DESIGN AND TEST STATUS OF BEAM POSITION MONITORS FOR ADS INJECTOR II PROTON LINAC

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Abstract

Beam Position Monitors (BPM) based on capacitive pick-ups are designed for Accelerator-Driven System (ADS) Injector II proton LINAC. This LINAC is aiming to produce a maximum design current of 15 mA at the 10 MeV energy with an operating frequency of 162.5 MHz. Non-interceptive BPM will be installed to measure the transverse beam position and beam phase in the vacuum chamber. Apart from the broadening of the electromagnetic field due to the low-beta beam, specific issues are affecting some of the BPMs: tiny space in the transport line between RFQ and Cryomodule, and the cryogenic temperature inside Cryomodule. For this reason two types of BPMs are being designed for each location (MEBT and Cryomoudule). In this contribution, the present status of the design and measured results for each BPM will be presented, focusing on the electromagnetic response for low-beta beams.

INTRUDUCTION

Beam Position Monitors (BPMs) are essential diagnostics for the ADS Injector II Proton LINAC. The capacitive types BPMs (CBPM) are chosen for its easy mechanical realization, high output signal and short insertion length to fit into the tiny space in the quadrupole magnets [1]. This device is composed of four electrodes mounted on a vacuum pipe. The challenge of the ADS Injector II Proton LINAC BPM design is that the BPM must work in normal and the cryogenic temperature varying from 2.1 MeV to 10 MeV. For these reason two capacitive types BPMs are being designed for each location.

Table 1: ADS Injector II Proton LINAC BPM Parameters

Parameters	Value
Beam pipe diameter	50 mm / 40 mm
Beam energy	2.1 MeV – 10 MeV
Bunch frequency	162.5 MHz
Beam pulse length	0.1 ms-CW
Bunch length(rms, sigma)	0.1 ns-0.5 ns
Average current	0.01 mA-15 mA
Peak current	20 mA
Position accuracy	1% of half-aperture
Position resolution	0.1% of half-aperture
Phase accuracy	1-3 deg
Phase resolution	0.1-0.3 deg

BPM's main measurement is to determine the beam position and beam phase, with a spatial resolution of 25 μm and 0.1 degree on a continue-wave (CW) beam, by calculating the ration of the difference over sum voltage between two opposite pick-ups. The sum signal from a BPM can be also used as a relative measurement for the beam current. The main parameters are summarized in Table 1.

ELECTROMAGNETIC AND MECHANICAL DESIGN

To improve and extend calculations of the signal response of the monitors, numerical simulations were done by using the code CST PARTICLE STUDIO (CST PS) with the wake-field solver [2]. The excitation source was defined by a Gaussian-shaped longitudinal charge distribution. For the investigation which the capacitive types BPM have the maximum output signal, three different BPM models were simulated by using CST PS [3].

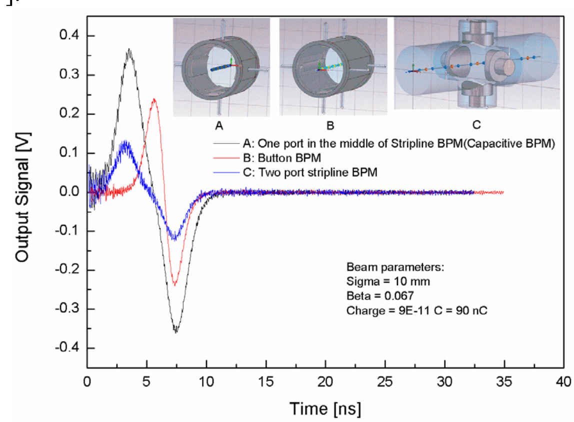


Figure 1: Comparison of the output signal from the different BPM models when the same parameters beam passing BPM.

As shown in Fig.1, according to the limitation of space room, three different BPM were designed. When the same parameters beam passing BPMs, one port in the middle of Stripline BPM and Button BPM have the maximum output signal for they are the CBPMs. And the two-port Stripline BPM has the minimum signal for it is the transmission line. As a conclusion, CBPMs have more sensitive and large signal for low beta beam. Thus we choose CBPM installing the quadrupole of MEBT and Button BPM installing in the Cryomodule.

Figure 2 shows the sensitivity map obtained by plotting the delta-over-sum values from the signals of two opposite pick-ups for the first harmonics of the accelerating frequency i.e 162.5MHz at $\beta = 0.067$. Figure 3 shows the simulated sensitivity of CBPM for the different harmonic frequency. The mechanical design is shown in the Fig.4.

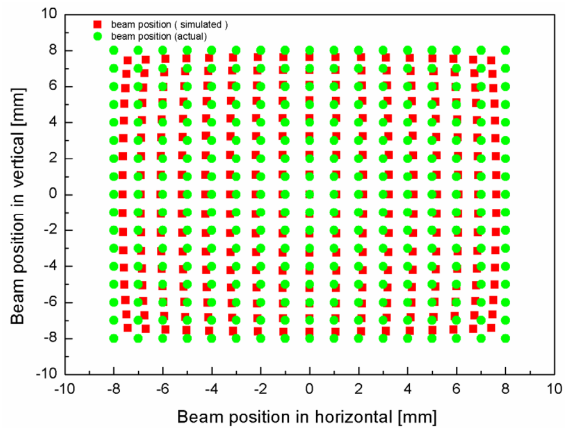


Figure 2: Sensitivity map of the CBPM at 162.5 MHz and β = 0.067.

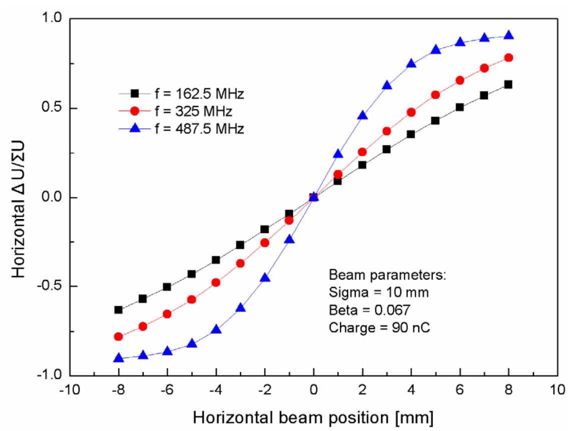
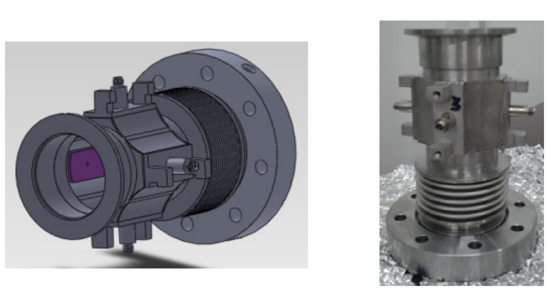
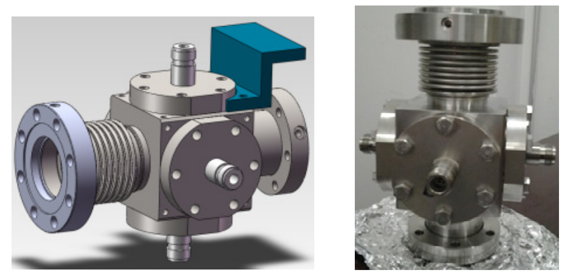


Figure 3: Simulation of the Difference over Sum method for CBPM for the fundamental, first and second harmonic frequency.

In MEBT, the vacuum aperture is 50 mm. CBPM length is 35 mm with the subtended angle of 42 degree. In Cryomodule, the vacuum aperture is 40 mm and button BPM diameter is 20 mm. We use removable feedthroughs help the maintenance and replacement of leaking elements. And the bellows and rotatable flanges are used to facilitate beam line installation and alignment. The foresee alignment plane references and alignment holes for targets are also designed and as shown in Fig.4.



(a)



(b)

Figure 4: (a) Mechanical design and photograph of CBPM in quadrupole of MEBT and (b) Button BPM in Cryomodule.

EXPERIMENTAL RESULTS ON TEST BENCH AND PROTON LINAC

The test bench is used to characterize the BPM and calibrate the complete electronics chain. Libera Single Pass H is used to the beam position and phase monitor. Figure 5 shows the photograph of our test bench. The 50 mm diameter CBPM is fixed on an X-Y positioning table and a wire is fixed on the longitudinal positioning, which is driven by the servo motors along the transverse axis. The precision of grating-ruler is 1 μm.

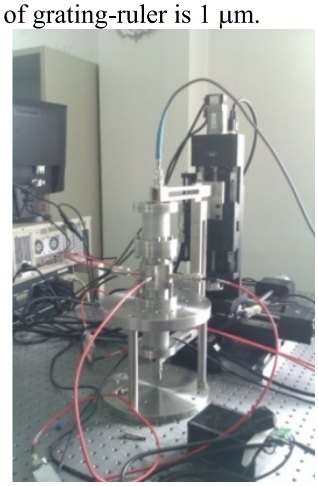


Figure 5: Photograph of ADS Injector II BPM test bench.

Figure 6 shows the output signal from CBPM on the test bench. Yellow line is the negative output signal from Pulse Generator. Green line is the output signal from CBPM, which is 75.5 mV voltage and 6.12 ns periods. Brown line means the output signal from the test antenna, which shows the transmission of test antenna not very well.

CBPM was installed into a Proton LINAC in the Institute of High Energy Physics, China Academy of Sciences (IHEP, CAS) on July, 2012. The output signal from CBPM induced by proton beam was shown in Fig.7. The macro bunch signal was got in the time domain and the frequency domain. The signal amplitude from peak to peak was 36.557 mV in the time domain with the bunch length of 44.64 μs. In the frequency domain, the amplitude is -28.3 dBm and -75.6 dBm at the fundamental

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and the first harmonic frequency after a 50 meters RF cable.

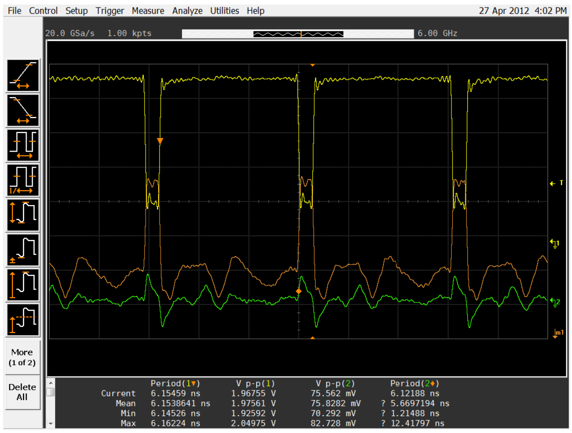

Figure 6: Output signal from CBPM on the test bench.

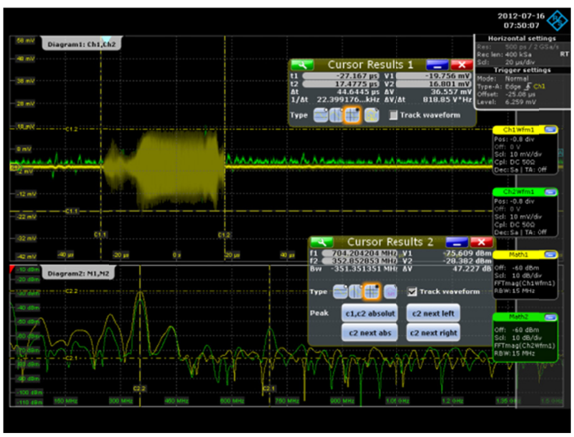

Figure 7: Output signal from CBPM on Proton LINAC in IHEP, CAS. The beam energy was 3.5MeV with bunch frequency of 352.2 MHz. The beam current was 15 mA with the macro bunch length of 50 µs.

SUMMARY

BPM are essential devices for the beam-based alignment and diagnostics of the ADS Proton LINAC accelerator. The capacitive type BPM have been designed and tested for low-beta proton beam. By the 3D numerical simulator, the size and sensitivity of BPM can be optimized to meet the requirement of beam diagnostics. The follow thing is to check whether the cold button BPM can suffer the cycling of the warm-cold temperature and calibrate all of CBPM in the room and cold temperature.

ACKNOWLEGEMENT

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