STATUS OF BEAM DIAGNOSTIC SYSTEMS FOR THE PEFP*

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Abstract

A proton linear accelerator is currently the construction at the KAERI (Korea Atomic Research Institute) to the PEFP (Proton Engineering Frontier Project) in Korea. We are accomplished the technique development of beam diagnostic system to be currently the construction. We treat beam diagnostics for the high power proton linear accelerator. Prototype beam position & phase monitor (BPPM) electronics was made and tested successfully in one of the beam diagnostic systems. The beam position monitor pickup electrode is a capacitive type (electrostatic type) which has a button form. Button form electrode, in common use around electron synchrotrons and storage rings, are a variant of the electrode with small button form (e.g., sub mm diameter). However, we are designed button form electrode to measure beam position of proton beam. The BCM (Beam Current Monitor) is developed Tuned CT (Current Transformer) for collaborate with Bergoz Instruments. This paper describes the status of beam diagnostic systems for the PEFP.

INTRODUCTION

Front-ends of modern HPPAs (High-Power Proton Accelerators), such as RFQs and DTLs are generally complex and have tight installation spaces. Space of the diagnostics systems is become very narrow space, it is difficult to the designer of the device. Therefore compact beam-diagnostic devices are highly demanding for the HPPAs. Refer to Table 1 for major beam parameters of the PEFP accelerator. PUs (Pick-Ups) for beam-position monitors of proton machines have been usually striplines because of their high sensitivity for weak-intensity proton beams. Another kind of PUs, buttons are simple and reliable but their applications to proton machines have been limited because of their insufficient sensitivity. Modern HPPAs such as the PEFP linac are designed to have very high beam intensities, so that even the buttons could generate enough signals for precision beam position measurements. In this thesis, we have chosen the button-type PU for use in the PEFP accelerator. One of the disadvantages of the buttons is that, it is difficult to predict the PU sensitivity using analytic formulas 1,2. In fact, the PU sensitivity for low-beta beams can not be practically determined even by experimental methods, due to the difficulty of simulating electromagnetic fields of the low-beta beams. In this regard, we have decided to utilize the computer code for determining the sensitivity of the button-type PU. We have chosen the MAGIC code which is a kind of the PIC (Particle-In-Cell) code and can treat the particle and electromagnetic system in the full three dimensional manner. The BPPM electronics has been developed by the Bergoz Instrumentation in accordance to our specifications. It is a full-analog processor that is based on the Bergoz Log-Ratio BPM electronics.

Table 1: Beam Parameters of PEFP/KAERI Accelerator.

	Operation Mode (Pulse)	**note**
Beam Energy	3 - 20 - 100 MeV	
β	0.08 – 0.20 – 0.43	BPM operation region
γ	1.003 – 1.021 - 1.107	
Beam Current	20 mA	Peak value of macro pulse
Macro Pulse Width	0.1 - 1 ms	
Bunch Length (FWAB)	200 ps	PARMILA simulation result

COMPACT PICK-UP WITH BUTTON

We already designed and fabricated the button-type PUs (Pick-Ups) with N-type RF connectors about the HPPA of the PEFP [1], [2], but it is not appropriated the systems with narrow space. So we have changed the design with SMA feed-through, see Fig. 2.

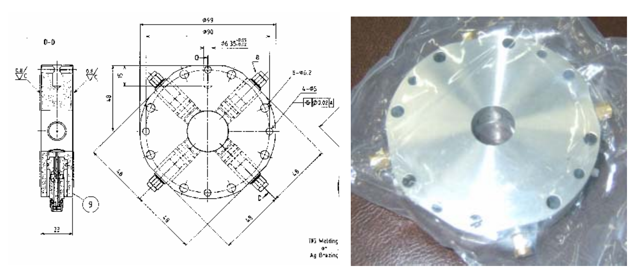

Figure 1: Fabrication of four-button-type PU with SMA feedthrough. Left figure: Fabrication drawing and Right Figure: fabricated BPM PU. Button inside beam pipe in right side figure indicates with capacitive electrode proton beam. Diameter of beam pipe is 20 mm and diameter of capacitive button is 12 mm.

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BPPM ELECTRONISCS

BPPM is designed with the resolution and stability of 50 ㎛ position and ± 0.1° phase and with the operation frequency of 350 MHz. Other specifications of the BPPM refer to the Table 2.

Table 2: Specifications for the BPPM electronics.

	Position	Phase
Operation frequency	350 MHz	←
Minimum Signal	-57.5 dBm @ 100 MeV	←
Powers	-4.56 dBm @ 3 MeV	←
Resolution & Stability	<50 μm @ 20-mmφ beam pipe	< ± 1 °
Operation Modes	CW or Pulsed	←
Bandwidth of output signal	> 5 MHz	←

The BPPM electronics has been developed by the Bergoz Instrumentation in accordance to our specifications. It is a full-analog processor that is based on the Bergoz Log-Ratio BPM electronics. A mezzanine board for measuring beam phase phase with respect to the RF reference is mounted on the LR-BPM. In order to realize very low drifts in phase detection circuit, simple low-pass filters were adopted. In addition the four button signals are combined and compared with the RF reference input, in order to minimize the dependence of the phase detection on the transverse beam position. Fig. 7 is the developed BPPM electronics with the phase-detection mezzanine board shown in the upper-right corner.

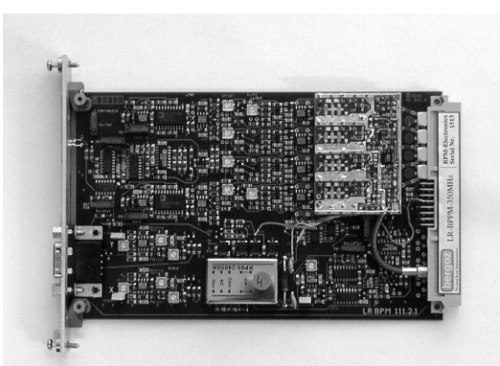

Figure 2: Developed BPPM electronics. Phase-detection mezzanine board is shown in the upper right corner.

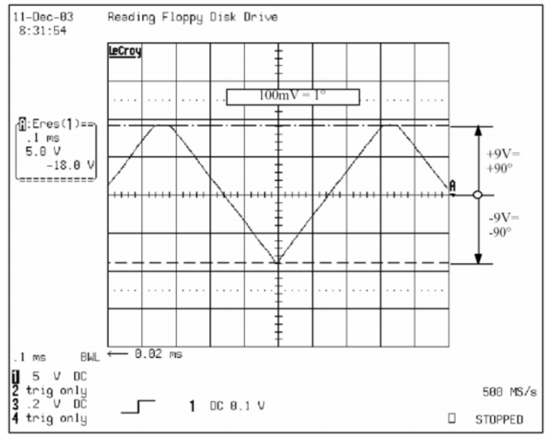

Figure 3: Linearity performance of phase detection circuit for single-frequency signal inputs.

The linearity performance of the phase circuit was also tested in the PLS (Pohang Light Source), the 3rd generaton light source in Pohang, Korea. The bunching frequency of the circulating beam in the PLS is 500 MHz and this is higher than the nominal operating frequency of the BPPM elelctronics. But since the cutoff frequency of the LPFs in the phase circuit front-end is roughly 700 MHz, the circuit operated well with the PLS beam. One uncertainty was on the bunch length. Since the PLS is an electron machine, the bunch length is very short. (~25 ps rms) Button signals from this short bunch contain very wide-band spectrum and could cause differences in the BPPM performances to the test-bench tests with single-frequency inputs. Fig. 10 is the test result of linearity error with the PLS beam signals. Note the increased linearity errors. Another test in the PEFP linac will be done in near future.

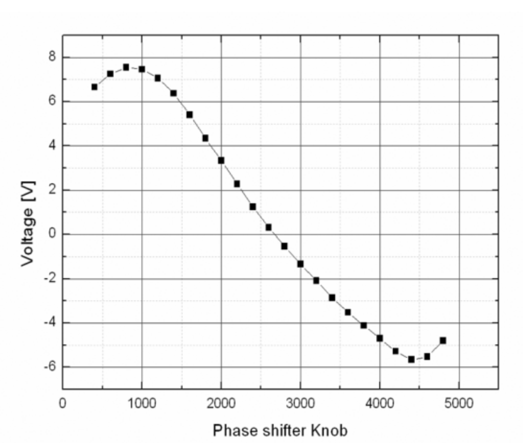

Figure 4: Linearity performance of BPPM phase circuit with PLS beam signals.

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TUNED CURRENT TRANSFORMERS

Efforts for developing BCM hardware will be saved by collaborating with companies including the Bergoz Instrumentation. In order to make BCMs highly stable and immune to bunch-length changes, it is recommended to limit the measurement bandwidth by tuning the current monitor to a specific frequency among various spectral contents in the beams. This can be realized by providing small capacitance, C in the winding of high-permeability core, which will oscillate at the frequency determined by the formula $f = 1/2\pi\sqrt{LC}$ where, L is the leakage inductance of the winding [3]. By adjusting the value of C, the oscillation can be tuned to a specific harmonic (e.g., 350 MHz) among the beam spectrum. The oscillation should be made low Q to avoid excessive or erratic responses. Prototype BCMs based on the above operating principle (Tuned-CT) are fabricated in the company and their performance will be tested at the PEFP accelerator, but the proton beam is not yet, so the tuned CT is tested in the laboratory experiments. The result of performance test in the lab is shown Table 3. See Fig. 5.

Table 3: The result of Performance test of Tuned CT.

Performance Parameters	Target Value	Achieve Value
Resolution & Stability	< 5 x 10-4	< 2 x 10-4
Frequency Dependency	< 5 x 10-4	~ 2 x 10-4
Axial Length	< 5 cm	~ 3.5 cm

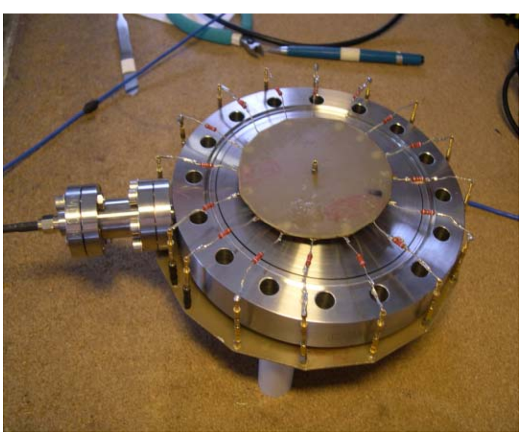

Figure 4: Performance test of Tuned CT in the laboratory.

CONCLUSIONS

We have developed the BPPM (Beam Position and Phase Monitor) system for the PEFP (Proton Engineering Frontier Project) proton linear accelerator. We conclude this thesis with the following summarizing remarks:

1. Button-type PU was designed utilizing the MAGIC code and a prototype one with N-type feedthroughs was fabricated [1], [2]. And then the PU is modified with SMA feedthroughs for the set-up.

2. Processing electronics based on the existing Log-Ratio BPM circuit was developed by the collaboration with the Bergoz Instrumentation. Phase detection circuit was integrated into a small mezzanine board that was mounted on the LR BPM circuit.

3. The phase circuit of the BPPM electronics can provide linearity error < ± 0.5^o. Rms noise of the circuit is < ± 0.1^o for signal input > -20 dBm. Phase error over 20-^{o}C temperature variation is less than 0.5^o. See Ref. 3

4. The BPPM electronics can be operated in both CW and pulsed (~ 1 ms) modes.

5. The prototype tuned CT is fabricated and tested with 2 E-4 of the stability and resolution about measuring beam currents in the laboratory performance test.

REFERENCES

[1] S. J. Park et al., “Design of BPM PU for Low-Beta Proton Beam Using MAGIC Code,” Proc. of the DIPAC03.

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[3] J. Bergoz, “Performance of BPPM Electronics developed for PEFP linac,” Project Report, Bergoz Instrumentation, December, 2003.