BPM SYSTEM DESIGN FOR THE BEPCII STORAGE RING*

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Abstract

BEPCII is a double-ring collider, which will adopt the schemes of multi-bunch and high current in order to increase the luminosity. According to the physics design, the BPM system is not only used to monitor the beam orbit during the injection and commissioning stage, and correct the closed orbit distortion (COD), but also used to perform the interaction point (IP) beam steering, and measure the dispersion functions. A total of 136 BPMs will be mounted in the BEPCII double rings, which include two common BPM detectors. In this paper, we will describe the BPM system design for the BEPCII storage ring in detail.

INTRODUCTION

The Beijing Electron Positron Collider (BEPC) was constructed for both high energy physics and synchrotron radiation researches. The machine has been well operated for 14 years since it was put into operation in 1989. As the second phase project of the BEPC, it will be upgraded to a double ring electron positron collider using the existing tunnel, namely BEPCII. BEPCII is a proposed two-ring collider, which will adopt the schemes of multi-bunch and high current. So the requirement to the BEPCII BPM system is different from the BEPC. The new machine will need to monitor the beam status quickly and accurately. The beam orbit measurement is important, especially in the interaction region. The measurement and control of the closed orbit is one of the basic functions of any accelerator beam instrumentation and control systems. The BEPCII BPM system is not only used to monitor the beam orbit during the injection and commissioning stage, and correct the closed orbit distortion (COD), but also used to perform the interaction point (IP) beam steering, and measure the dispersion functions.

A total of 136 BPMs will be mounted in the BEPCII double rings, which includes two special BPM detectors. Each special BPM having eight electrodes will be located at the front of the QSC magnets toward the interaction point (IP). Basically, the BPMs will be mounted close to every quadrupole magnet. 128 BPMs are used for the closed orbit and turn-by-turn measurements. The rest of the BPMs detectors are used for the signal pickups of the tune measurement (2 units), the bunch current monitor (BCM) and the feedback systems (6 units).

A set of low loss coaxial cables brings up the pick-up signals of each detector to the local control room where the signal processing electronics is located. The lengths of cables vary from 60 to 100 meters depending on the locations of the detectors in the storage ring.

Fig.1 shows the architecture of the BEPCII BPM system. The output signals Δx, Δy, Σ of the BPM electronics are fed to a VME crate, and then are digitized through the high speed ADC module. The data transmission between the local stations and the central control room will be performed through Ethernet. The measured data of the closed orbit will be stored in the real-time database.

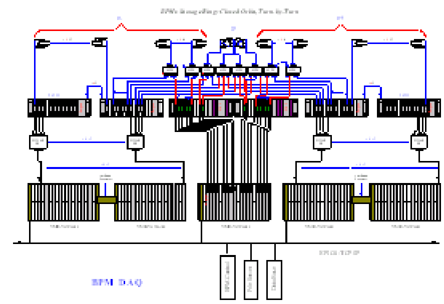

Figure 1: the architecture of the BEPCII BPM system.

SYSTEM PERFORMANCE AND PARAMETERS

Table 1 describes the main technical parameters of the BPM system. It is determined according to the physics design. Table 2 shows some parameters of BEPCII. These parameters must be considered in the BPM system design.

Table 1: Main parameters of the BPM system

Measurement modes	Parameters
First turn & Turn-by-turn	Measurement area (x × y): ±40mm×±20mm Accuracy: 1mm Resolution: 0.1mm
Closed orbit	Measurement area (x × y): ±20mm×±10mm Accuracy: 0.1mm Resolution: <0.01mm Measurement time of COD: < 4 s

Table 2: The main parameters of BEPCII storage ring

Parameters	Unit	Value
RF Frequency (f_{rf})	MHz	499.8
Revolution Frequency (f_r)	MHz	1.262
Harmonic Number (h)		396
Bunch Number (N_b)		93
Bunch Spacing	m	2.4
Bunch Current	mA	9.8
Total Beam Current	A	~1
Bunch Length (cm)	cm	~1.5
Crossing Angle	mrad	±11

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BPM BLOCK DESIGN AND SIMULATION

BPM Block Design

The button type electrodes, which are capacitive coupled to the beam, are most popular with electron / positron rings because they occupy very little longitudinal space and the coupling impedance is small. The beam positions in the BEPCII storage rings will be measured with button-type pickup electrodes, and the SMA-type feedthrough will be mounted for improving the high RF response.

The positron ring vacuum duct will adopt the antechamber type in order to minimize the effects of ECI, but the electron ring vacuum duct is similar to that used in BEPC. For the structure of the antechamber cross section, we adopt the octagon shape due to the mechanical reasons.

By referring to the PEPII BPM structure, and taking into account the heating problem of the pickup power, we adopt the electrode with 15-mm in diameter. The gap between the button and the housing is 1 mm in order to minimize the HOM effects. Fig. 2 shows the cross-section of the BPM block. The left one is for the electron ring and the right one is for the positron ring.

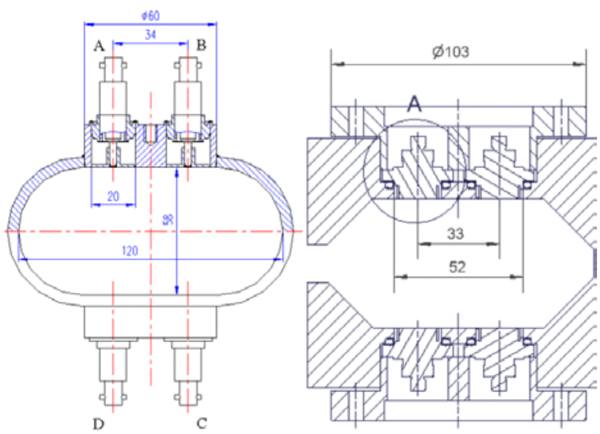

Figure 2: The cross-section of the beam position monitor.

BPM Detector Support

It is important to keep the relative position between the BPM electric center and the adjacent quadrupole magnetic center unchanged. In order to minimize the mechanical movement, the BPM detector will be fixed directly on the magnet support.

Position Sensitivities Simulation

In order to make the same sensitivities of the beam position detection in both the horizontal and vertical planes, simulation had been carried out by using finite element method. The simulation results shown that the same sensitivities will be got when the horizontal center space between two buttons is 33mm and 32mm for the antechamber and racetrack BPM detectors, respectively. Fig.3 shows the simulation.

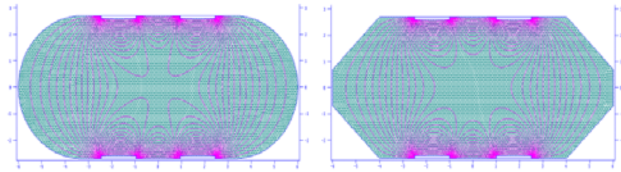

Figure 3: Sensitivities simulation for antechamber BPM and racetrack type BPM, respectively.

BPM Block Calibration

Before the installation of the BPM block in the storage rings, all BPMs must be mapped by using the calibration system. For the calibration of the antechamber type BPMs, we only need to calibrate one standard BPM prototype because we can ensure the assembly precision for all BPMs by the strict control of the machining tolerance. But for the electron ring BPMs, the vacuum pipe is extruded vacuum pipe, so we have to calibrate every BPM by using a set of antenna mapping system. In addition, the beam based alignment method will be used to find out the offset value. The signal transmission cables and the signal processing electronics should be also calibrated.

SIGNAL PROCESSING

According to the physics design, the BPM system is required to have three measurement modes such as the closed orbit measurement, turn-by-turn measurement and IP beam position steering. There are different commercial BPM signal processing electronics available at present. The signal processing electronics may be chosen, as traditional analog electronics such as MX-BPM or newly developed such as digital BPM. This is determined by considering the function and cost. Digital BPM has much more advantages in the aspect of programmable bandwidth extremely wide dynamic range than the conventional analog BPM. The digital BPM has also the prospect of development. But digital BPM is more expensive than the conventional analog BPM. For the COD measurement, the MX-BPM signal processing electronics of the Bergoz Company will be adopted.

Except the COD measurement, other two measurement modes are also important. The first turn measurement can help us to optimize the beam injection process, and take an important action at the beam commissioning stage. The turn-by-turn measurement can provide much more valuable information. Similarly, because BEPCII is a double ring collider with a crossing angle, a beam position steering system based on the beam-beam deflection technique is necessary for maintaining an optimum beam collision condition at the interaction point (IP). In order to satisfy these requirements, digital BPM is to be used. A total of 16 digital BPMs will be used in double ring as the BPMs for the function of first turn, turn-by-turn measurement and IP beam position measurement.

The MX-BPM electronics

Fig.4 shows the schematic diagram of the Bergoz MX-BPM electronics. This MX-BPM adopts a method of input multiplex by switching sequentially from one input channel to the next, and adopts a single superheterodyne receiver to measure the input signals. Thus this electronics has a major advantage that the gain of four channels is always identical, and consequently the measurement precision can be improved. For measuring the closed orbit easily at any bunch injection pattern, RF frequency of 499.8 MHz is chosen as the detecting frequency.

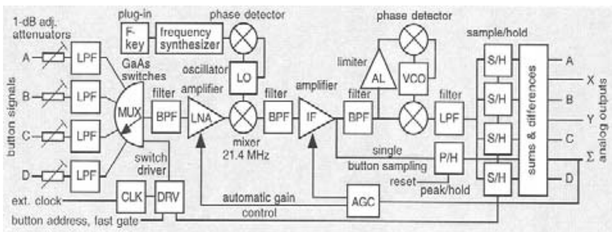

Figure 4: Block diagram of the MX-BPM electronics.

The digital BPM electronics

The digital BPM is much more powerful than analog BPM. Due to its digital nature, it can offers much more reproducibility, wider bandwidth capability, and flexibility. Moreover, it can be easily integrated into the EPICS control system. This is much better because BEPCII control system will be constructed under the EPICS environment.

The DBPM consists of a RF front module and a digital receiver module. The RF front module and a digital receiver module have four independent channels respectively. The four pickup signals from BPM electrodes enter the RF front module, where they are frequency translated to the IF. The IF signals then enters the four channels digital receiver module, where they are filtered and sampled. The rest of the processing is done digitally. Fig.5 shows the block diagram of the DBPM2 electronics.

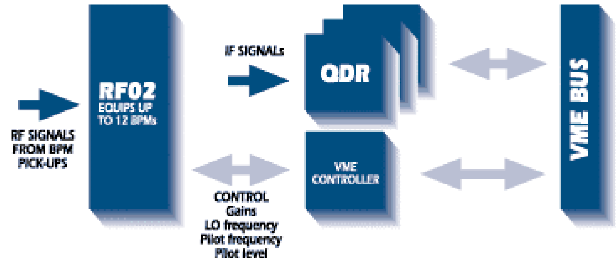

Figure 5: Block diagram of the DBPM2 electronics.

SUMMARY

With the advantage opporunity time of that the BEPC is operating, one set of MX-BPM electronics sample for the COD measurement had been tested on line in first half year of 2003. The on-line testing results of the MX-BPM electronics shown that the COD measurement accuracy is five times better than the BEPC used. One set of digital BPM electronics, which will be used for first turn and turn by turn measurement, had also been tested in second half year of 2003. The program for digital BPM sample was developed based on the Labwindows CVI.

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