BEAM INSTRUMENTATION USING BPM SYSTEM OF THE SPring-8 LINAC

K. Yanagida*, T. Asaka, H. Dewa, H. Hanaki, T. Kobayashi,
A. Mizuno, S. Suzuki, T. Taniuchi, and H. Tomizawa
Japan Synchrotron Radiation Research Institute, Mikazuki, Hyogo, 679-5198, Japan

Abstract

Beam position monitors were installed in a SPring-8 linac's dispersive sections, and the entire beam trajectory could be measured along the linac. A fast and synchronized accumulating database system started, that accumulated beam position data from all forty-seven BPMs simultaneously at 10-pps operation of the linac. Feedback control of steering magnets and an energy compression system for beam position stabilization were also successfully examined.

INTRODUCTION

In a SPring-8 linac a beam position monitor (BPM) system has been developed and installed for several years. BPMs for the non-dispersive section were installed in August 2000. The non-dispersive section BPM is an electrostatic stripline monitor whose aperture is a circule of ϕ32 mm [1]. Its stripline length is 27 mm, and the detection frequency is 2856 MHz. Signal processors were installed in March 2001 whose basic processes are filtering by a band pass filter, detection by a logarithmic detector (AD8313), and analog-to-digital conversion [2]. At this time a simple data acquisition system from signal processors to an operator console was started to measure the trajectory of the non-dispersive section.

In August 2003 BPMs were installed in the dispersive section, and an entire beam trajectory could be measured along the linac. Finally, in November 2003 a fast and synchronized accumulating database system was started. After completion of the BPM system, the next task is to prepare beam instrumentation using the BPM system. The final goal is automatic tuning or operation of the linac. First beam position and energy feedback programs were developed, examined, and designed for long term stabilization in a top-up operation of the SPring-8 and the NewSUBARU storage rings [3] [4]. An examination of the programs was successfully carried out in July 2004, and they will be implemented from September 2004.

INSTALLATION OF DISPERSIVE SECTION BPM

The structure of the dispersive section BPM is the same as the non-dispersive section BPM, except that the cross-sectional aperture is larger. Its aperture is 62×30 mm ellipse as shown in Fig. 1 that was carefully designed to block RF noises around the detection frequency (2856 MHz), generated outside of BPM. Almost all BPMs were installed into quadrupole magnets. Figure 2 shows the location where the dispersive section BPMs were installed.

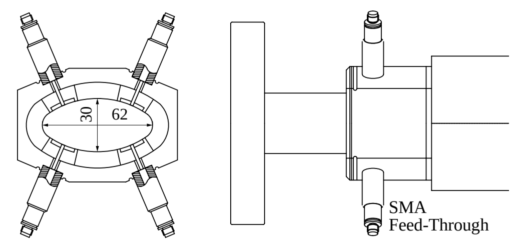

Figure 1: Schematic drawing of dispersive section BPM.

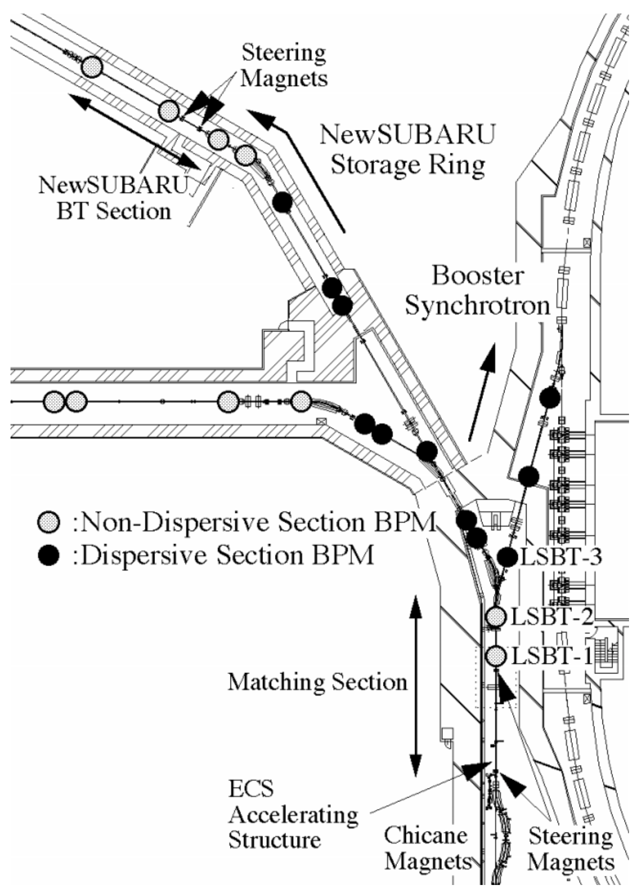

Figure 2: Location of installed dispersive section BPMs.

* ken@spring8.or.jp

DATA ACCUMULATION DATABASE

The database system is designed to collect all beam position data from forty-seven BPMs that synchronize every beam shot. The collected data are accumulated automatically into the database. The accumulated data can be always extracted from the database for beam diagnosis.

The maximum beam repetition of the linac is originally 60 pps. Therefore a database system was required to process data acquisition even at 60 pps operation of the linac. Software framework with a shared memory network has been developed to satisfy this requirement [5]. The most important thing is that all accumulated data must be completely synchronized, even if an acquisition error occurs.

At present the data acquisition rate into the database is not fast enough to collect all the data at 60 pps operation of the linac, but it is sufficiently fast at 10 pps operation. The beam repetition of the linac has now been reduced to less than 10 pps to prolong life of linac's components, e.g. thylatrons and klystrons, and to reduce electrical power consumption. Thus a serious acquisition error has not occurred during usual operations.

Figure 3 shows processed data and variations of horizontal beam trajectories along the linac. Trajectory variation was induced by a kicking perturbation imposed at the injector section, which is located upstream of the linac where beam energy is ∼60 MeV. Trajectories are expressed as the differences from the reference trajectory at 14:00:48.32. They clearly exhibit betatron oscillations along the linac.

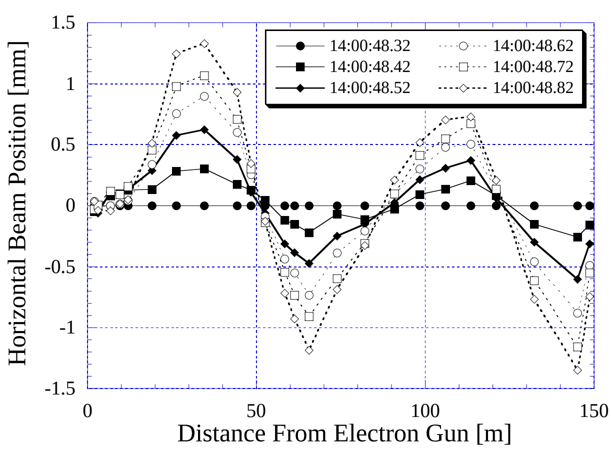

Figure 3: Horizontal beam trajectories along the linac. Trajectories are expressed as differences from reference trajectory at 14:00:48.32.

BEAM POSITION FEEDBACK

A beam trajectory of the linac sometimes varies based on a room temperature. Trajectory variation affects beam injection to the booster synchrotron or the NewSUBARU storage ring. Therefore, beam trajectory must be as stable as possible. A beam position feedback control program was developed in order to stabilize the beam positions at the following three sections.

In the linac there is at least one steering magnet for one BPM so that the steering magnets can correct beam position at each BPM. However, beam angle cannot be simultaneously corrected because one steering magnet can either correct beam position or beam angle. There are only three sections where both the position and angle can be corrected. Each of them was designed with double steering magnets in their drift space upstream of the two BPMs. The three sections are the injector section, a matching section and a NewSUBARU beam transport (BT) section.

The matching section is located upstream of the switching magnet for the booster synchrotron or NewSUBARU storage ring as shown in Fig. 2. The NewSUBARU BT section is located downstream of the second bending magnet toward the New SUBARU storage ring (see Fig. 2).

The position feedback control scheme is quite simple. The program consists of three feedback loops corresponding to the injector, matching, and NewSUBARU BT sections. The program calculates the excitation current of the steering magnets by using of measured beam positions. The program adjusts the excitation current of the steering magnets to keep the beam position within a tolerance. Each feedback loop works locally and independently in each section. Therefore a trajectory change due to an upstream feedback loop may interfere with the correction of the downstream feedback loop. Weight factors are introduced for each feedback loop to avoid serious interference expressed as correction ratios for one feedback loop. The weight of the upstream feedback loop is small, and the weight of the downstream feedback loop is large. The weight of the injector, matching, and NewSUBARU BT sections are 12.5%, 25% and 50%, respectively.

Figure 4 is an example of the horizontal position feedback examination. The tolerance of the position feedback control was $\pm 30\ \mu$m. All the sections - injector, matching, and NewSUBARU BT - work together. A kicking perturbation was created by a steering magnet located upstream of the injector section. A variation of the magnet excitation current gave the beam positions large initial displacement; they finally converged within the tolerance. The feedback interference resulted in a slight overshooting of the beam positions observed in the matching and NewSUBARU BT sections.

BEAM ENERGY FEEDBACK

The linac has a beam energy compression system (ECS) that compensates for or stabilizes beam energy [6]. However, small beam energy drift at the downstream of the ECS was observed when the room temperature changed. This unwanted energy drift slightly affected the injection efficiency of the booster synchrotron and the NewSUBARU storage ring. For additional stabilization of the beam energy or injection efficiency, beam energy feedback control was developed and examined.

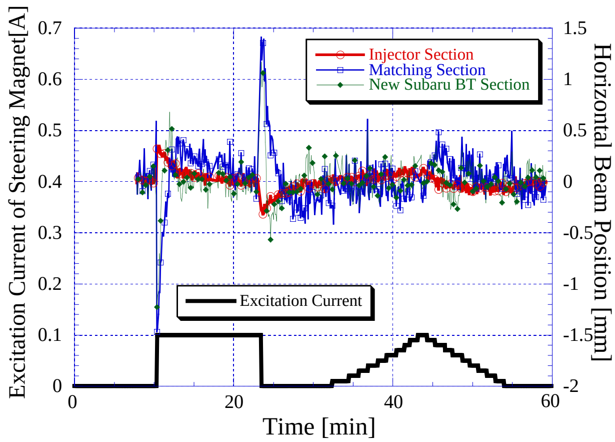

Figure 4: Example of horizontal position feedback control.

The energy feedback scheme is also quite simple. The horizontal beam positions in the matching section are corrected within double tolerance of the position feedback control, and an energy feedback program adjusts the ECS phase shifter to keep the beam position within the tolerance of the energy feedback control in the downstream dispersive section.

The energy feedback program was examined in July 2004. The tolerances of the position and energy feedback control were ± 30 μm and ± 0.5 mm ($\sim \pm 0.05\%$ of beam energy), respectively. A perturbation was created by varying RF power and phase of ECS klystron that feeds RF power to the ECS accelerating structure: The actual varied parameter was the pulse forming network (PFN) voltage of the modulator for the ECS klystron. A 1 kV variation of the PFN voltage corresponds to a phase compensation of more than 10° for ECS.

Figure 5 shows the variation of PFN voltage as a perturbation and the phase set values given by the program. Figure 6 is the behavior of the horizontal beam position. First, beam positions of LSBT-1 and LSBT-2 (see Fig. 2) were corrected by the position feedback program. Next, the beam position at LSBT-3 was automatically corrected within the tolerance.

CONCLUSION

A BPM system of the SPring-8 linac was completed. The database system is regularly collecting and accumulating beam position data. These accumulated data are always available or can be extracted from the database system. The application programs of beam position and energy feedback control were successfully examined. The beam positions displaced by a kicking perturbation eventually converged. These programs will be implemented from September 2004.

Remaining tasks includes tuning the database system faster, tuning the feedback program more reliably, and developing other application programs such as automatic tun-

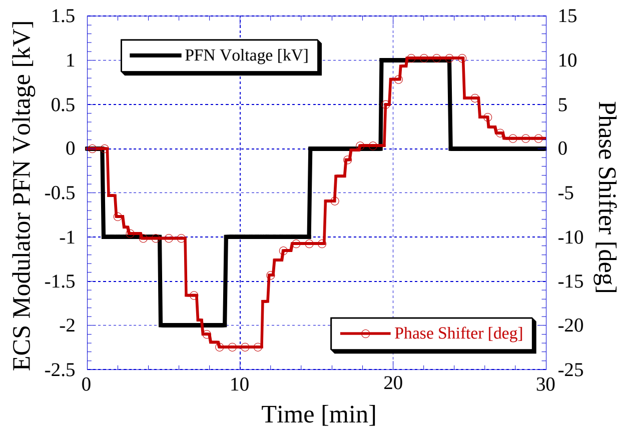

Figure 5: ECS PFN voltage and phase of ECS phase shifter on beam energy feedback examination.

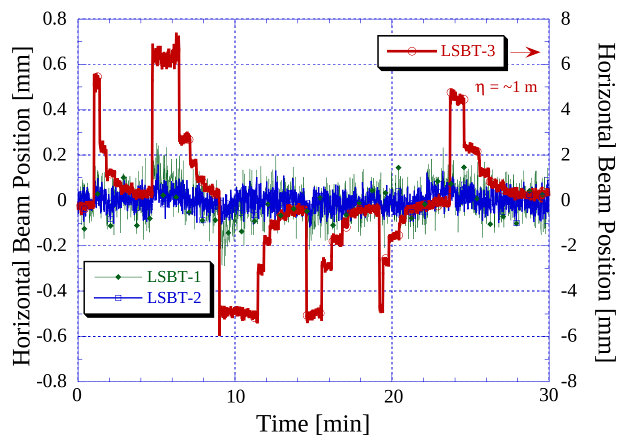

Figure 6: Horizontal beam positions in non-dispersive section (LSBT-1 and LSBT-2) and in dispersive section (LSBT-3) on beam energy feedback examination.

ing or operation of the linac.

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