A real-time beam loss monitoring system for storage ring of SSRF

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Abstract In this paper we report the real-time beam loss monitoring (BLM) system at the storage ring of SSRF. The BLM-XS detectors and Ethernet data acquisition system are used in this system. Some applications and experiments of the BLM system are also presented. The BLM system provides dynamic information of beam loss for the storage ring, and is helpful to ensure the facility commissioning, investigate the problems of machine, optimize the machine parameters and further increase the beam lifetime.

Key words Beam loss monitoring system, Beam lifetime, Ethernet, SSRF

1 Introduction

Shanghai Synchrotron Radiation Facility (SSRF), an intermediate energy synchrotron radiation light source, is composed of a 150-MeV linear accelerator, 3.5-GeV booster storage, and a 3.5-GeV storage ring with 432 meter circumference and 20 cells. The stored beam current for routine operation is 300 mA, and the beam lifetime is about 10 hours, with a repetition frequency of 2 Hz[1]. According to the physics of accelerator, the electron beams loses inevitably along the orbit in the storage ring because of the Quantum effect, Touscheck effect and Coulomb Scattering[2]. The lost electrons may hit the vacuum pipe, giving rise to shower-electrons, gamma-rays, neutrons, etc.

The real-time beam loss monitoring (BLM) system is to monitor the shower-electrons at the storage ring and provide dynamic information of the beam loss. It helps to solve problems in the facility commissioning, and problems in the injection-mode and operation-mode of machine, so as to optimize the machine parameters and increase the beam lifetime. This BLM system consists of 80 detectors, 20 data collectors and a console PC. The detectors are installed in pairs on the vacuum chamber behind the dipole magnets in every cell, with one inside the vacuum chamber, and the other outside of the chamber. The layout of the installation is illustrated in Fig.1.

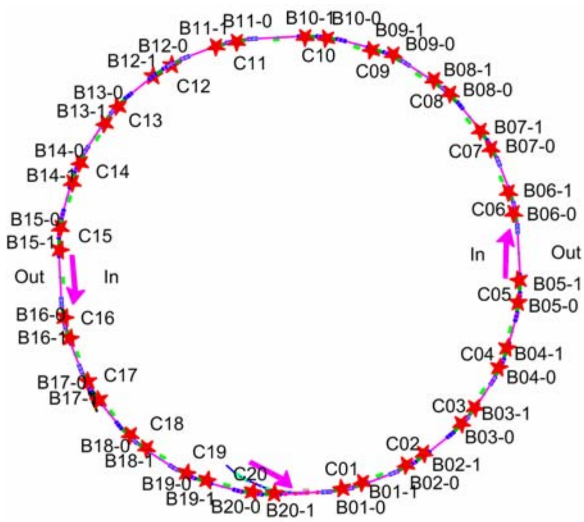

Fig.1 Layout of BLM system in the storage ring.

2 System structure

Fig.2 shows the structure of BLM system. As can be seen it is a distributed system. The pulse signals from detectors are received and stored by the data collectors, and transmitted to the host PC in the radiation control center via Ethernet network. Every data collector can

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be connected with four BLM detectors. The Ethernet exchanges messages between the PC and data collectors. In order to improve the real-time BLM data, the UDP protocol is adopted.

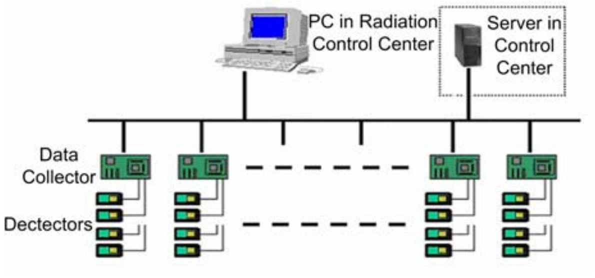

Fig.2 Functional block diagram of BLM system.

2.1 Detectors

The BLM system uses BLM-XS detectors developed originally at DESY, Germany and produced by Bergoz Instrumentation, France[3]. The detector is composed of two PIN-diodes mounted face to face to form a 2-channel coincidence detector (Fig.3). When an electron hits both the PIN-diodes, a coincidence occurs and an output pulse is generated, but the synchrotron radiation photons being stopped in either PIN-diode do not cause a coincidence. The BLM-XS detector is sensitive to maximum ionization particles (MIP), with a single electron detection efficiency of over 30%. The maximum pulse frequency is 10 MHz, with a dynamic range of $>10^8$. Because of this performance, many synchrotron radiation facilities have utilized this kind of detector to monitor the beam loss[4-8].

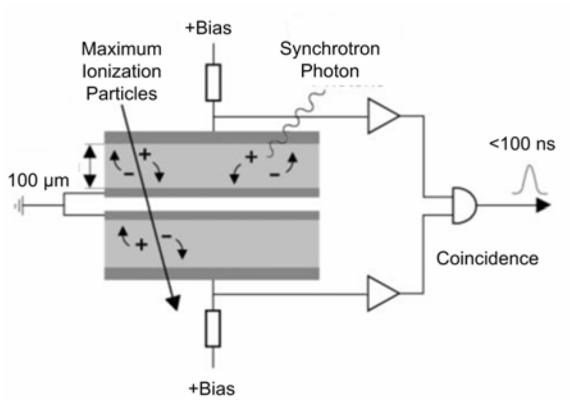

Fig.3 Principle diagram of the BLM-XS detector[3].

2.2 Data collector and software

The data collector is designed to reprocess the pulse signal from the detectors, make the clock stamp, store the temporary data and accomplish message exchange with the PC *via* Ethernet. It consists of a 32-bit Freescale ColdFire microprocessor as the main controller and a high-speed ALTERA FPGA running uClinux operation system. It has 16 M byte RAM to store the data, and a 24 MHz working frequency.

The PC is responsible for controlling the whole system, processing and storing the data, displaying real-time diagram in histogram or curves, and reflecting the work-status of data collectors. The software was developed with LabVIEW7.1 in Windows environment. It offers an interface to display the detector positions and configure each collector.

3 BLM system applications

3.1 Spotting the machine obstruction

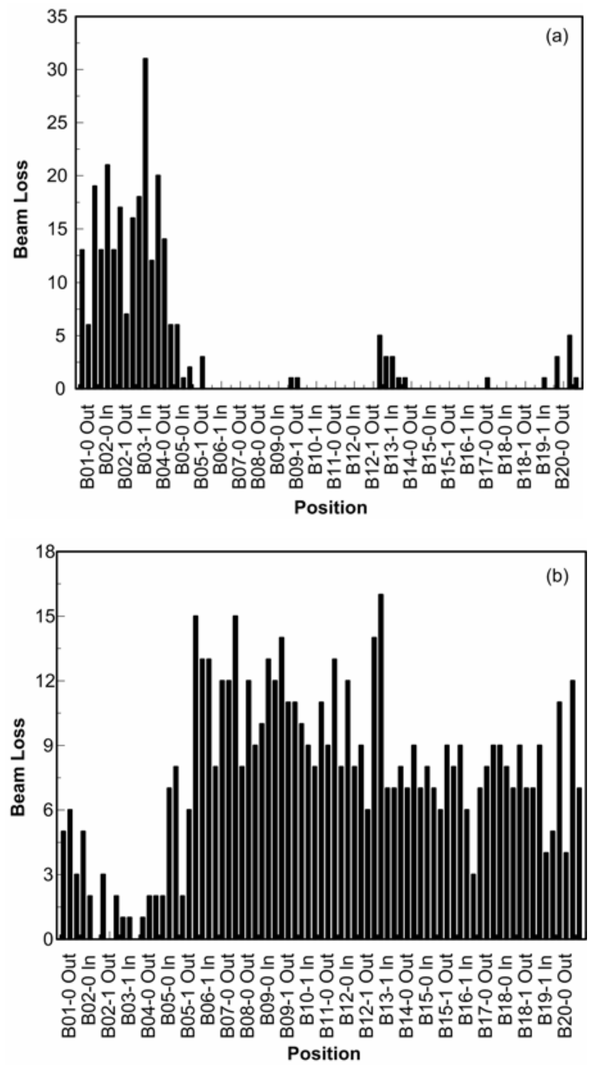

Fig.4 Beam loss of SSRF storage ring during commissioning on Dec. 21, 2007. (a) Severe beam loss was found at Position B03-1 at 19:17, and the storage ring was off the open-orbit status. (b) Beam loss at 20:00, when it resumed the open-orbit status, after adjustments of the machine parameters at B03-1.

With the BLM system, we can clearly find changes in the beam loss in the close- or open-orbit status of the storage ring, and investigate the position of machine obstruction. Fig.4 shows the BLM record on the first day of the storage ring commissioning. At 19:17, the storage ring could not be operated in close-orbit status, and the beam loss mainly happened in the position of B03-1. By adjusting the machine parameters in this position, the storage ring resumed the close-orbit status at 20:00.

3.2 Beam loss during injection mode

Generally, the beam injection results in more beam loss and higher radiation level, which may destroy the equipment. High injection efficient is desired from the radiation safety and machine safety. The BLM system provides a useful tool for beam injection study. Fig.5 shows a typical beam loss track of the storage ring during the injection mode. The highest beam loss occurs during injection near the B01-0 position located in the first cell of storage ring. It was also found that the highest beam loss point is the inside part behind the first dipole magnet of B01-0. The possible reasons causing the beam loss in this position include the leak field, stronger power of the Septum magnet, and beam injection launching condition. This demonstrates that the BLM system is very helpful for injection study to optimize injection mode.

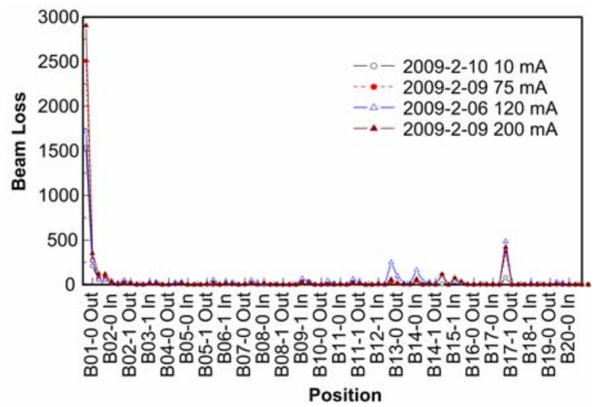

Fig.5 Beam loss in SSRF storage ring in injection mode at 3.0 GeV.

The SSRF storage ring also runs the top-up injection mode. Fig.6a shows the beam current of top-up injection mode for the DCCT. Fig.6b shows the beam loss at C16 in the storage ring. Beam loss peaks occurred at the instant of injection. From the magnitude of beam loss, we can have a better knowledge of the machine status.

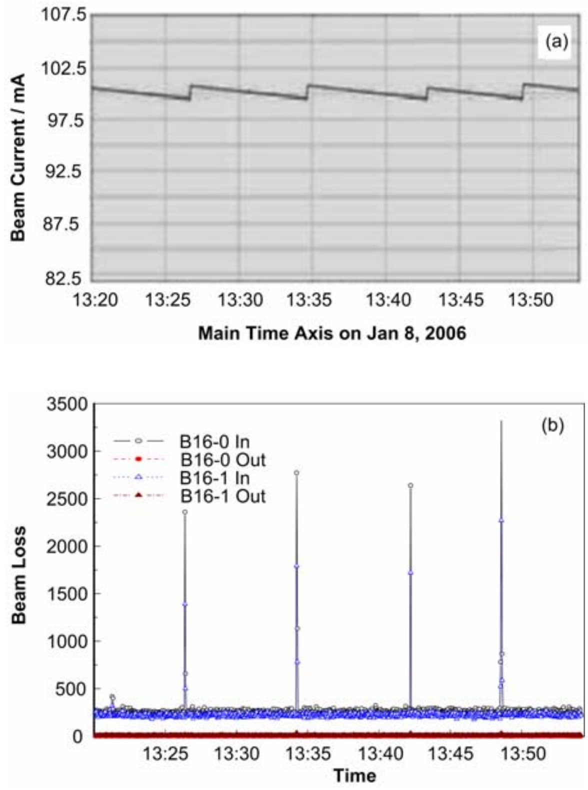

Fig.6 Beam loss for Top-up mode test in storage ring. (a) Beam current for Top-up mode test at 1 GeV, (b) Beam loss at C16 in storage ring.

3.3 Beam loss during normal-operation mode

When the storage ring was in the normal-operation mode, we obtained some interesting results, too. Fig.7 shows beam loss of the storage ring during normal- operation at different beam currents. This beam loss is different from the beam loss of injection mode. High beam losses were observed at B17. B05, B08 and B14, and at B15 the beam loss was fairly high. The beam loss positions were investigated. The B05 is behind the RF-cavity, B08 is behind the beamline of Undulator BL08U1, B14 is behind the beamline of Wiggler BL14W1, B15 is behind the beamline of Undulator BL15U1, and B17 is behind the beamline of Undulator BL17U1. The vacuum at these positions might be affected, and the vacuum life became short, which results in great beam loss. The highest beam loss at B17 was due to the biggest β-function in this position.

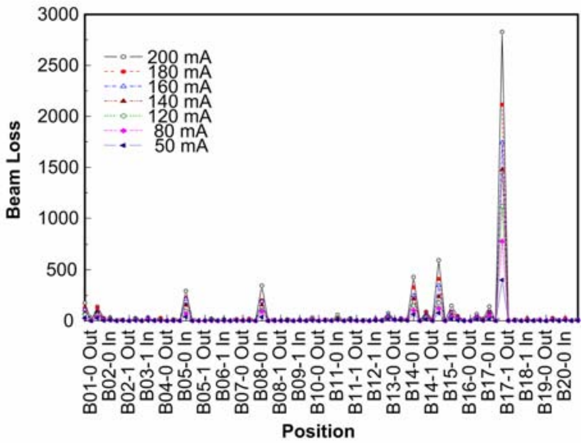

Fig.7 Beam loss for normal-operation mode in storage ring at 3.0 GeV.

4 Conclusion

The beam loss monitoring system has been installed in the storage ring of SSRF. It is a useful diagnosing tool for machine study and operation. In our future work, the control software will be integrated into the EPICS, which will be merged into the SSRF control system to provide more help on the machine study.

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