation BLMs, after the beam orbit is corrected. Result obtained at the upstream point suggests that the misalignment which would be caused by the earthquake is still left in the DTL cavity. The result at the downstream points has a tendency of beam orbit dependence, but the misalignment is not remarkably suggested. Alignment of DTs should be confirmed more in detail.

Beam loss which is detected at the surface of DTL cavity is successfully measured by the scintillation BLM even the low beam energy. Beam loss occurs at DTL1 depends on the beam orbit which pass through the cavity inside. This is a predictable result by the specification of scintillation. Because the serious beam loss had not been seen in this section, we had not focused it. But these residual radiation and beam orbit dependence of beam loss show the important lessons for beam commissioning. Also, the scintillation BLM would become an essential beam commissioning tool, based on the development of electrical circuits which has the functions of high speed beam loss detection system, qualification of the beam loss events and high accuracy. In future, the beam loss detection system using scintillation will be developed.

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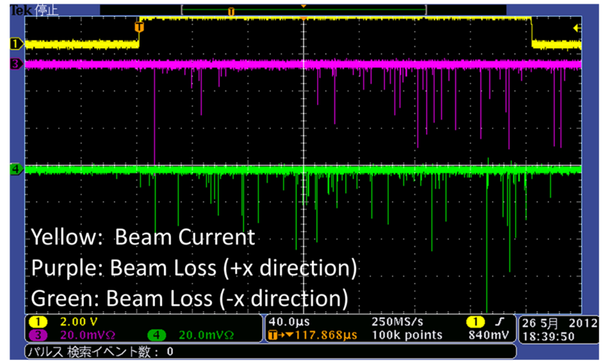

Figure 7: Beam Loss Events Occurred at DT25. Beam orbit is corrected with observing beam losses occurring from DTL to downstream section.

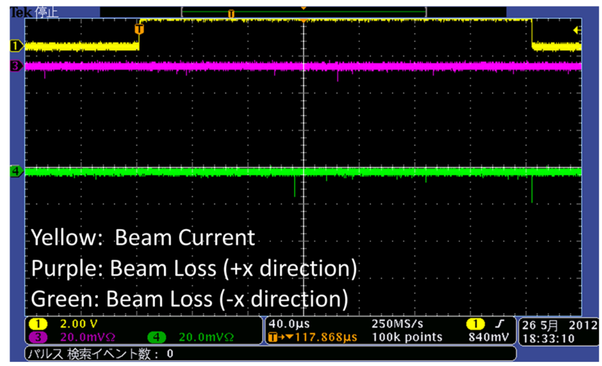

Figure 8: Beam Loss Events Occurred at DT25. Many beam loss events are disappeared, after the beam orbit is slightly shifted.

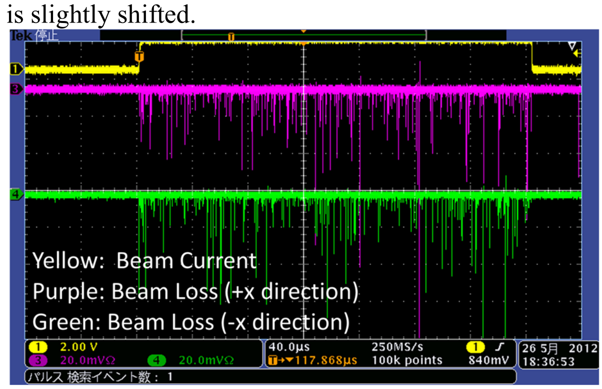

Figure 9: Beam Loss Events Occurred at DT55. Beam orbit is corrected with observing beam losses occurring from DTL to downstream section.

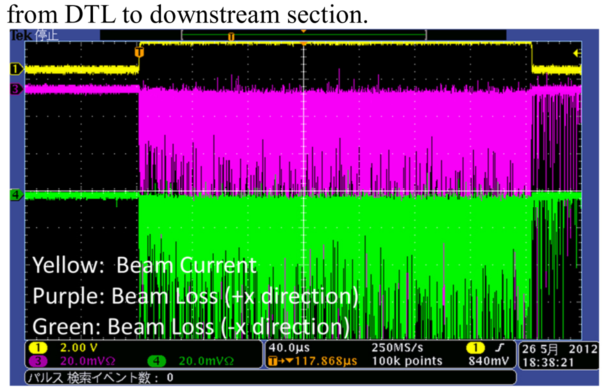

Figure 10: Beam Loss Events Occurred at DT25. Many beam loss events are observed, after the beam orbit is slightly shifted.