THE BEAM LIFETIME STUDIES BY TWO SPECIAL SCHEMES

Ian C. Hsu, Cha-Ching Chu, G.-H. Luo, W. T. Weng, T.-I. Chen, C.-H. Lee, U.-H. Tsay, and C.-T. Wang
Department of Nuclear Science, Nation Tsing-Hua University
and
Synchrotron Radiation Research Center
Hsinchu, 30043 Taiwan

Abstract

The knowledge of the relative beam lifetime contributions from the Touschek effect and from the gas scattering effects, is very important for making the strategies of lengthening the beam lifetime. Two unequal bunches method was well known for this purpose. However, it is basically the single bunch lifetime. In multibunch operation, due to the beam size growth which could be caused by the couple bunch effects, the Touschek lifetime could be differed with that of the single bunch case by a significant amount. We proposed another method which is to fill every bucket and enlarge the vertical beam size by driving the beam into the difference resonance. In this case, the Touschek lifetime was enlarged by a factor of 10. This allowed us to estimate the gas scattering lifetime which including the ion effects if they exist. The ion effects will not show up if measured by the two unequal bunches method. Our measurement results do show that the Touschek lifetime was longer when measured by the multibunch method than that was measured by the two unequal bunch method.

1. INTRODUCTION

The intensity of the charged particle beam in storage rings will decrease with time. The parameter which describes this phenomenon is the beam lifetime. There are several well known effects[1] which cause the beam has finite lifetime. Particles lost by inter-beam scattering, i.e., scattering on the residual gas and ions inside the storage ring vacuum system, which also called as the gas scattering effects. Particles lost by intra-beam scattering, i.e., scattering between beam particles, which also called as Touschek effect. Particles lost by the statistical nature of the synchrotron radiation emission, which also called as quantum lifetime. Particles can also lose by beam instabilities. Usually, if a storage ring did not encounter vital instabilities the dominated beam lifetime effects are the gas scattering effects and the Touschek effect. Therefore, the knowledge of the relative beam lifetime contributions from the Touschek effect and from the gas scattering effects, become very important for making the strategies of lengthening the beam lifetime. For example, if the beam lifetime is Touschek effect dominated, we will try to increase the lifetime by increasing the RF voltage, increasing the physical or dynamic apertures, or decreasing the beam density by increasing the beam volume. However, if it is the gas scattering effects that dominates the beam lifetime, we will try to increase the lifetime by spending our efforts on improving the vacuum condition and/or getting ride of ions which may trapped by negatively charged stored beam. Two unequal bunches method[2] was well known for the purpose of separating the beam lifetime contributions from those two effects. However, what it measured is basically the single bunch lifetime. In multibunch operation, due to the beam size growth which could be caused by the couple bunch effects, the Touschek lifetime could be differed with that of the single bunch case by a significant amount. Also, if there are trapped ions in the multibunch operation mode, in this method, we will have more chance to miss counting the lifetime reduction due to the scattering between beam and ions which is considered as part of the gas scattering effects. It was because that we only filled two bunches; there will have one or two big gaps of the beam population in the storage ring. The ion trapping theory predicted that there will have less trapped ions. Therefore, We proposed another method which is to fill every bucket and enlarge the vertical beam size by driving the beam into the difference resonance. In this case, the Touschek lifetime was enlarged by a factor of 10. This allowed us to estimate the gas scattering lifetime which including the ion effects if they exist. Our measurement results do show that the Touschek lifetime was longer when measured by the multibunch method than that was measured by the two unequal bunch method. The results consistent with our prediction.

2. THE EXPERIMENTS AND RESULTS

The experiments were performed on the storage ring of Taiwan Light Source (TLS). In this section, we will present the beam lifetime measurement results by the two methods. We will compare both results and discuss them in the next section.

2.1 Two unequal bunch method

This was done by filling two bunches in the opposite bucket in the ring. One bunch had large current and one bunch had small current. Because Touschek effect was dependent on the particle density , if the bunch volume is the same for the two bunches, the particle density will be different, so as the Touschek lifetime. The assumption of the equal bunch volume is adequate as long as the current of each bunch is below threshold current of the microwave instability and the potential well distortion can be neglected. The threshold current of the microwave instability of the storage ring of TLS was measured to be above 3 mA. In all of the experiments in this method, the bunch current of the large one is always below 3 mA. According to the bunch length measurement of this machine, the potential well distortion is negligible for 3 mA beam current with 700 kV RF voltage. The lifetime due to gas scattering effects was dependent on the vacuum which will in turn be dependent on the total beam current which is the same for the two bunches. Therefore, we can measure the bunch current dependent of the beam lifetime of the individual bunch. Then subtract them, it will give us the information of the beam lifetime due to Touschek effect along. Subtracting the beam lifetime due to Touschek effect along from the total lifetime, we will get the lifetime due to gas scattering effects along. The individual bunch beam current was measured by the voltage signal of a broad band pickup. The measurement results was shown in Fig. 1. The horizontal axis is the difference of the two bunch currents in units of voltage. The vertical axis is the difference of the inverse of the bunch lifetime.

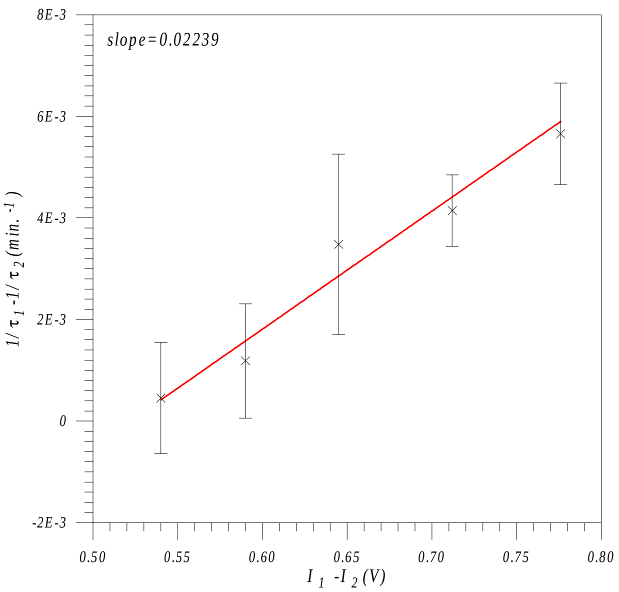

Fig. 1 The Touschek lifetime measurement by two unequal bunch beam.

From the slope, we can calculate the Touschek lifetime for a given bunch current. The detail formula can be found in the Ref. 2. The results we find here is

Touschek lifetime(hrs) = 6.1/single bunch current(mA)

For 195 mA total beam current (filling 140 bunches), the single bunch current is 1.39 mA. The Touschek lifetime is 263 mins. The measured total beam lifetime at 195 mA with multibunch mode was 238 mins. Subtracting 1/(263 mins) from 1/(238 mins), we got the beam loss rate due to the gas scattering effects along is 1/(2500 mins), i.e. the gas scattering lifetime at this current and the condition we did the experiment is 2500 mins. Later we will prove that this results under estimate the gas scattering lifetime in multibunch mode due to the over estimation of the Touschek lifetime. The over estimation was caused by using the single bunch Touschek lifetime as the multibunch Touschek lifetime without correcting the bunch lengthening effects due to the couple bunch effects.

2.2 The Multibunch method

In this method, we first measured the total beam lifetime at the multibunch mode with the normal transverse beam size. The beam current was 195 mA with beam lifetime, τ_{o_total} = 238 mins. Then we driven the beam into the difference resonance and increased the transverse beam size by a factor of 10. The beam current was 194.3 mA with beam lifetime, τ_{total} = 960 mins. If we ignored the difference between the beam current of 195 mA and 194.3 mA. We can simply solve the following two equations to get the Touschek lifetime, τ_T = 285 mins and the gas scattering lifetime, τ_{gas} = 1443 mins which including the ion effects if they exist.

$$1/\tau_{o\_total} = 1/238 = 1/\tau_T + 1/\tau_{gas}$$

$$1/\tau_{total} = 1/960 = 1/(10\tau_T) + 1/\tau_{gas}$$

The results are correct for the multibunch mode because all of the measurements are done in the multibunch mode.

3. DISCUSSIONS

The measurement results in section 2 do showed that the Touschek lifetime was longer when measured by the multibunch method than that was measured by the two unequal bunch method. The reason of that is because that in the two unequal bunch method, we had used the single bunch Touschek lifetime for multibunch Touschek lifetime which cause the over estimation of the multibunch Touschek lifetime. The reason that the multibunch Touschek lifetime is longer is because of the bunch lengthening effects which is due to the couple bunch effects. In Fig. 1, we saw the large measurement error bar. It is the intrinsic character of this type of measurement because we are subtracting the inverse of two small numbers and then taking inverse of the result.

If there is a small error occurred in the two small numbers, it will cause a big change in the final result. The multibunch method reduced this kind of error by enlarge both of the two small numbers. Also, in the multibunch method, we can use DCCT to measure the beam current which has higher accuracy than that of the broad band pickup used in the two unequal bunch method.

With the new method, we can also measured the decrease of gas scattering lifetime due to closing down the Wiggler. This is useful knowledge for figuring out the lifetime shorten mechanisms due to closing the Wiggler.

4. ACKNOWLEDGMENT

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[2] J. C. Besson, and et al., *Commissioning of Super-ACO*, ORSAY Report **RT** - 88-01, p. 34.