BEPC BEAM INSTRUMENTATION SYSTEM AND ITS UPGRADE FOR BEPC-II

L.Ma, J.Cao, L.Wang, Q.Ye, Z.Zhao, IHEP, Beijing, China

Abstract

The Beijing Electron Positron Collider (BEPC) has been successfully operated for many years since 1989. Now BEPC is proposed to upgrade to BEPC-II. The beam instrumentation system of the BEPC storage ring includes many subsystems such as BPMs, tune measurement, current monitor, synchrotron radiation monitor, etc. This paper will describe the present operation performance of the beam instrumentation system of the BEPC storage ring and its upgrade plan for BEPC-II.

1 INTRODUCTION

The Beijing Electron-Positron Collider (BEPC) has been put into operation since 1989. The collider can provide beams for high-energy physics experiments as well as the synchrotron radiation research in parasitic or dedicated modes. The peak luminosity of the BEPC storage ring is reached to 5 x 10^{30} $cm^{-2}s^{-1}$ at the J/ψ resonant energy of 1.55 GeV. The beam diagnostic instrumentation system has played an important role during the machine commissioning and operation. The system has been made minor upgrades for several times since 1996, for example the upgrades of the BPM system [1], the tune measurement system [2] and the beam loss monitor system [4].

It is proposed that BEPC will be upgraded to BEPC-II, a double-ring collider with the design luminosity of 1 x 10^{33} $cm^{-2}s^{-1}$ at 1.55 GeV. The design of BEPC-II is going smoothly at present. The main features of the BEPC-II storage ring are 1.5-cm β_y at IP, 1.1 A current per beam, the horizontal crossing angle of ±11 mrad, and 500 MHz superconducting RF. The beam instrumentation system will also be upgraded to satisfy the requirements of BEPC-II. In this paper we will first describe the present status of the BEPC beam instrumentation system, and then give the brief introduction to the BEPC-II beam instrumentation system.

2 BEPC INSTRUMENTATIONS

The monitors of the BEPC storage ring include 10 fluorescent screens, a DCCT, a wall current monitor, 32 BPMs, 2 stripline electrodes, 2 synchrotron light monitors, and 20 PIN photodiode beam loss monitors.

2.1 Fluorescent Screens

There are 8 fluorescent screen monitors in the BEPC storage ring and 2 immediately after the exits of Lambertson magnets at the electron and positron injection areas, respectively. The 50 mm x 50 mm screen Model AF995R can detect the injected beam with even 1 mA peak current. These screens are driven by the compressed air system, which are controlled manually at the centre control room. The position repeatability of screens is 0.5 mm. The screen monitors in the ring are seldom used at present except the problems occur. The two screen monitors located near the injection points are still used very often to monitor positions of injection beams.

2.2 DCCT

The DCCT and its signal processing electronics used for the BEPC storage ring were designed and built in our lab. The DCCT toroid is installed outside the 20-mm long ceramic gap, which breaks the stainless steel beam pipe of a 103-mm inner diameter. The main parameters of the DCCT are 0.1 - 200 mA dynamic range, 0.1% linearity, and 24.7 mV/mA sensitivity. At the outside of the DCCT toroid, a cylindrical electric shield was placed. There is no magnetic shield outside the DCCT toroid so that the zero drift can reach to a couple of mA during the energy ramping. When exciting currents of the nearby bending and quadrupole magnets keep constants, the zero drift of the DCCT is small enough to make the good measurement of the beam current. We plan to design and add magnetic shields outside the DCCT toroid at the next step.

2.3 Wall Current Monitor

Twenty 9.1-Ohm resistors in parallel across a ceramic gap along the beam pipe forms a simple wall current monitor. Four short coaxial cables are directly welded to two ends of resistors at the right angle of the circumference of the ceramic ring. A broadband hybrid junction Model SD-4-4 combines the signals from four cables to eliminate the factor of the position dependence. The sum signal is brought up to the centre control room on a 1/2-inch cable. Because of the simple and crude construction, there are some reflections in the output waveform. It is still good enough for the relative bunch current measurement. It is also used to monitor the bunch shape oscillation when some beam instabilities occur.

2.4 Beam Position Monitors

BPM pickups are installed in 32 locations next to defocusing quadrupole magnets along the BEPC storage ring. Each BPM consists of four button-type electrodes. The button with a 20 mm in diameter is mounted on a BNC-type feedthrough. A set of four RG223/U coaxial cables bring up pick-up signals of each monitor to the local control room where the signal processing electronics is located. The lengths of cables vary from 60 to 90 meters depending on locations of the monitors in the ring. The relative attenuations of four cables for each monitor have been carefully measured and saved into computer.

In order to improve the measurement resolution and reduce the measurement time, the hardware and software of the BPM system had been partially modified in 1996 [1]. The BPM processing electronics and the measurement behavior can be fully controlled by a personal computer in the local control room. The short-term reproducibility of measurements is improved from larger than 20 μm to 10 μm. The measurement time for scanning all 32 BPMs is reduced from 50 seconds to 11 seconds. The dynamic rang of the system is 81 dB and the minimum measurable beam intensity is less than 0.5 mA. The reliability of the measurement is guaranteed by the self-consistency check. The absolute beam position of each BPM with respect to the magnetic center of the adjacent quadrupole magnet is determined directly with the beam.

2.5 Stripline Electrodes

Two identical 4-stripline electrode monitors were built for the tune measurement, one is used as the shaker and another as the receiver. Each electrode is made of a stainless steel plate with 27 mm in width, 1 mm in thickness and 277 mm in length. Four electrodes are mounted on a vacuum chamber, which has the circular cross section with a 103-mm inner diameter, at right angle around the chamber wall. Each end of an electrode has a feedthrough with a N-type connector. Signals from electrodes are brought up to the centre control room on eight 1/2-inch cables Model LDF4-50A. The signal processing electronics and a spectrum analyzer are located in the centre control room.

The BEPC tune measurement system has been upgraded by replacing the original TEK 7L5 spectrum analyzer with the HP3588A spectrum analyzer and by using a PC in the system [2]. This upgrade has lead to an increase in the measurement speed and resolution. The resolution of the system can reach the order of 10^{-4} in tune and the dynamic rang is 0.4 - 40 mA.

2.6 Synchrotron Light Monitors

Two primary flat and optically polished mirrors in the vacuum chamber, one each for the positron and electron beams, are made of Cu coasting with gold. The visible part of the synchrotron radiation is reflected horizontally through the side window by the water-cooled mirror and then directed vertically by a remote controllable mirror to the optical building where contains an optical table, diagnostic instruments and the work space. Those diagnostic instruments include a CCD camera providing the image of the beam transverse profile on a TV monitor, a lens system focusing the synchrotron light onto a solid state scanned photodiode arrays to obtain the beam height or width, a streak camera system to measure the bunch length for a single pass, and a two-dimensional position sensing photo-detector to monitor the drift of the beam position.

Two new optical tables have been put into use since 1998. The surface area of the optical table is 1.81 x 1.2 m^2 and is more than 5 times as large as the area of the original optical table. Almost all measurement subsystems were modified during the period from 1996 to 1998 [3]. These modifications have improved the performance of the synchrotron radiation monitoring system and are very useful for the overall machine operation and machine studies.

2.7 Beam Loss Monitors

The beam loss phenomena are frequently observed in the BEPC storage ring, especially when BEPC operates in the dedicated synchrotron radiation mode. The beam loss monitors (BLMs) have been developed for detecting and locating any possible excessive beam loss in the ring [4]. At present the BLM system, which is based on the CAN field-bus, includes 20 PIN photodiode beam loss detectors and is able to detect the small beam losses along the storage ring. The system is easy to be extended. We can measure any interesting point in the ring by simply adding a new detector on the CAN bus.

3 PRELIMINARY CONSIDERATIONS OF BEPC-II INSTRUMENTATIONS

It is proposed to upgrade BEPC to BEPC-II, a double-ring electron positron collider. The conventional beam instrumentations in BEPC-II are similar to that used in BEPC, for example, the DCCT for the averaged beam current measurement, fluorescent screens for monitoring the injected beam position and profile, stripline electrodes for the tune measurement, the photon monitoring system which includes a CCD camera for monitoring the beam profile, solid state scanned photodiode arrays for measurements of the beam height and width, a streak camera for the single-pass measurement of the bunch length, and so on. Some monitor systems required for BEPC-II are quite different from that used in BEPC. These systems are described in detail below.

3.1 Bunch Current Monitor

There are at least following two reasons for filling each ring with an equal population in all bunches: to optimize the beam-beam tune shift and to control the stability of individual bunches. This requirement makes it necessary to measure the beam current bunch-by-bunch and arises additional demands on the injection system.

The bunch current monitoring system first measures the relative intensity of each bunch through a pickup electrode, and then controls the beam pulse from the linac to be injected into the required bucket within 20 ms, which is the repetition period of the linac. The bunch current measurement is synchronized with the linac beam pulse at 50 Hz. Each measurement performs a series of the current detections and A-to-D conversions for all bunches at the 500-MHz RF frequency of the ring. The bunch current information is stored in a memory board and used for the bucket selection circuit with the time delay module.

3.2 Beam Steering System at IP

A beam position steering system based on the beam-beam deflection technique is necessary for maintaining an optimum beam collision condition at IP where the electron and positron beams circulate in separate rings. This beam-beam deflection technique was pioneered at SLC [5] and was further studied at LEP, PEP-II and KEKB [6].

Figure 1 shows a block diagram of the orbit steering system. This system can measure the relative orbit offset of two beams at IP and then remove the offset once it is found. The orbit offset is obtained with the measurement of the beam-beam deflection when the beam-beam scan is made. The beam-beam deflection is detected by measuring the orbit changes at BPMs around the IP. The steering magnets in Figure 1 are used for both the beam-beam scan and the maintenance of the zero orbit offset.

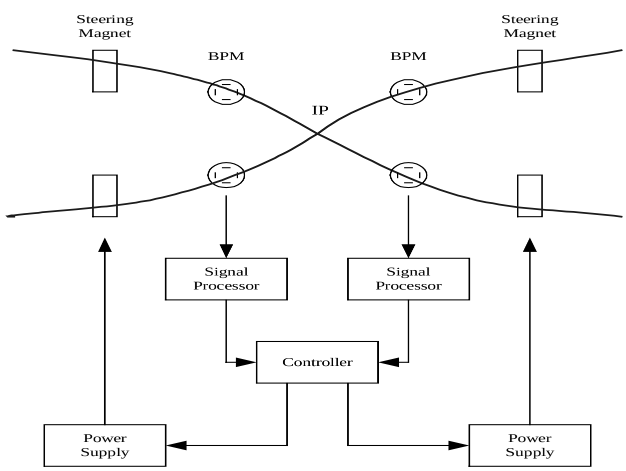

Figure 1: Conceptual block diagram of the beam position steering system at IP.

3.3 Bunch Feedback System

The high beam current of 1.1 A per beam and the large number of bunches in BEPC-II rings can cause the coupled bunch (CB) instabilities, and active feedback systems are required to suppress these instabilities. There are two possible impedance sources which gives rise to the CB instabilities: higher order modes (HOMs) of accelerating cavities and the resistive wall impedance of the beam pipe. The bunch feedback systems, which feed the signals detected from each oscillating bunch back to that same bunch, will be used in BEPC-II because the details of the particular modes that are unstable are not known. Such bunch-by-bunch feedback has the additional advance of suppressing transient bunch motions driven by the beam-beam interaction or introduced by the injection process.

A feedback system mainly consists of three parts: the beam pickup part, the signal processing part and the kicker part. Figure 2 is the block diagram of the bunch feedback system for the BEPC-II rings. The latest results and successful operating experiences of the bunch feedback systems for the two B-factories will be referred for the design of the BEPC-II bunch feedback system [7].

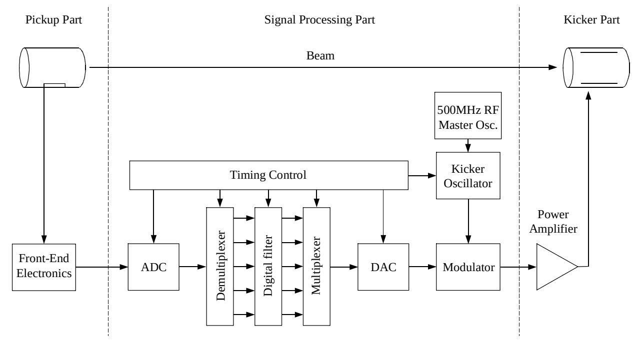

Figure 2: Block diagram of the bunch feedback system.

4 SUMMARY

The beam diagnostic instrumentation system has played an active role since BEPC was put into operation in 1989. After some upgrades from 1996, the system basically satisfies the requirements of the machine commissioning and operation.

BEPC-II is a proposed two-ring collider, which is accommodated in the present BEPC tunnel. The luminosity of BEPC-II is 1 x 10^{33} $cm^{-2}s^{-1}$. The beam instrumentation system is one of the important systems to archive the goal of BEPC-II. This system should provide precise and sufficient information of the beam and machine parameters so that accelerator physicists and machine operators can improve the injection efficiency, optimize the lattice parameters, monitor the beam behaviours and increase the luminosity. The detailed design of the system is underway.

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