BEAM DIAGNOSTICS IN THE J-PARC LINAC FOR ACS UPGRADE

Akihiko Miura[#], Susumu Sato, Tetsuo Tomisawa,
J-PARC Center, Japan Atomic Energy Agency, Tokai, Ibaraki, 319-1195, Japan
ZenEi Igarashi, Tomoaki Miyao, Masanori Ikegami, Takeshi Toyama,
J-PARC Center, High Energy Accelerator Research Organization, Oho, Tsukuba, 305-0801, Japan

Abstract

J-PARC had developed the beam diagnostic devices for the present J-PARC linac and has used them since the operation start. J-PARC linac began the energy upgrade project since 2009 and 21 ACS (Annular coupled Structure) cavities will be installed. Because the beam parameters are updated due to the project, new beam diagnostic devices are additionally fabricated and the diagnostic devices at the downstream part where the beam energy will be increased up to 400 MeV by ACS cavities should be developed. In this paper, we introduce the development of the beam diagnostic devices for the project and the new developing devices.

INTRODUCTION

J-PARC LINAC employs the following beam diagnostic devices for the beam commissioning; 38 beam current monitors (SCT: slow current transformer), 61 phase monitors (FCT: fast current transformers), 36 beam profile monitors (WSM: wire scanner monitor), 102 beam position monitors (BPM) and 124 beam loss monitors (BLM) [1-2]. Figure 1 shows the location of these monitors along the beam line.

In the present situation, an RFQ, three DTL cavities and 15 SDTL cavities are employed for the beam acceleration to obtain the beam energy of 181 MeV. Sections of A0BT and L3BT which have two debuncher cavities include the matching points to inject the downstream rapid cycling synchrotron (RCS). In the energy upgrade project, present two debuncher cavities are replaced to SDTL section as the 16th acceleration cavity and 21 ACS cavities are newly installed in the A0BT subsection. Along with this project, the beam diagnostic devices which will be employed for the future ACS section and L3BT section for the beam commissioning are newly designed and fabricated. Because the beam energy will be upgraded, the devices not only for the future ACS section but also for the L3BT section should be developed.

Table 1: Energy Upgraded Linac Operational Beam Parameters

Particle	H^-
Peak Beam Current	5 - 50 mA
Source Energy	180 - 400 MeV
Typical Bunch Length	1 - 2 deg. (rms)
Typical Transverse Side	1 - 2 mm (rms)
Pulse Length	> 50 usec
Bunch Repetition Frequency	324 MHz
Operational Repetition Rate	1 - 25 Hz

REQUIREMENT OF BEAM DIAGNOSTIC DEVICES

Operational parameters of the energy upgraded linac are listed in the Table 1. In the project, the beam energy will be upgraded up to 400 MeV and the peak beam current will be increased up to 50 mA. Acceleration frequency of the ACS cavities employs 972 MHz, but the beam is accelerated by 324 MHz RF from the DTL cavities actually. The high frequency beam monitoring devices are tuned at 324 MHz. The total precision of the beam position measurement is required less than 0.1 mm by the beam commissioning. And the total precision of

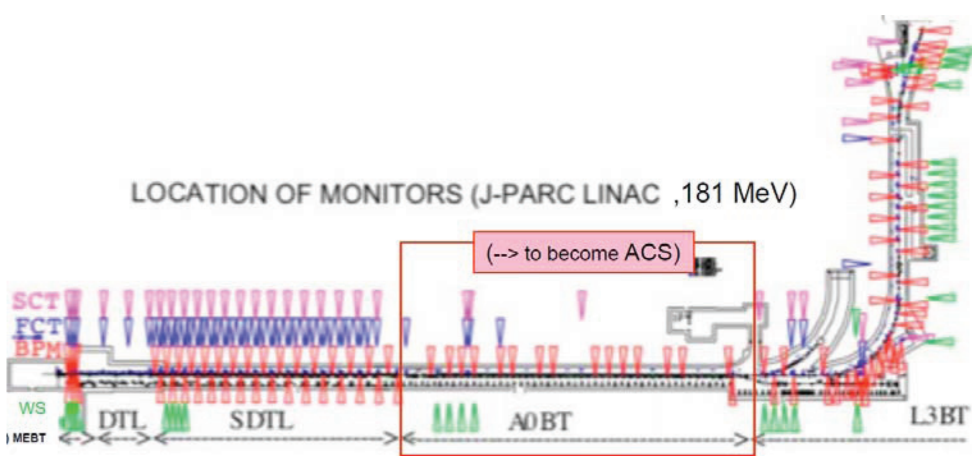

Figure 1: Location of beam monitors in present J-PARC linac. Pink marks are SCT monitors, blue are FCT monitors, red are BPM monitors and green are profile monitors respectively. Beam transport (A0BT) in the red square will become the ACS section where the ACS cavities will be installed.

#miura.akihiko@jaea.go.jp

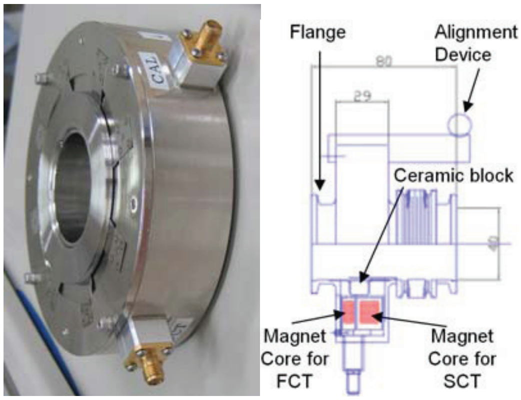

Figure 2: Beam current and phase monitor (SCT/FCT).

the beam current monitor (SCT) and the phase monitor (FCT) are tuned and usually maintained less than 0.1 mA, 1.0 degree respectively. Also, the precision of the transverse profile monitor is less than 0.1 mm. Present beam diagnostic devices are achieved above precisions. The same precisions are required for the developing ones.

Beam Current and Phase Monitor (SCT: Slow CT, FCT: Fast CT)

In the future J-PARC linac, totally twenty-three SCTs and forty-nine FCTs will work in the future ACS section. All twenty-three SCTs are combined with the phase monitor due to the installation in the limited space. The number of the SCT and FCT are compared in Table 2.

Table 2: Numbers of SCT/FCT Monitors for Present and Future ACS Section

	Present		Future	
	Total	ACS section	Total	ACS section
SCT	38	3	58	23
FCT	61	4	106	49

Finemet^{TM} core (Hitachi Metals, Ltd.) with high magnetic permeability is employed for the SCT, a coil is combined with 50 turns and a single turn coil on the Finemet core with 10 mm thickness is for calibration. The magnetic core is also employed for the FCT, a single turn coil on the Finemet core with 5 mm thickness is for a coil (Fig. 2). Except for MEBT and DTL subsection, each current transformer has its inductive core outside of the vacuum chamber in order to avoid any outgas from the monitor parts. Therefore a small ceramic block is used for RF signal to be transmitted through (toward the inductive core) while a vacuum enclosure is tightly kept (Fig. 2).

The monitors have experienced many earthquakes, but there had been no damage of the monitors until the last biggest earthquake. The earthquake occurred at March 11, 2011 caused the damage of the SCT/FCT monitors. Damage is mainly observed at the part where the ceramics and metal parts are brazed [3].

Beam Profile Monitor (WSM: Wire Scanner Monitor)

In order to take the transverse matching, four WSMs are alocated in each matching section. Totally 36 WSMs are presently alocated in the linac and the beam transport line which connects with the downstream RCS. Four of 36 WSMs are presently working at the A0BT and all four will be replaced.

Tungsten wire with 50 μm diameter is connected on the ceramic frame for over 50MeV beam. But for the 3MeV section, 7 μm diameter carbon wire is employed for present WSMs. Because the energy is upgraded at the high energy part where the downstream from the future ACS section, tungsten wire should be exchanged to the wire with larger diameter. Based on the thermal calculation, we chose the 80 μm diameter for the beam detecting wire for the high energy part [4].

Beam Position Monitor (BPM)

Fourteen of 102 BPMs are presently working at the A0BT and these will be replaced and additional BPMs will be installed. Totally 48 BPMs will work in the future ACS section.

J-PARC Linac employs the stripline type beam position monitor. The diameter and the length depend on the aperture size and the accelerated energy.

Accuracy of the position is stably maintained at 0.1 mm using a test bench. Because new BPMs are also required the same accuracy, we designed the pickups and the body. Basic design is taken over from the present BPMs and in order to define the design of the pickup, two-dimensional simulation is conducted. After obtained the simulation results, we fabricate the prototype one for the measurement. A variety of the width of pickup are tried to match the corresponding impedance and finally decide the pickup and body design. Forty-eight BPMs are newly produced using the decided specification of the pickup and the body, all BPMs are calibrated at the test bench one by one. Calibration of the BPMs is just started. This work will be continued and they are installed in the summer of 2012. This calibration result is reported in the reference [5].

Beam Loss Monitor (BLM)

Gas proportional counter (present beam loss monitor) is a detector that makes use of the ionization effect of radioactive rays on an internal gas (Ar-CO_2). An E6876-600, Toshiba Electron Tubes & Devices Co., Ltd., is employed for the beam loss measurement, because it is easy to make and maintain, and it has an advantage by composing with only a passive components, that is a practically key issue for the detector under the radiation surrounding. Gas proportional counters are installed along the beam line. Because the gas proportional counters are sensitive to the background noise of X-ray emitted from the RF cavities, the combination of a gas proportional counter which has the neutron sensitivity and scintillation monitors would bring more accurate beam loss measurements with suppression of X-ray noise.

Plastic scintillation monitors with less X-ray sensitivity are installed to test the beam loss measurement. The photo-multiplier is Hamamatsu H3164-10 and the plastic scintillator is Saint-Gobain BC-408. Three scintillation beam loss monitors are tested in the beam line. We successfully measured clear beam loss signals with low noise and confirmed the high time resolution. Based on the beam loss simulation, we will optimize the detecting position [6].

Bunch Shape Monitor (BSM)

Bunch shape monitors (BSM) have been developed under corroboration with INR (Institute for Nuclear Research: Russia) for the measurement of the longitudinal distribution. Three BSMs will be installed in the beginning of ACS section in order to tune the longitudinal matching, because the acceleration frequency of 324 MHz until the end of SDTL is jumped to 972 MHz of ACS cavities. The design of BSMs was started since 2009 and the fabrication of three BSMs was started since 2010. Due to the earthquake, start of the beam operation will be postponed and the BSM development plan should be changed. In addition, these BSMs are originally designed to match between the SDTL exit and the upstream part of ACS. The small design changes would be required to be compatible for the future debuncher cavities, because the measurement of the longitudinal beam profile at the exit of the future debunchers might be required.

Delivery of Beam Diagnostic Devices

Along with the installation of the ACS, the beam diagnostic devices will be installed. A typical layout of the devices is indicated in Fig. 3. An ACS cavity has two symmetrical modules and also has a drift space between the modules. Two FCTs are located between the exit of the cavity and the entrance of the next cavity to measure the beam energy at the point without any acceleration devices. The position of the BLM is temporary defined. This will be optimized by the simulation and the vilification tests.

SUMMARY

New beam diagnostic devices for the ACS cavities are introduced. Most of all devices are based on the design of present devices and the basic concepts are taken over. Because the temperature loading for the beam destructive monitors and the residual activity is getting serious along with the energy increasing, minor development should be needed. Beam loss detecting system is presently under development. This R&D is introduced in another reference [6]. Procedure of the design and fabrication of BPM is briefly introduced, but the detail is referred [5].

Development of the non-destructive profile monitor is taken into consideration. Prototype profile monitor using a laser technology could successfully detect the transverse beam profile at the test bench [7]. The technology can be continued to the J-PARC linac.

Finally, J-PARC had the damage by the biggest earthquake occurred at Tohoku. Unfortunately, a part of monitors installed at the beam line had damaged, but the recovery is progressing uneventfully.

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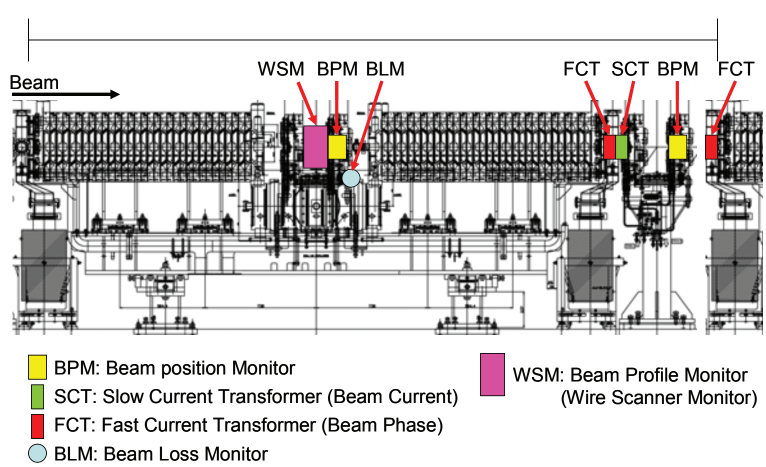

Figure 3: Typical layout of the beam diagnostic devices between the ACS cavities.