BEPC STORAGE RING BEAM LOSS MONITOR SYSTEM DESIGN

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Abstract

The Beijing Electron Positron Collider (BEPC) is a large experimental equipment for high energy physics as well as synchrotron radiation research in parasitic or dedicated mode. The beam loss phenomenon is frequently observed in the BEPC storage ring, especially when BEPC operates in the dedicated synchrotron radiation mode. Although the accelerator physics group has carried out some studies on this phenomenon, but so far this phenomenon has not well explained. The beam loss monitors (BLMs) have been developed for detecting and locating any possible excessive beam loss with the injection process, beam instabilities, bad vacuum, ion trapping, etc. This paper will discuss the system design considerations such as the detector-type selection, the BLM location in the ring and related experiment results, and so on.

1. INTRODUCTION

The BEPC facility consists of a 200-meter linac injector, a 120-meter beam transport line and a 240 -meter storage ring. The collider can provide beams for the high-energy physics experiment as well as for the synchrotron radiation research in parasitic and dedicated modes. Generally electrons and positrons are injected into the storage ring at the energy of 1.3 GeV and are then accelerated to 1.55 GeV for the collision or to 2.2 GeV for the synchrotron radiation research. The injected beam pattern is single bunch or multi-bunch when BEPC runs in the dedicated synchrotron radiation mode. The phenomena of the beam lifetime reduction or the beam sudden loss are frequently observed in the BEPC storage ring, especially when BEPC operates in the dedicated synchrotron radiation mode. These phenomena have some features as below:

- Likely occur at any beam current.
- May occur for any filling pattern (single bunch or multi-bunch).
- Sometimes the beam lifetime can be recovered by using some methods such as changing the RF voltage or applying an exitation on the beam, but sometimes the beam lifetime can't be recovered.

The accelerator physics group has made many machine studies and try to find the reasons of the beam loss. But the results of these machines studies are unsatisfied due to the lack of the effective beam diagnostic tools. According to the requirements of machine physics people, we developed this BLM system to detect and locate any possible beam loss. At present, this system is in the test operation. We just installed 20 detectors at some specified points along the half storage ring (quadrants Ⅰ and Ⅳ). Figure 1 shows the distribution of beam loss detectors along the BEPC storage ring. The beam loss detector's outputs connect to the front-end electronics, namely, counting devices as astral symbol shown in figure 1. Every counting device receives signals from two detectors installed inside the beam pipe of the storage ring in the horizontal direction.

All fron-end electronics were similar to that used in Hefei Light Source (HLS).

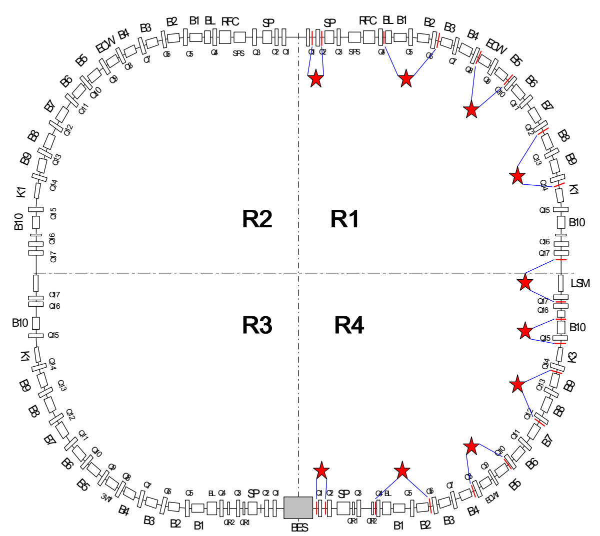


Figure 1: Distribution of Beam Loss Detectors along the BEPC storage ring

The system employs the PIN photodiode detectors designed at DESY. They can detect shower electrons induced by lost beam particles hitting the vacuum wall. The detecor is insensitive to the background of the synchrotron radiation around the storage ring and very small size and low unit cost which make it possible to monitor all locations where the beam loss is predicted. So we decided to adopt PIN photodiode as our BLM detectors. The specific model is BLM-XS of Bergoz company.

2. DETECTOR LOCATION

2.1 The beam loss mechanism

Beam loss mostly results from the inelastic scattering (including ion trapping), the Touschek effect and the quantum effect.

Inelastic scattering (Bremsstrahlung) mainly results from the collision between beam electron and nuclei of the residual gas molecules. It makes electrons loose energy ΔE. Thus the electron orbit has a change, which depends on the dispersion function (η) and on ΔE. The electrons may be lost at one of the next dispersion maximal point. Ion trapping and dust trapping can also results beam loss.

Touschek effect mainly exists in the low energy electron storage ring. In the BEPC case, the Touschek effect isn't serious. So we don't need to place the detector doublet inside and outside the beam pipe of the ring at each longitudinal position, just like HLS.

Quantum effect is mainly determined by the finite beam transverse apertures or energy acceptance when the beam is Gaussian particle distributions in 6-D phase space. With the enough RF voltage, the quantum lifetime is mainly dominated from the horizontal aperture, especially in the injection case. Because the horizontal aperture of the BEPC beam pipe is fairly large, so the quantum effect is not a serious problem.

2.2 The consideration for detector location

As mentioned above, the electrons may be lost at the dispersion function (η) maximal point and β function maximal point. So these dispersion maximal points and β function maximal points are the most sensitive positions for measurements of beam losses. BEPC has totally 40 bending magnets and 68 quadrupole magnets. Generally there are three operation modes, which are the injection mode, the collision mode and the dedicated synchrotron radiation mode. Because the beam loss phenomenon is frequently occurred when BEPC operates in the dedicated synchrotron radiation mode, we concentrate to study the lattice of this mode. Figure 2 shows the path of electrons through a FODO structure with an energy loss of $\Delta E/E$ = 1.5 % to 6 % when BEPC is running in the dedicated synchrotron radiation mode.

Because the full horizontal aperture of the BEPC beam pipe is 12 cm, beam electrons will hit the vacuum wall when electrons have an energy loss of $\Delta E/E$ > 4.5 %, as we can see in Figure 2.

With studies of the lattice structure of the dedicated synchrotron radiation mode and giving consideration to the lattice structure of the injection mode and collision mode, we decide to mount detectors on the inside of the beam pipe just behind the quadrupole magnets Q1, Q2, Q4, Q6, Q8, Q10, Q12, Q14, Q17, the wiggler magnet and Lambertson magnet. These positions are dispersion function (η) maximal points and β function maximal points.

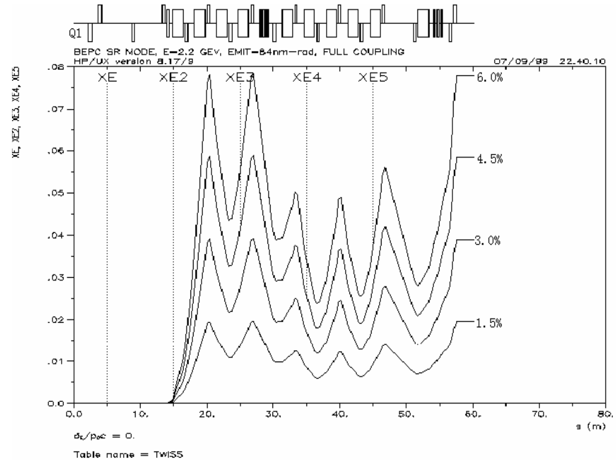


Figure 2: The path of electrons through a FODO structure with an energy loss of $\Delta E/E$ = 1.5 % to 6 %.

3. BLM SYSTEM STRUCTURE

Figure 3 shows the structure of BLM system. The BLM detector outputs feed to front-end electronics, the counting devices. All of the counting devices connect to a PC with the CAN bus. The PC console locates in the local control room. The counting device counts the pulses from the BLM detector and communicates with the PC console. Every two BLM detectors share a counting device.

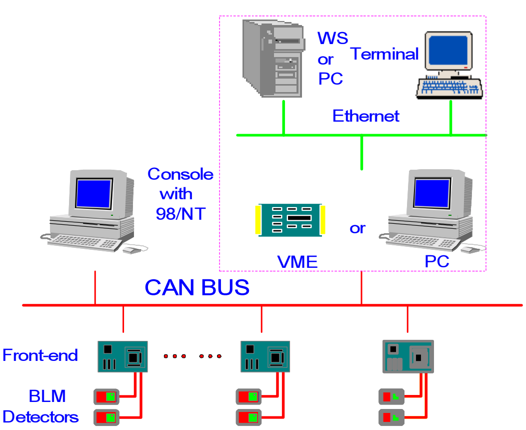


Figure 3: Structure of the BLM System

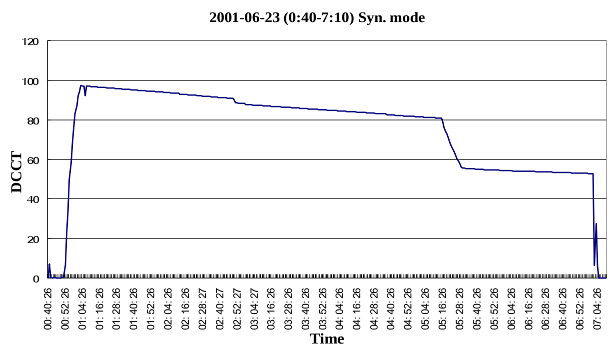
Just as we can see in figure 3, the system structure is a CAN bus based, distributed system along the storage ring. On the top level, a PC is employed as the console with Microsoft Windows 98 operation system running on it. The front-end electronics, the counting devices are on the bottom level. At present, there are totally 20 BLM detectors, which are mostly installed just behind the quadrupole magnets along the half storage ring (quadrants Ⅰ and Ⅳ). Every BLM detector is installed inside the beam pipe of the storage ring in the horizontal direction. One of the most important parts in the front-end electronics is a pulse accumulator, which counts the pulses from BLM detectors. The accumulator has two channels to connect the two BLM detectors respectively. The counting rate of the accumulator is higher than 10 MHz. The accumulator can work continuously without losing any pulse. For the implementation of CAN communications in our BLM system, a CAN-bus interface board model NI-PCI-CAN2 is plugged into the PC.

At present, we only developed a smallest system. The work to integrate BLM system into the whole control system of the BEPC storage ring has not finished yet. So up to now it is only a stand-alone system.

The software on the PC is developed with Microsoft Visual C++ 6, and is based on Microsoft Foundation Class Library. The software enables us to watch not only the data of every point in histogram, but also the curve display of data for a certain point as a function of time.

4. RESULTS OF MEASUREMENTS

When BEPC operated in the second run for the dedicated synchrotron radiation mode in this year, we began to put the BLM system into the test operation. Measurement results show us that this BLM system is sensitive enough to detect any slight beam loss. Figure 4 shows an example.



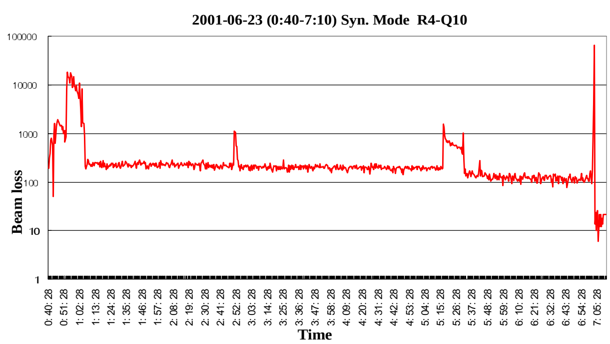


Figure 4: Beam losses on BEPC

The upper curve in figure 4 stands for the averaged beam current of the ring. The lower curve stands for the corresponding beam loss counting rate at the measurement point of R4-Q10. From the measurement results we can see that the beam loss goes down slightly after the injection. When the beam suddenly lost, the BLM's counting rate become higher.

At the test operation, we found that the integrated circuit chip used in counting devices for pulse forming frequently damaged. Using a Zener diode to limit the output pulse level from the BLM detector has solved this problem.

At the same time, according to the measurement results we also found that the beam loss was small near the RF cavity.

5. CONCLUSION

The distributed BLM system based on the CAN bus is able to detect the slight beam losses along the storage ring. PC and CAN bus are fast enough to display the real-time beam losses. The system is easy to be constructed and extended. We can easily measure any interesting point by simply adding a new detector and inserting a counting device into the CAN bus.

In addition, this BLM system can not only detect the beam losses, but also give more help on machine studies. For example, finding the position of the vacuum leakage, optimizing the running parameters of the storage ring, and studying the beam lifetime.

However, some measurement results have shown us that the beam loss counting rate couldn't match the corresponding beam lifetime, maybe this is because the measurement points are not more enough. So we will increase the measurement points covering the whole storage ring on the next step.

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