RECOVERY EFFORTS FROM THE TOHOKU EARTHQUAKE AND ENERGY UPGRADE PREPARATION OF THE BEAM TRANSPORT FROM J-PARC LINAC TO 3-GeV SYNCHROTRON

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Abstract

In 2013, the beam energy of the Japan Proton Accelerator Research Complex (J-PARC) linac is going to be increased from 181 to 400 MeV. This energy upgrade is carried out by adding the Annular-ring Coupled Structure (ACS) linac to the beam transport at the downstream of the 191-MeV drift tube linac. To install and condition all the ACS cavities in only five months, we decided to replace and upgrade most of the related components of the beam line (cables, power supplies for magnets and vacuum control systems) for the 400-MeV operation, in the annual maintenance period in summer and the period of the recovery from the 2011 Tohoku Earthquake. The original 181-MeV beam line is operated by using some part of the 400-MeV componets. In this paper, the recovery of the beam transport, the present status of the beam operation, and the future tasks of the beam energy upgrade will be presented.

INTRODUCTION

In the J-PARC linac, H- beams are accelerated by 3-MeV RFQ, 50-MeV DTL, and 181-MeV Separate-type DTL (SDTL). Then, the beams are transported to the 3-GeV synchrotron. To achieve the beam power of 1 MW after the 3-GeV synchrotron, we are planning to increase the injection energy into the synchrotron from 181 to 400 MeV. The beam energy upgrade is scheduled in 2013 and carried out by adding the ACS linac to the beam transport at the downstream of SDTL [1]. Figure 1 shows the diagram of the J-PARC linac. Twenty-one ACS accelerating modules are going to be installed in A0BT. Two ACS buncher modules are going to be installed in MEBT2, which is a matching section for the ACS accelerating section. Two ACS debuncher modules are going be installed in L3BT, which is a beam transport from the linac to the 3-GeV synchrotron.

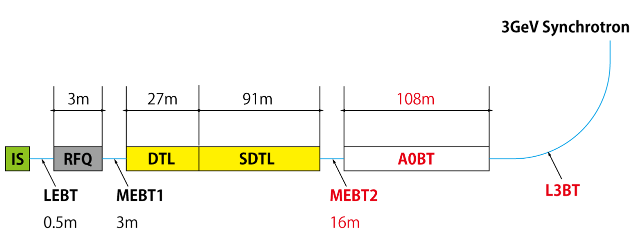

Figure 1: Diagram of the J-PARC linac.

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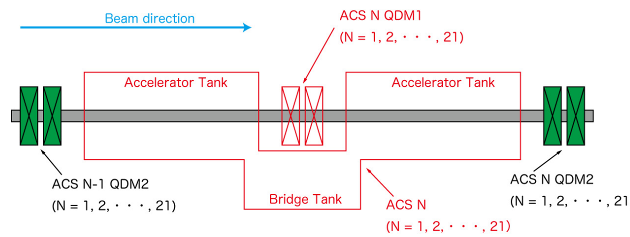

Figure 2: Layout of the quadrupole array in A0BT.

The ACS cavities are operated at 972 MHz, While the RFQ, DTLs and SDTLs are operated at 324 MHz.

MEBT2 and A0BT have 6 and 21 quadrupole doublets, respectively. The drift space length of MEBT2 and A0BT increase gradually from 2.5 to 3.4 m and from 4.6 to 5.7 m, respectively. Figure 2 shows the layout of the quadrupole array in A0BT. ACS accelerating modules and doublets over the ACS bridge tanks, which are drawn by red line in Fig. 2, are going to be installed in the 2013 energy upgrade shutdown.

Before the 2011 Tohoku Earthquake, the beam energy upgrade was scheduled to be completed in 2012. The earthquake caused a tremendous damage to the J-PARC accelerator facility. It made beam operation impossible for nine months and delayed the beam energy upgrade from 2012 to 2013. In this paper, the recovery of the beam transport, the present status of the beam operation, and the future tasks of the beam energy upgrade will be presented.

BEAM LOSS REDUCTION BY BEAM DUCT REALIGNMENT

In the J-PARC linac, almost all the cavities and magnets were precisely realigned because the accelerator tunnel had been deformed by the 2011 Tohoku Earthquake [2]. In MEBT2 and A0BT, the beam ducts have been roughly aligned after the precise alignment of the quadrupole doublets. The beam ducts are made up of titanium pipes with inner radius of 41 mm and branch ducts for vacuum pumps in the center of two doublets.

The beam study operation in the linac has been resumed on 9th of December 2011 [3]. During the first beam operation after the earthquake, remarkable beam loss and residual radiation have been observed at some parts of MEBT2 and A0BT. This beam loss had a strong correlation with the beam orbit. The beam loss has been reduced by adjusting the beam orbit using steering magnets, but it were

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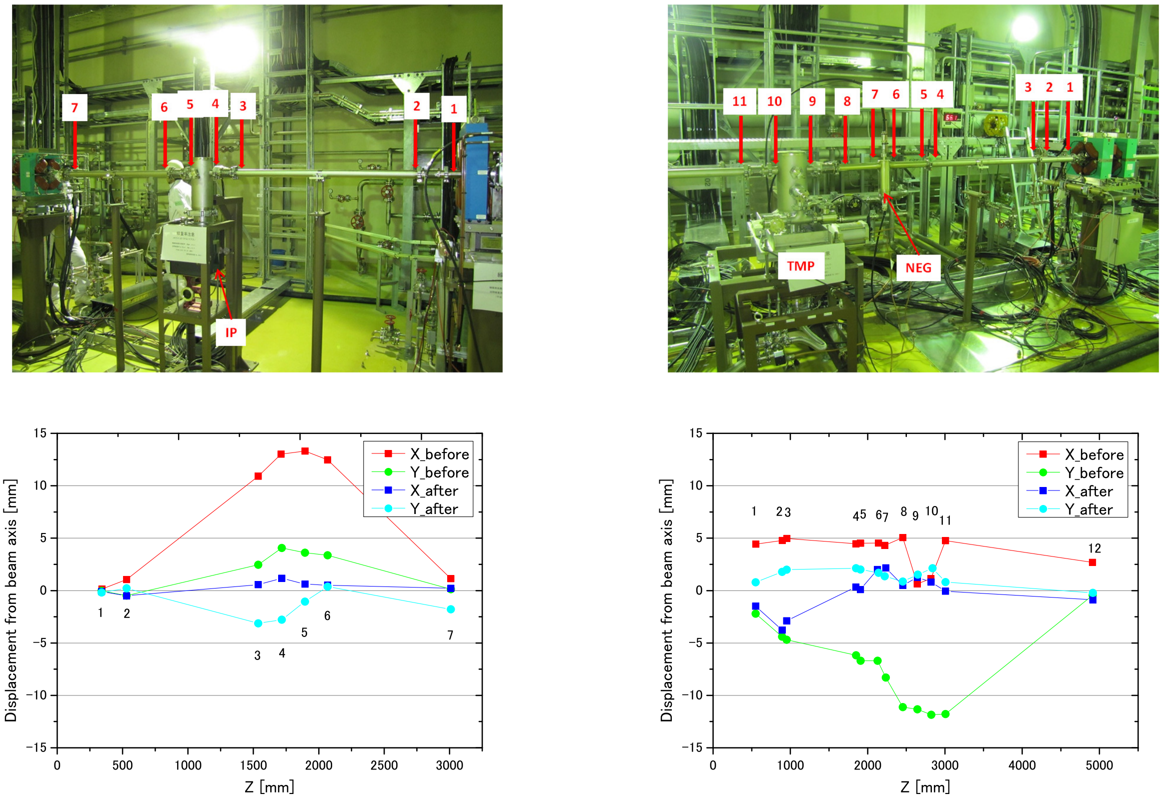

Figure 3: Beam duct realignment in MEBT2 (left) and ACS11 (right). Upper-left figure shows the section between MEBT2-QDM02 and MEBT2-QDM03 which have an IP in its center. Upper-right figure shows the ACS11 section which have a TMP in its center and a NEG Pump just before the TMP. Lower figures show the results of the duct position measurement before and after the duct realignment in MEBT2 (left) and ACS11 (right).

still much bigger than that before the earthquake. The loss and the residual radiation were localized to a branch duct for an ion sputter pump (IP) between MEBT2-QM02 and MEBT2-QM03 of MEBT2 and to a branch duct for a turbo molecular pump (TMP) and a non-evaporable getter (NEG) pump in ACS11 section. Therefore, we decided to check the alignment of the beam ducts with a laser-tracker. As the result of the duct position measurement, the misalignment of over 10 mm displacement from the beam axis were found. Figure 3 shows the displacement of the beam ducts from the beam axis in MEBT2 and ACS11. In MEBT2, there were 13.3 mm of displacement in a horizontal direction at the branch duct while less than 5 mm in a vertical direction. In ACS11, there were 12 mm of displacement in a vertical direction at the branch duct while less than 5 mm in a horizontal direction.

In the maintenance period after the first beam operation called Run#40, the beam ducts between MEBT2-QM02 and MEBT2-QM03, and in ACS02, ACS10, ACS11 and ACS14 have been realigned using a laser level marker [4]. This type of alignment tool based on a laser beam had not been used in the rough alignment before the beam operation. The result of the duct realignment is shown in lower figures of Fig. 3. Although not all the beam ducts in MEBT and A0BT could be realigned due to the limited time, the beam loss and the residual radiation were successfully reduced by the beam duct realignment. Table 2 shows the trend of the residual radiation of the branch ducts in MEBT2 and ACS11.

PREPARATION FOR THE BEAM ENERGY UPGRADE

To install and condition all the ACS cavities in only five months of the energy upgrade shutdown in 2013, we decided to replace and upgrade most of the related components of the beam line (cables, power supplies for magnets and vacuum control systems) for the 400-MeV operation, which are in use in the present 181-MeV operation. Due

Table 1: Trend of the residual radiation (unit: mSv/h). The beam duct realignment has been conducted after the residual radiation measurement on 2/22. The residual radiation listed in this table were measured on the surface of the branch ducts.

	2/22	3/15	3/22	4/11
MEBT2QM02-03	8.0	1.5	1.0	0.7
ACS11	10	2.5	2.5	1.8

Table 2: Cable installation and replacement in the beam line. These installation needs to be carried out in annual summer maintenance period. "•" stands for the original configuration for the 181-MeV operation. It is noted that the first SDTL debuncher is operated in ACS03 section for the 181-MeV operation. "○" and "×" stands for the cable installation and the cable removal, respectively.

	MEBT2			ACS																				
	M	B1	B2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Origin	•				•	•			•				•				•				•			•
2010		○	○	○			○	○		○		○		○	○	○		○		○		○	○	
2011	×				×				×				×				×				×			×
	○				○				○		○		○				○		○		○			○
2012																								
2013						×																		
						○																		

to the beam operation, an equipment installation and a facility expansion in the accelerator tunnel are restricted to three months of annual maintenance period in summer. In the beam operation shutdown after the 2011 Tohoku Earthquake, the energy upgrade preparation have been carried out in parallel with the recovery from the Earthquake.

In the original configuration for the 181-MeV operation, equipments such as magnets, vacuum pumps and beam monitors in MEBT2 and A0BT were operated by their power supplies and controllers set in terminal racks of MEBT2M, ACS02, ACS06, ACS10, ACS14, ACS18 and ACS21 in the klystron gallery. The history of the cable installation and replacement is summarized in Table 2. In 2011, the power supplies for quadrupole magnets have been relocated to the regular position of the control terminals corresponding to the ACS module number. And then, the magnets in MEBT and A0BT started to be operated by the corresponding power supplies with the exception of ACS03. ACS03-QDM02 is operated by the power supplies for ACS04-QDM01. Vacuum pumps and beam monitors are operated by using the cables installed in 2010. Cables for ACS-DB1 and ACS-DB2 have been installed in 2011 and 2012, respectively. The length of the cables for ACS-DB2 is about 120 m, while the others are 50 m long.

Rectangular waveguides have been installed from the klystron gallery to the position just before the RF window of the ACS cavities in 2009 and 2010 except for ACS03 and ACS-DB2. In ACS03, a coaxial waveguide is in use for the SDTL-DB1. In 2013, after the removal of the waveguide for SDTL-DB1, waveguide for ACS03 operated in 972 MHz is installed. Installation of the waveguide for ACS-DB2 was started in 2011. This is conducted also in 2012 and is going to be finished in 2013.

In 2013, the cables, waveguide and cooling water system for ACS03 are going to be installed after the removal of the associate equipments for S-DB01.

SUMMARY

We have been preparing for the energy upgrade of J-PARC linac and continuing recovery efforts from the Tohoku Earthquake. We have delivered 181-MeV H- beams to 3-GeV synchrotron mitigating the beam loss in the transport line which had not been observed before the earthquake. In 2012 summer maintenance period, we conducted the beam duct realignment throughout the MEBT2 and A0BT. It will contribute to the beam loss reduction due to the beam duct misalignment. The beam energy upgrade preparation is still going on for the ACS cavity installation in 2013.

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