CONFIGURATION OF BEAM PROFILE MONITORS FOR ENERGY UPGRADED J-PARC LINAC

H. Sako#, T. Morishita, S. Sato, Japan Atomic Energy Agency, Tokai, Japan
M. Ikegami, High Energy Accelerator Research Organization, Tsukuba, Japan

Abstract

Wire Scanner Monitors (WSMs) and Bunch Shape Monitors (BSMs) are going to be installed in the entrance part of ACS (Annular Coupled Structure) section at the energy upgraded J-PARC linac. WSMs are used to measure transverse beam profiles, and BSMs are used to measure longitudinal beam profiles. Both are used to match beams from upstream SDTL (Separated-type Drift Tube Linac) accelerator cavities to ACS. Only a BSM will be installed in the beggining and the best location for the BSM has been chosen through studies of the tuning schemes.

INTRODUCTION

Currently J-PARC linac is being operated at 181 MeV. The linac is going to be upgraded to increase energy to 300-400 MeV with addition of ACS cavities in summer of 2010. This paper concentrates on designed configuration of transverse and longitudinal beam profiles monitors at the matching section MEBT2 (Medium Energy Beam Transport 2) just before ACS section through studies of the matching scheme.

Three WSMs for transverse profile measurements will be installed in the ACS section which are essentially same as those currently installed there. A WSM scanner has a horizontal wire and a vertical wire of gold-plated tungsten with 30µm thickness [1]. Induced current signal of electrons from H^- beams are detected. The wire frame moves in 45-degree direction in the horizontal-vertical plane with a stepping motor. Transverse matching has been performed in the linac with 4 WSMs at periodic lattice positions and upstream quadruple magnets in each matching section at SDTL, ACS, and 3 L3BT sections (Linac-to-3 GeV RCS Beam Transport) where mismatch factors of less than 10 % have been achieved [2]. In the upgraded ACS, similar matching scheme will be taken.

In the current linac, there is no device for longitudinal profile measurements. Longitudinal mismatch of beam from RFQ to the DTL in MEBT1 has been recently found to be related to emittance growth in DTL. Similarly longitudinal matching at MEBT2 should be very important in order to suppress emittance growth and halo formation. For longitudinal profile measurements, we are going to adopt a type of BSM developed at SNS, CERN, and DESY [3]. BSM uses secondary electrons produced by interaction of beam with a wire target. The electrons pass through double slits perpendicularly to the beam line. Parallel electrode plates are set in the electron path onto which RF voltages are supplied. The parallel plates rotate the time distribution of electrons by 90 degrees to the horizontal distribution and electrostatic lens focuses it onto the second slit. Only electrons in a narrow phase range of the RF pulses can pass through the second slit. By scanning the phase, a longitudinal profile is obtained. Electrons exits the second slight are then bent in magnet field and finally detected by an electron detector. Ideally, simultaneous measurements of longitudinal profile widths with 3 BSMs determine longitudinal beam parameters and matching can be done by equating the profile widths by corrections of amplitudes of Bunchers 1 and 2 at MEBT2. However, due to cost limitation, only one BSM will be installed in the beginning. With single BSM, several measurements of profiles with scanning amplitudes of Bunchers 1 and 2 are required.

OPTIMIZATION OF BSM LOCATION

For WSMs and BSMs, 6 candidate positions (ACS01A-ACS03B) are allocated as shown in magenta rectangles in Fig. 1. ACS section consists of 42 ACS cavity tanks where the beam is accelerated from 190 to 400 MeV. A pair of tanks (named upstream "A" tank and downstream "B" tank) are connected by a bridge tank and driven with a Klystron [4].

A pair of tanks corresponds to a focusing period, whose

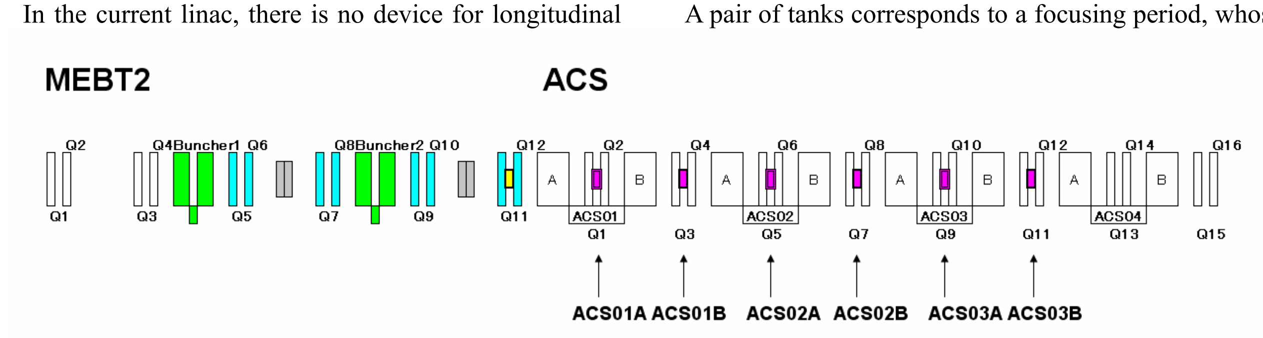

Figure 1: A schematic layout of MEBT2 and the beginning of ACS. The geometry is not to scale. Magenta rectangles show candidate positions for WSMs and BSMs.

#sako.hiroyuki@jaea.go.jp

horizontal, vertical, and longitudinal phase advances of about 41, 43, and 40 degrees respectively are good for beam matching. Therefore, either 3 WSMs or 3 BSMs (including two more future ones) should be placed at the bridge tanks (ACS01A, ACS02A, ACS03A), and the others between pairs of tanks (ACS01B, ACS02B, ACS03B).

There is no difference whether the 3 WSMs are placed at the bridge tanks or between the pairs of tanks. The location of the first BSM should be optimized for highest matching power and then the rest positions should be assigned for other BSMs and WSMs.

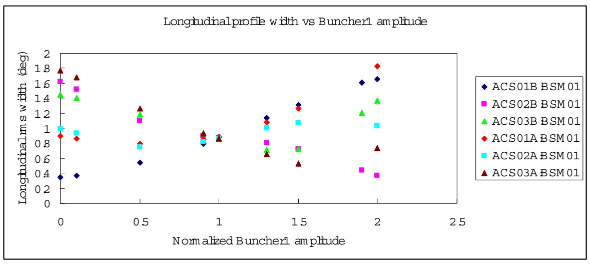

Figure 2: Longitudinal profile width in degrees of 324 MHz as a function of Buncher 1 amplitude.

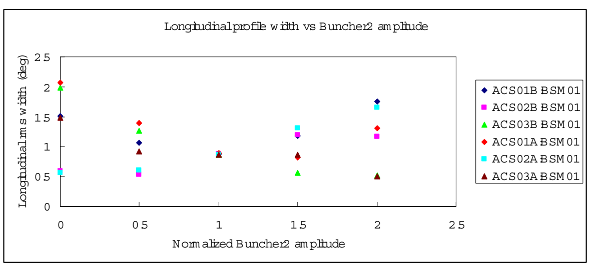

Figure 3: Longitudinal profile width in degrees of 324 MHz as a function of Buncher 2 amplitude.

We decide the optimum location of the BSM with dependence of the longitudinal profile on amplitudes of Bunchers 1 and 2 as shown in Figs. 2 and 3 calculated by the XAL model [5]. The phase unit is defined at 324 MHz of micro bunches. In case the BSM is measured at 972 MHz of ACS RF sources, phases should be scaled by 3. At the design amplitudes, all of the profile widths are about 1 degree, because of longitudinal matching. The amplitudes of Bunchers 1 and 2 are normalized to the designed values of in 0.237 MV and 0.327 MV in ETL, respectively. At most of the BSM locations, widths vary monotonically in amplitude ranges of 0-1.5. As shown later, non-monotonic dependence in both Bunchers 1 and 2 is suitable to determine precisely longitudinal beam parameters (α_z, β_z, ε_z). Only ACS01A and ACS02A have non-monotonic dependence both on the 2 bunchers. ACS01A is better because phase variations are larger. Therefore, ACS01A is the best location for the BSM and two more bridge tank positions (ACS02A and ACS03A) are reserved for future BSMs. WSMs are then placed between pairs of tanks (ACS01B, ACS02B, and ACS03B).

To examine validity of the XAL model for longitudinal dynamics, beam profiles are calculated with IMPACT particle-in-cell model. Fig. 4 shows comparison of longitudinal profiles at ACS01A position with different Buncher 1 amplitudes. The widths at each setting are consistent with the XAL calculations in Fig. 2.

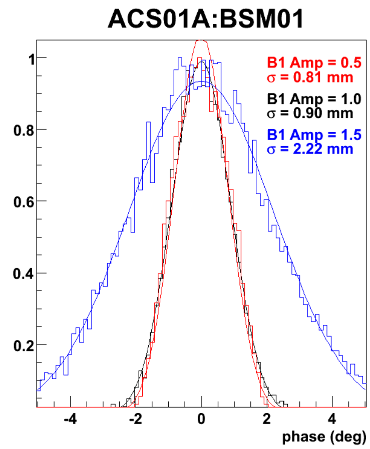

Figure 4: Longitudinal profiles at ACS01A calculated by IMPACT for Buncher 1 amplitudes of 50% (red), 100% (black) and 150% (blue) of the design amplitude.

LONGITUDINAL MATCHING SCHEME

Three longitudinal matching methods are compared with 3 BSMs (Scheme A), with 1 BSM (Scheme B), and with 1 BSM and 3 WSMs (Scheme C). The common matching procedure is as follows.

1. Fit of (α_z, β_z, ε_z) at an upstream point is done. Fit methods are different for the 3 methods.
2. With the fit parameters, amplitudes of Bunchers 1 and 2 and 4 quadruple magnets are corrected, so that transverse and longitudinal Twiss parameters (α_x, α_y, α_z, β_x, β_y, β_z) at the 3 periodic positions agree. Transverse beam parameters are supposed to be determined by WSMs beforehand. Since longitudinal mismatch causes also transverse mismatch, the simultaneous longitudinal and transverse matching is required.

Results for these matching procedures are shown in Fig. 7 for Scheme C. The above calculations are done in Newton-Raphson method with a response matrix calculated by the model. For realistic simulation, random errors in "measured" profile widths are given. The longitudinal and transverse resolutions are estimated to be about 5 % and 0.03 mm from measurements in the first paper in [3], and measured widths in the current linac. To examine robustness of the fit, initial beam parameters are shifted from the true values by 20-30% for α_z, ε_z, and 200% for β_z.

Table 1: Fit results of longitudinal beam parameters in TRACE3D units. Values in bracket show the true beam parameters in the model

Configuration	α_z	β_z(deg/keV)	ε_z(πdeg keV)
3 BSMs	-0.456 (-0.444)	0.0174 (0.0178)	465 (484)
1 BSM(ACS01A)	-0.395 (-0.444)	0.0177 (0.0178)	467 (484)
1 BSM(ACS02B)	-0.835 (-0.444)	0.0472 (0.0178)	325 (484)
1BSM+3WSMs	-0.551 (-0.533)	0.0521 (0.0534)	612 (629)

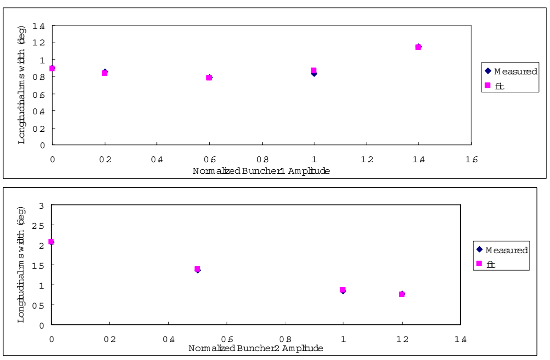

Figure 5: "Measured" (blue) and fitted (magenta) longitudinal widths as a function of amplitudes of Bunchers 1 (top) and 2 (bottom) in Scheme B for ACS01A.

A) Matching with 3 BSM

Although only 1 BSM will be installed initially, the ideal 3 BSM scheme is studied as a baseline. The fit to profile widths at 3 BSMs is done at 3 Bunchers 1 and 2 amplitude settings. A good fit is obtained as in Table 1.

B) Matching with 1 BSM

With 1 BSM, longitudinal profile widths are measured at 5 amplitude settings of Buncher 1 and 4 amplitude settings of Buncher 2. As expected, ACS01A with non-monotonic dependence on amplitudes has a better fit result than ACS02B as shown in Table 1. For ACS01A, good agreements between measured (simulated) and fitted phase widths are shown in Fig. 5.

C) Matching with 1 BSM and 3 WSMs

Scheme B works for designed beam parameters, but does not work well when beam parameters in the model (α_z, β_z, ε_z) = (-0.533, 0.0534, 629) are deviated significantly from the design values (-0.444, 0.0178, 484), where non-monotonic dependence disappears. More robust method is desirable. Transverse envelopes are coupled to the longitudinal envelope via space charge. Measurements of horizontal and vertical profile widths by 3 WSMs with good resolutions improve fit precision as shown in Table 1, and Figs. 6 and 7. Matching correction results are shown in Fig. 7 with the two bunchers and 4 quadruple doublets in MEBT2 (cyan rectangles in Fig. 1).

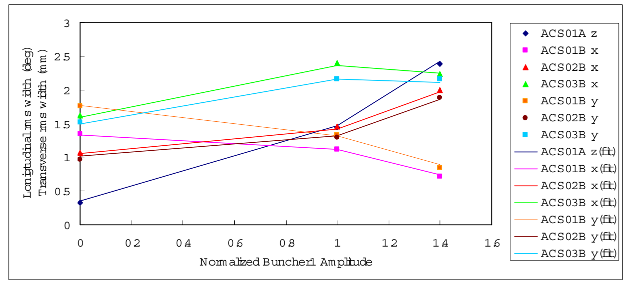

Figure 6: "Measured" (symbols) and fitted (lines) longitudinal and transverse profile widths in Scheme C for ACS01A.

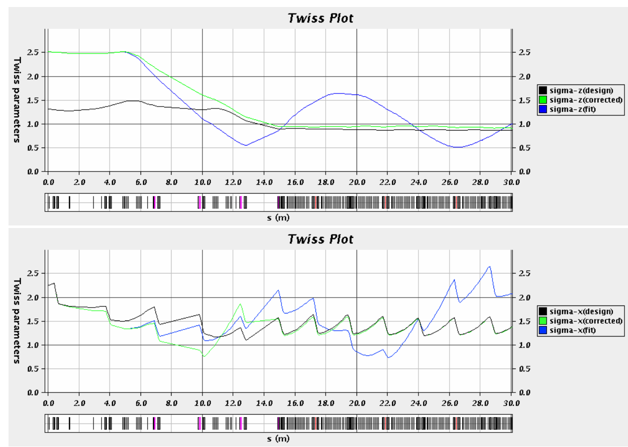

Figure 7: Design (black), fitted (green), and matched (blue) longitudinal (top) and horizontal (bottom) envelopes from MEBT2 to the entrance of ACS with Scheme C.

SUMMARY

ACS01A position is the best candidate for the BSM. Longitudinal profile measurements with 1 BSM combined with transverse profile measurements with 3 WSMs in several amplitudes of Bunchers 1 and 2 give best precision of estimating longitudinal beam parameters, and best longitudinal matching power.

REFERENCES

[1] H. Akikawa, et al, LINAC06, Knoxville, USA, TUP021, p.293.
[2] H. Sako, et al, LINAC08, Victoria, Canada, MOP078.
[3] A. V. Feschenko, et al, PAC07, Albuquerque, USA, THOAAB01, p.2697; A. Feschenko, et al, LINAC04, Luebeck, Germany, TUP63, p.408; A. Feschenko, et al, LINAC96, Geneva, Switzerland, p.196.
[4] H. Ao, et al, LINAC08, Victoria, Canada, THP056.
[5] J. Galambos, et al, ICALEPCS 2003, Gyeongju, Korea; C. K. Allen, et al, MOPAN029, PAC07, Albuquerque, USA.