A NEW TOOL FOR BEAM-LIFE RESEARCH AT HLS STORAGE RING

Yuxiong Li [#], Juexin Li, Zuping Liu, Weimin Li
National Synchrotron Radiation Laboratory, University of Science and Technology of China
Hefei, Anhui 230029, P.R.China

Abstract

A beam loss monitoring system was set up for HLS（Hefei Light Source）last year. The beam loss message includes some beam life related factors. So, besides detecting vacuum failures in the storage ring, this system may serve as a useful tool in beam life research.

The beam life is composed of three parts: Touschek life, quantum life and vacuum life. The exact loss position of the corresponding stored electrons can be concluded if we detect shower electrons, which give a distinct clue of loss location, but not to detect bremsstrahlung photos or neutrons. So it is important to analyze the positions where beam losses take place and qualitatively distinguish them.

With the help of this system, the researchers have found and resolved following problems: A 20-40 mA beam loss frequently observed during ramping process; vacuum dead area near the front ends of beam lines; a beam life decline when a 6-Tesla superconducting wiggler was powered; etc.

PREFACE

We completed a beam loss monitoring (BLM) system for HLS (Hefei Light Source) last year. The original purpose was detecting vacuum failures in the storage ring. During the design stage, by calculation we found that the beam loss message includes some beam life related factors and it is possible to expend BLM system's function. It may serve as a useful tool in beam life research. This idea has been proved.

THEORETICAL ANALYSIS

Part of the beam loss component ΔI is measured by this system. For HLS, the total electron amount is about 10^{13} when the stored current is 100 mA and the loss rate is about 10^7/s if the 1/e beam life is 10 hours. There are about 10^4 records of lost electrons per second even if only 1/1000 of them can be detected. So it is easy to get high measurement sensitivity by this system.

The main points for designing and applying such a system in beam life research are as following: beam loss mechanisms, different components of the lost beam and how to distinguish them, suitable and cheap measurement devices, the best positions to install the devices along the storage ring.

The beam life can be roughly explained by following formula:

$$\frac{1}{\tau}=\frac{1}{\tau_T}+\frac{1}{\tau_q}+\frac{1}{\tau_v}$$

τ -beam life time τ_T- Touschek life time
τ_q-Quantum life time τ_v-Vacuum life time

Here τ_q can usually be omitted since it is much longer than τ_T and τ_v when the machine operates well. The collision among inner-bunch electrons is an elastic one and may bring about large momentum deviations and hence electron loss, that determines Touschek life τ_T. This kind of loss always involves a pair of electrons, for which the chances to hit inner or outer wall of the vacuum chamber are equal. The electron colliding with residual gas molecule may lose energy, and then hit the inward wall of the chamber during or after passing dipoles, if the energy loss exceeds a certain amount. By calculating we know the critical value of energy loss is about 2.4% and learn how the loss rate is distributed along the ring. [1]

Shower occurs when the electron hits the vacuum chamber wall. Among this process, shower electrons carry more distinct position information of lost electron than photos and neutrons do. To understand their distribution we tracked the shower electrons, whose energy down to 1.5 MeV, outside the vacuum chamber wall by EGS4 method. We use the detector which is very sensitive to shower electrons (the detection efficiency is over 30% to the shower electron whose energy higher than MIP) but nearly no response to photos and neutrons (its sensitivity to gamma is lower than 0.06%). Therefore where the electrons are lost can be determined.

The important thing is to analyze the different positions where various beam loss components take place. To qualitatively distinguish them, we will select corresponding measure points.

APPLICATION

Based on the theoretical analysis we completed this new beam loss monitoring (BLM) system.[2] In addition to the high sensitivity to vacuum failures, we have applied it in beam life research successfully. Different from the similar systems we use the detectors in pairs along the storage ring. Twelve pairs are fixed on 12 dipole exits separately and another one is fixed on the linear section. We think the sum of count rate coming from half of all the detectors, which are fixed on the outward chamber wall, may be more or less related with Touschek life time. The difference between the count rate sums from the detectors, which are fixed on the inward

lyx@ustc.edu.cn

and outward wall separately, reflects the vacuum life time. This BLM system has made an important contribution to machine study.

EXPERIMENTAL RESULTS

The system runs well after completed. The primary results we got are indicated below:

Additional beam loss during ramping process

The 200 MeV electrons will be ramped to 800 MeV after injected to the storage ring. There often existed 20-40 mA beam loss at the beginning of the ramping process. See Figure 1.

With the help of the BLM system we found this part of the beam loss took place at the downstream of the first dipole B01, the inner wall of the storage ring. We think this is because of the delay from the kicker closed to total stopped. Therefore the obit keeps moving after raping begins. We resolved this problem by locking the time between injection stops and ramping begins with a MCU. The beam loss at B01 decreased two orders of magnitude. The total beam loss is only several mA's during the ramping process. See Figure 2.

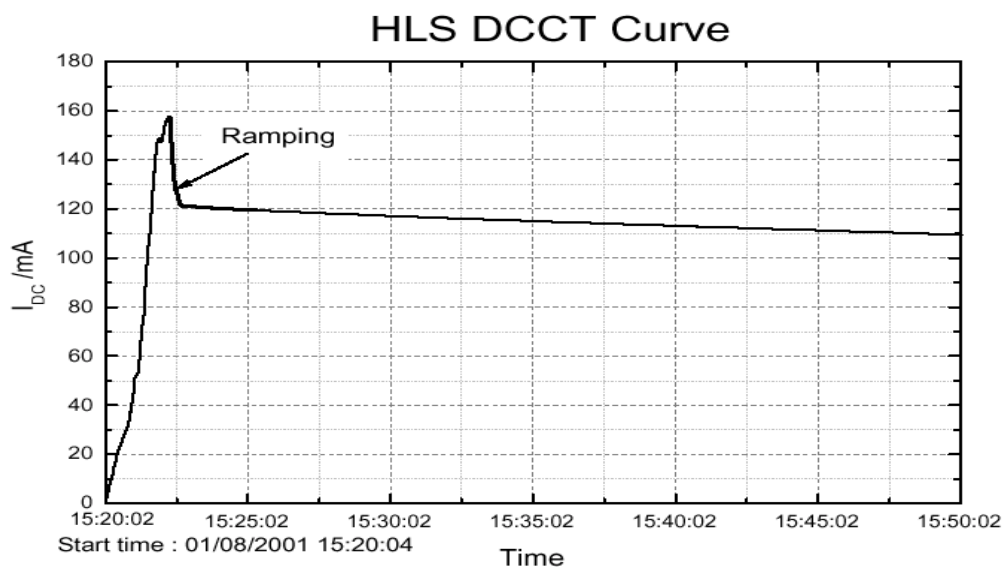

Figure1: The beam loss during ramping process before improvement

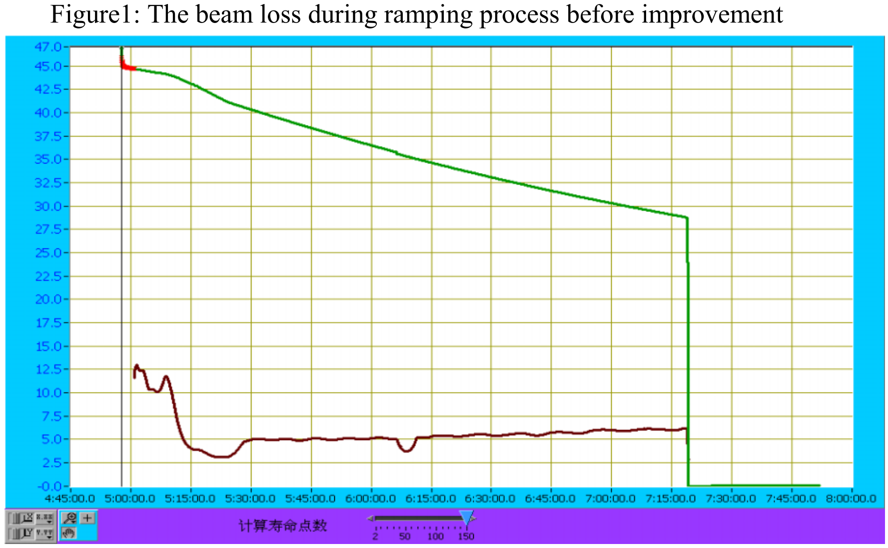

Figure2: The beam loss during ramping process after improvement

Beam loss caused by the accumulated gas at the front ends

Due to lack of vacuum pumps near the water-cooling masks at the front ends of photon beam lines, some gas was accumulated there and would impact the electron beam strongly later, when the gate valve was opened. This phenomenon was clearly recorded by the BLM system. We can see this phenomenon clearly in Figure 3. So the local vacuum system should be improved. Less beam loss will be propitious to beam life .

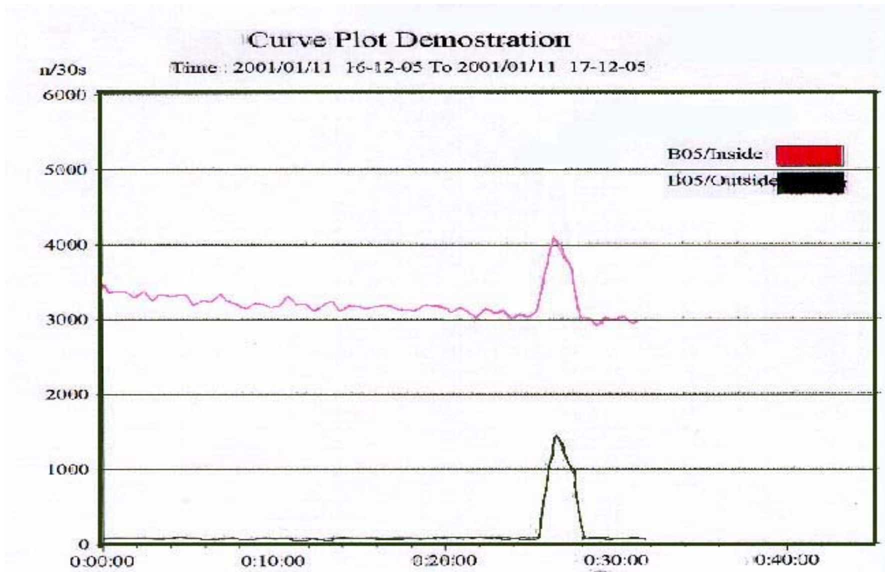

Figure 3: Beam loss caused by the accumulated gas at the front ends

The Influence comes from the superconducting wiggler

The beam lifetime decreased seriously when a 6-Tesla superconducting wiggler was powered if the machine operation parameters were not properly chosen. It once declined from 9.7 hours to 2.9 hours because of this, as a result of beta function distortion and quantum lifetime reduction. After calculations, a quadrupole strengths global compensation was carried out and let to a great success. Figure 4 is the beam loss before-and-after the global compensation. In Figure 2, the lower line is the beam life curve. The beam life suffered from a small drop caused by wiggler powering and it recovered after the compensation. The machine runs well after the parameters were readjusted.

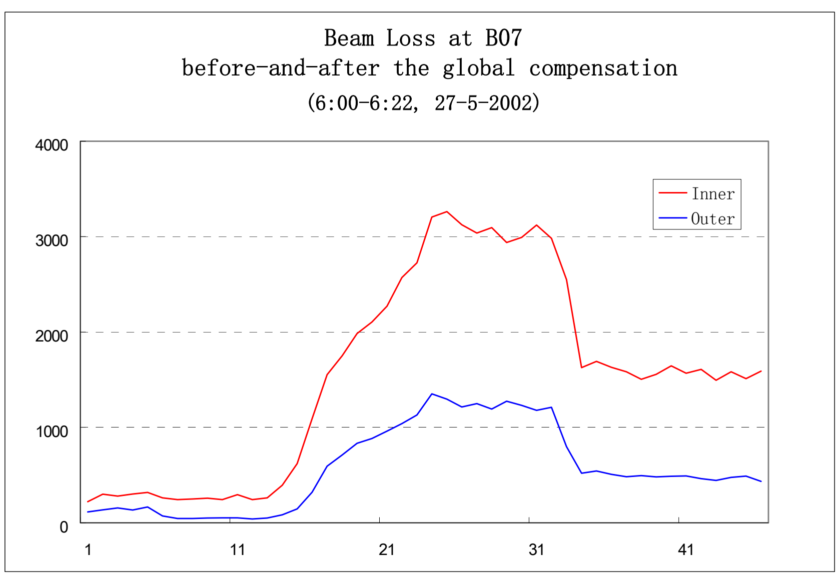

Figure 4: The beam loss before-and-after the global compensation

The BLM system for storage ring is outside the vacuum chamber, does not influence the machine operation and is reliable and cheap. It is really a useful new tool for beam life research.

REFERENCES

[1] Cui Yonggang etc. Nuclear Techniques,Vol.25(2002), No.2, p. 95-98,
[2] Li Yuxiong etc. NIMA 467-468(2001) p.80-83