MEASUREMENT OF BEAM PHASE AND ENERGY USING BPMS AND FCTS AT THE MEBT SECTION OF CSNS H- LINAC

F. Li, M.A. Rehman, Z.H. Xu, W.L. Huang, R.Y. Qiu, L. Zeng, R.J. Yang,T. Yang

Institute of High Energy Physics, Chinese Academy of Sciences, Beijing
ChinaSpallation Neutron Source Science Center, Dongguan, China

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Abstract

Accurately measuring the beam phase is critical when determining the ideal RF cavity parameters for beam acceleration. In the past, only Fast Current Transformers (FCTs) were used to measure the beam phase. However, with the upcoming upgrade of the MEBT section for the CSNS-II project, shorted strapline-type Beam Position Monitors (BPMs) will now be utilized to measure beam position, phase, and energy. LIBERA singlepass electronics are employed to measure the beam position and phase from the BPMs. Pairs of BPMs were used to measure beam phase shift, which can also be used to calculate beam energy. This paper compares beam phase measurement systematically by BPMs and FCTs.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is a platform for scientific research, consisting of an RF ion source, a 3 MeV Radio Frequency Quadruple (RFQ), 80 MeV Drift Tube Linac (DTL), 1.6 GeV Rapid-Cycling Synchrotron (RCS), and several beamlines. Significant upgrades will be made to the Medium Energy Beam Transport (MEBT) for the future CSNS-II as part of a power upgrade. With the upgrades planned for the second phase, the functionality of the existing FCTs will be replaced by a BPM system.

A comparative study of FCT and BPM systems for phase and energy measurements is necessary, which includes system calibration, consistency in phase measurement and energy measurement .The BPM system will use Libera SPH, an electronic device designed for beam position and phase measurement in particle accelerators and beamlines, and the FCT system has been using self-developed electronics on CSNS for about 10 years. This study mainly compares two sets of closely located beam position monitors (BPM05 and BPM07) and fast current transformers (FCT03 and FCT05) in the MEBT section. Figure 1 shows beam instrument layout of the CSNS MEBT

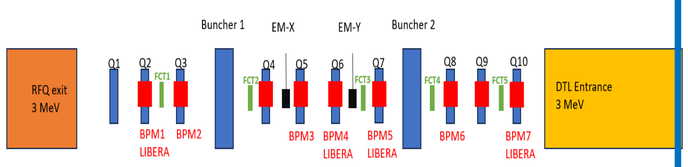


Figure 1: Layout of the CSNS MEBT

MEASUREMENT

Cable offset measurement of BPM system

Since all detectors have been installed on the accelerator beamline, calibration measurement was only performed on the FCTs in the past phase, with no calibration done for the BPM. Additionally, the differences between electronic channels are minimal. Therefore, calibration is only carried out on the BPM cables in this study.

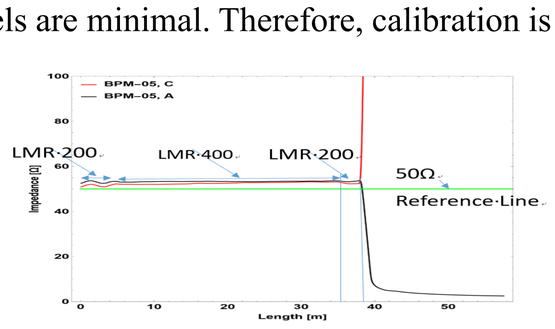


Figure 2 Cable length measurement using Time Domain Reflectometry (TDR) method.

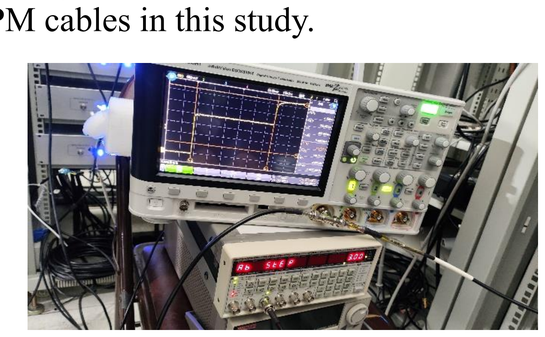


Figure 3 Measure cable delay using an oscilloscope with a function generator

Table 1: BPM Cable Length Measurement

Cable length	A(m)	B(m)	C(m)	D(m)
BPM05	37.81	37.93	37.93	37.93
BPM07	37.87	37.83	37.88	37.87

Table 2: The cable delays of the two BPM

Probe (line NO.)	A(ns)	B(ns)	C(ns)	D(ns)
BPM05(1020)	144.14	144.92	144.92	144.92
BPM07(1022)	144.92	144.92	144.92	144.92

Phase scan

We verified the consistency of two methods for phase measurement and the impact of beam slicing on phase measurement, as well as the stability of BPM Libera SPH electronics in measuring different harmonics of BPM and their jitter within the same macro pulse.

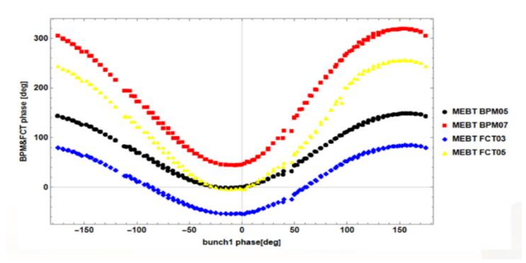


Figure 4 Performance of BPM and FCT phase measurements in bunch cavity phase scanning.

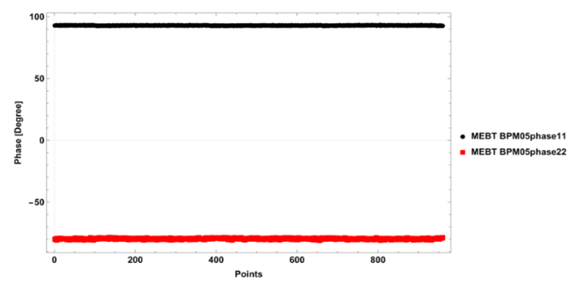


Figure 5: Stability testing of phase information from approximately 1000 fundamental and second harmonic BPM signals.

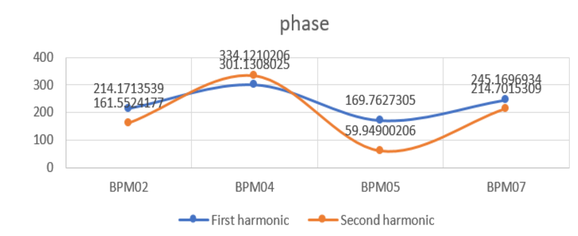


Figure 6: The average values of the fundamental and second harmonic signals from 78 data of four BPMs using Libera SPH

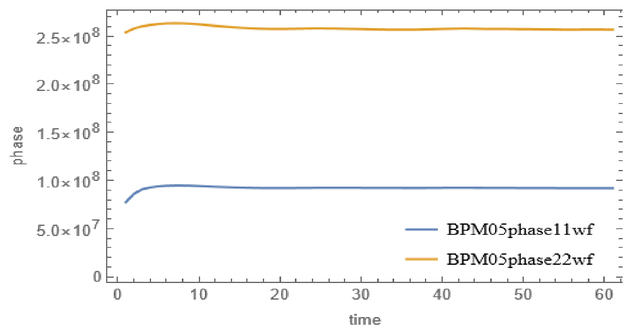


Figure 7. Jitter of phase within a macro-bunch： The phase stability of the second harmonic relative to the fundamental within a macro-pulse is relatively stable; BPM05 phase11wf means the fundamental, and BPM05 phase22wf means the second harmonic.

Table3 impact of beam chopping on accelerator beam phase measurements.

Probe(line NO.)		WO/ Chopper	W/ chopper	Delta
BPM01	Mean Std	160.63 0.10158	161.043 0.08429	-0.25%
BPM04	Mean Std	92.02 0.1469	92.252 0.16945	-3.3%
BPM05	Mean Std	222.149 0.16116	226.239 0.19214	-1.8%
BPM07	Mean Std	147.68 0.4011	149.53 0.25979	-1.2%
FCT03	Mean Std	158.458 0.1519	153.9 0.1234	2.9%
FCT05	Mean Std	42.187 0.248	39.05 0.352	7.9%

Energy Measurement

Time of Flight (TOF) is a commonly used method for measuring accelerator energy. By knowing the distance and the time of flight, the velocity of the particles can be calculated using the formula:

$$v = \frac{D}{NT + \triangle t}$$

Where D is the distance between the two BPMS, v is the velocity, N is the number of micro-bunches within D, T is the radio-frequency (RF) period, and △t is time of phase difference.

Once the velocity of the particles is determined, their energy can be calculated using the relativistic energy-momentum relation:

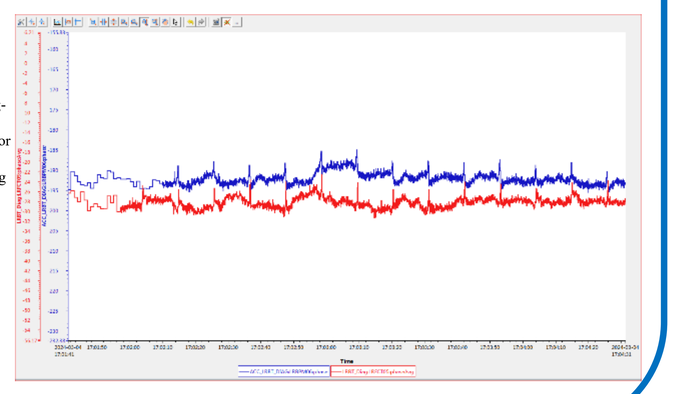
$$Energy = (\gamma - 1) * m * bc^2$$

Where γ is the Lorentz factor, m is the rest mass of the particle, and c is the speed of light.

As shown in right table, The similar result of energy measurement from Two methods is obtained.

	FCT	BPM
Location	3 and 5	5 and 7
D(meter)	0.85378	0.896
N	11	12
Phase(deg)	42.98 and 156.81	91.24 and 160.25
T(ns)	3.086	3.086
System offset (deg)	178.566 and -140.946	0
Energy(MeV)	3.093	2.988

There good consistency and long-term stability in calculating accelerator energy measured by BPM and FCT during operation at 25Hz.



CONCLUSION

In this paper, the comparison of phase measurement and energy measurement between FCT and BPM has been achieved, and the measurement of phase includes scanning applications, phase jitter within macro pulses, and the difference in beam phase before and after beam choppered, the conclusion, the results indicate that BPM has excellent phase and energy measurement capabilities.

lifang@ihep.ac.cn