OPERATIONAL PERFORMANCE OF WIRE SCANNER MONITOR IN J-PARC LINAC

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Abstract

A wire scanner monitor (WSM) is one of essential measurement devices for beam commissioning of current accelerators. J-PARC Linac employs a number of WSMs for transverse beam profile. The transverse matching is performed based on the measured beam width. In addition, we have tried to measure beam profile. In this paper, we describe the experimental results obtained in a beam study to characterize the operational performance of the WSMs.

INTRODUCTION

Thin metallic or carbon wire which is inserted in an accelerated beam can capture electrons from ion beams. Because the signal from captured electrons proportionally depends on the number of ions, many small steps of the wire position can bring the beam profile.

J-PARC proposed the scheme for transverse tuning to suppress beam halo generation and resulting uncontrolled beam loss using wire scanner monitors (WSM) and four-strip-line beam position monitors which were installed arbitrarily in the matching sections in linac [1]. A WSM is one of essential measurement devices for beam commissioning. This paper describes the specifications of WSM installed in J-PARC linac and its measurement result. Finally, dynamic range and related performances are discussed.

SPECIFICATION OF WIRE SCANNER MONITOR IN J-PARC LINAC

A system of WSM has a beam measurement head with wires, bias voltage supplier, stepping motor unit and electrical circuits which treats signals and the control system. Figure 1 indicates the installed WSM and its head.

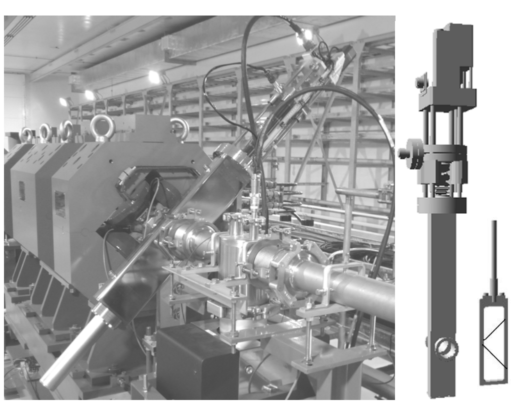

Figure 1: Whole view, head and wire frame.

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Because the wires are connected on a frame with 45°, if the frame is installed with 45° against the horizontal axis, both horizontal and vertical profiles can be measured in a stroke.

Positions of Wire Scanner Monitors in Linac

J-PARC linac has an ion source, RFQ, DTL, SDTL, A0BT (beam transport from the beginning of ACS to 0 degree beam dump) and L3BT (beam transport from linac to following 3GeV rapid cycling synchrotron). In order to take the transverse matching, four WSMs are placed. Although three WSMs are sufficient for matching, redundant ones are prepared to improve the tuning accuracy statistically. Totally 36 WSMs are placed in linac and L3BT.

Wire, Frame and Head

Frame of wire head is made of aluminium oxide ceramics to prevent any noise from secondary electron capture at metallic frame. Tungsten wire with 30 um diameter is connected on the ceramic frame for over 50MeV beam. But for the 3MeV section, 7 um diameter carbon wire is employed because of the thermal problem [2]. In addition, WSMs installed in the beam dump and L3BT section, carbon plates with 2.0 mm thickness are installed and they have especially been used to measure beam size (Figure 2). Because of wide detecting surface of the carbon plate, it is considered to be sensitive for small signals.

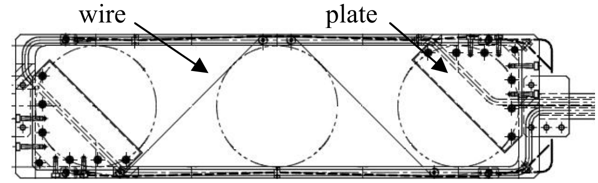

Figure 2: Frame of Wire Scanner Monitor. Flame, wire and plate are made of ceramics, tungsten and carbon respectively.

Bias Voltage Supply

When the negative ion beam passes through the wire, electrons are left inside the wire. In the case of supplying a positive bias for wire, it suppresses the emission of secondary electrons. On the other hand, in the case of supplying a negative bias, the emission of secondary electrons is increased and counter electrical current is not negligible to measure. In the beam test, when the beam profile was measured in the range from -240 V to +240V, proper bias was 20 - 60 V [3]. If no bias was supplied, almost same profiles were obtained. But in this case, edge part of the beam was underestimated, when it was compared with that taken with the bias as +20V.

Stepping Motor Unit

Commercial products are employed for the stepping motor unit. This unit can operate the wire head by 0.1 mm step and it is remotely controlled from the ground floor.

Electrical Circuit

Signals pass through the pre-amplifier. Because this amplifier can extend the signal 10 times and 100 times, small signals such as the beam tail and so on are possibly recognized. WE7118 (Yokogawa Electric Co.) is used to digitalize the measured signal. VME 1314 is used to control the pre-amplifier and bias voltage supplier.

BEAM PROFILE MEASUREMENT

Beam profiles and background are measured using the accelerated beams with 181 MeV as beam energy, 15 mA as peak beam current, 500 us as pulse length, chopped or no-chopped beam at A0BT section and 0 degree beam dump (0BD).

Beam Profile at A0BT Section

Beam profile is taken by WSM installed in ACS02 which is a downstream part of SDTL section. A vertical profile of no chopped beam is indicated in Figure 3. Since the data are taken normally, 10 times and 100 times enlarged, all data are normalized using gain coefficient and their maximum value. And the data are taken by the averaged value using 5 signals. In Figure 3, in the case of gain 10 and 100, because the signal heights are beyond the range of electrical circuits, only the beam tails can be measured. Because the beam profiles can be fitted using the Gaussian formula, beam size and emittance can be calculated based on the measured values.

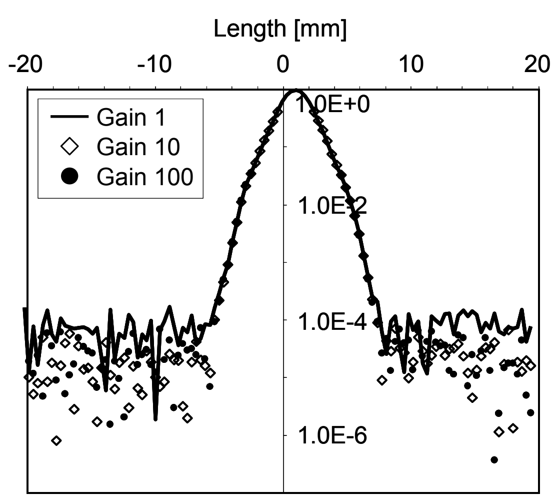

Figure 3: Vertical Beam Profile at ACS02.

Background Noise of WSM

Background noise is taken at ACS02. This result can be compared with the beam profile taken at same WSM. In Figure 4, background noise is described. When the data are taken, no beam operation is conducted using the insertion of Faraday cup. Both horizontal and vertical characters are almost same and they are under 1.0e-4. When all data are averaged using the least-square method, interception of horizontal data is 1.65e-5 and that of vertical is 1.67e-5. Compared with Figure 3, beam tail appears also below 1.0e-4. This result suggests that the dynamic range of WSM is above 1.0e+4 and WSM can measure small signals up to the range of 1.0e-4.

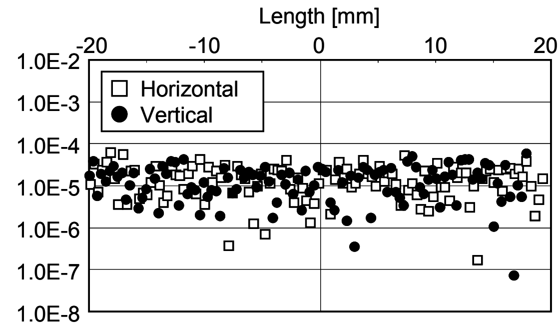

Figure 4: Background noise at ACS02 taken at no beam operation.

Beam Profile at 0 Degree Beam Dump (0BD)

Because it is thought that the carbon plate is more sensitive than tungsten wire to measure the small signals, WSM with both tungsten wire and carbon plate installed in the 0BD is employed for comparison. No chopped beam with the pulse length as 100 us is measured by the tungsten wire. Because the carbon plate is too sensitive to measure no chopped beam profile, duty of the beam is decreased. To prevent the thermal loading, chopped pulse with 90 ns and 180 ns are employed to measure using a carbon plate. These are corresponding to about 1/1000 and 1/500 respectively of no chopped beam (100us).

Because the carbon plates are set in parallel as Figure 2 on the frame of WSM in 0BD, one plate can detect the half of the vertical beam profile and another can detect another half. In this measurement, in order to observe the peak by one plate, beam is shifted upper side using a steering magnet. When the chopped beams with 90 ns and 180 ns pulse length are measured, gain coefficient is set as 100 and 5 signals are averaged to be indicated in the figure.

Results are described in Figure 5. Black line is no chopped beam profile taken by tungsten wire. In Figure 3, tungsten wire can obtain the range as up to 1.0e-3. But the wire can not detect the chopped beam with both 90 ns and 180 ns pulse length in this case. Peaks appear around 8.0 mm and beam tails are observed around 20.0 mm. Due to defocusing just before 0BD to suppress excess thermal loading, the vertical beam size at 0BD is broader than that at ACS02. Even the peak of no chopped beam in 0BD, signal height reaches only half or less compared with that in ACS02 because of the broad profile in 0BD.

Red and blue lines are chopped beam with 90 ns and 180 ns pulse length respectively and the profiles taken by carbon plate are indicated from 0 to 30 mm perpendicular upper side. Since the data are averaged with 5 signals, remarkable noise on the main signal is observed. It is thought that even the quite small noise, the plate can sensitively detect. Because of no change of the detail beam structure between chopped and no-chopped beam, no difference is observed in the profiles.

When tails of no-chopped and chopped beam profiles are compared, the tails of chopped beam are observed higher than that of no-chopped beam. It is thought that small signals are sensitively detected by the carbon plate and it is suggested that there are some particles which can not be detected by tungsten wire.

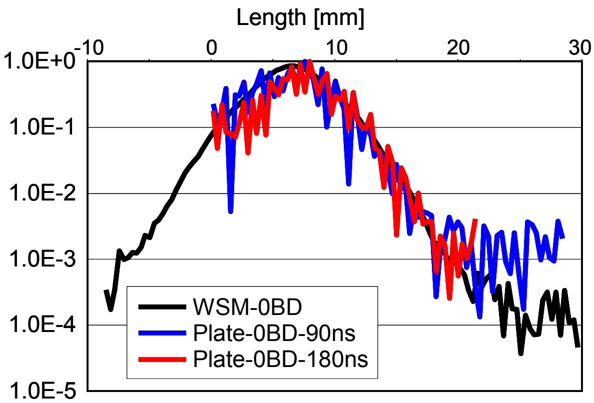

Figure 5: Chopped and No-chopped Vertical Beam Profile Taken by Carbon Plate at 0 degree Beam Dump (0BD). Black: Beam Profile Taken by Tungsten Wire at 0BD, Blue: Beam Profile of Chopped Beam with 90ns Taken by Carbon Plate, Red: Beam Profile of Chopped Beam with 180ns Taken by Carbon Plate

Background Noise of Carbon Plate

Background noise is taken at 0BD using tungsten wire and carbon plate. These results can be compared with the beam profile taken at same plate and background noise taken by tungsten wire. When these data are taken, same way of taking the data of Figure 4 is used. When the data are averaged using the least-square method, interception of wire data is 8.7e-5 and plate data is 1.1e-4 respectively. These are slightly worth than the data taken at ACS02, because of noisy point which is affected by the radio activity from beam dump and refraction of beam by beam dump. In addition, it is thought that because the neutral hydrogen atoms (H0) generated along with the beam transport line reach and interact with the wire and plate, they might appear as the small signal.

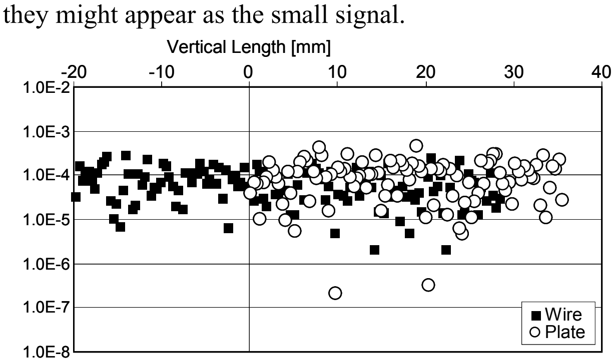

Figure 6: Background Noise at 0BD Taken at No Beam Operation Using Tungsten Wire (Wire) and Carbon Plate (Plate).

Future Study

In this study, it is confirmed that the dynamic range of WSM is over 1.0e+4 especially for tungsten wire. Because the carbon plate can detect less than 1/1000 signal, if the beam has the beam halo with the signal height less than 1/1000 to 1/10000 compared with the main signal, it might be measured using a combination with tungsten wire and carbon plate.

The H0 particles which are generated by the interaction with residual gas and negative hydrogen particles (H- ions) are considered as the one of the biggest cause of beam loss in beam transport line. If the small signal obtained from H0 particles would be measured using the plate, it might lead the development for suppression of beam loss.

DISCUSSION

Dynamic range of the WSMs employed in J-PARC linac reaches over 1.0e+4, compared with Figure 3 and 4. This indicates that the small signal of over 0.1% can be measured. But, in the operation, no recrementitious contents are observed in the measured signal.

Although the 1/500 and 1/1000 chopped pulses cannot be measured by the tungsten wire, carbon plate is enough sensitive to measure these chopped pulses. Because the carbon plate is sensitive, it receives the influence of the noise and is obstructed even the small noise. In the computer software, signals can be integrated, if we employ this function, much smaller signals, for example the signal from H0, would be measured.

SUMMARY

The dynamic range of the WSMs employed in J-PARC linac is confirmed. This performance is enough high to tune for linac and the possibilities for measurement of beam halo and so on which generates small signals are confirmed because of high sensitivity of carbon plate.

REFERENCES

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