LSB/01-96/ER

Papers presented at the

5th European Particle Accelerator Conference, EPAC-96

Sitges, Barcelona, Spain, 10 - 14 June 1996

by the

Laboratori del Sincrotró de Barcelona - IFAE

LSB
LABORATORI DEL SINCROTRÓ DE BARCELONA

LIFETIME CALCULATIONS FOR THE LSB STORAGE RING*

F.Pérez and M.J.Vicente
Laboratori del Sincrotró de Barcelona - IFAE
Edifici Cn, Universitat Autònoma de Barcelona. E-08193 Bellaterra, Spain

Abstract

A total lifetime of more than 24 hours has to be achieved in order to ensure a good performance for the LSB Light Source. There are two main processes contributing to the overall lifetime: the beam residual gas scattering and the Touschek scattering. The beam residual gas lifetime is determined mainly by Coulomb and Bremsstrahlung scattering on the nuclei of the residual gas. An analysis of the contribution of each of these processes as a function of the vacuum pressure, the composition of the residual gas, the physical acceptance and the momentum acceptance will be presented. Later on the effect of the introduction of Insertion Devices with small gap in the Storage Ring will be analysed.

1. INTRODUCTION

A great variety of processes can produce a continuous loss of electrons of the beam. In this paper we will deal with losses due to single particle scattering, and no mention of the losses due to the instabilities is made.

The scattering of one electron by another electron of the beam or by the residual gas can bring the electron out of the acceptance of the machine, then this electron is lost. The beam current slowly decreases due to this continuous loss, and the time during which the beam current decreases down to 1/e of its initial value is called the lifetime. We have analysed each one of the phenomena that affect the lifetime of the beam: Intrabeam scattering (IBS), Touschek, Coulomb, Bremsstrahlung, and elastic and inelastic electron-beam electron-gas scatterings. Finally, the conditions for the LSB to have a lifetime greater than 24 h and the influence of micro-undulators are presented.

The LSB Storage Ring [1] is planned to operate in two modes: the multibunch (MB) mode, where 250 mA will be stored in the machine by filling 294 contiguous buckets, leaving a gap in the bunch train in order to minimise the ion trapping effect; and the single bunch (SB) mode, where only one bucket is filled with a current of 10 mA.

2. INTRABEAM SCATTERING

Multiple small-angle Coulomb scattering within a bunch causes diffusion of the particles, leading to an increase of the emittance. This effect has to be added to the radiation damping and the quantum excitation, that define the natural emittance, in order to find the new equilibrium emittance. Calculations of this equilibrium emittance as a function of the beam energy have been done with the code ZAP [2] for the MB and the SB operation modes. Figure 1 shows the result for the SB mode, where the IBS is more relevant because the electron density is higher.

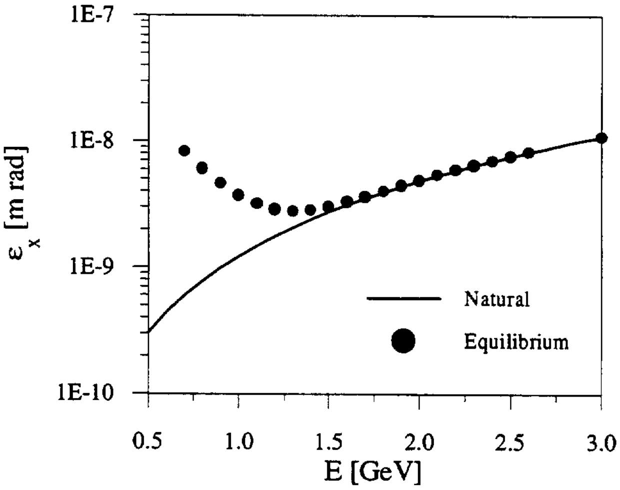

Figure 1. Natural and equilibrium emittance

At low energy the effect of the IBS is very pronounced, for example, at 1 GeV the equilibrium emittance is three times larger than the natural one. Nevertheless, at the nominal energy of the storage ring of the LSB, that is 2.5 GeV, the IBS effect is inappreciable and can be ignored in further lifetime calculations.

3. TOUSCHEK SCATTERING

Single large-angle Coulomb scattering within a bunch can induce a momentum deviation of the electron larger than the energy acceptance of the machine. When this happens the particle is lost and the beam lifetime is reduced. For a fixed beam energy, this effect depends mainly on the energy acceptance and on the electron density of the bunch. The bunch density depends on the bunch current. Figure 2 shows the calculations of Touschek lifetime as a function of the momentum acceptance for 0.9 mA/bunch (MB) and for 10 mA/bunch (SB). For the singlebunch mode, the bunch lengthening due to microwave instability has been taken into account.

---

* Work supported by CIRIT and CYCIT

For the MB mode, with a momentum acceptance of 2%, the Touschek lifetime is around 55 h. For the SB mode, a lifetime of 11 h is obtained for an energy acceptance of 2.8%.

To obtain these acceptances a RF peak voltage of 2.2 MV for the MB operation and 3.4 MV for the SB operation are required [3].

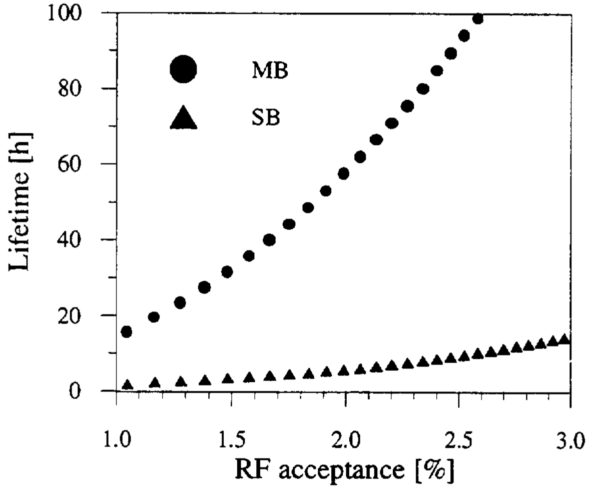

Figure 2. Touschek lifetime for MB and SB operation

4. BEAM-GAS SCATTERING

The scattering of the electrons of the beam with the residual gas atoms in the vacuum pipe is mainly determined by the vacuum system. This scattering depends obviously on the composition of the residual gas, that is on the atomic number Z, but it also depends on the vacuum level and on the different acceptances of the machine. There are four distinct scattering processes:

- *Bremsstrahlung (B).* It is the inelastic scattering of the beam electron with the residual gas nuclei. The electron is decelerated in the collision, losing its energy by electromagnetic radiation.
- *Coulomb Scattering (C).* Elastic scattering of the beam electron with the residual gas nuclei.
- *Elastic Scattering (E)* of the beam electrons with the electrons of the residual gas.
- *Inelastic Scattering (I)* of the beam electrons with the electrons of the residual gas.

The physical acceptance is determined by the vacuum pipe dimensions, that for the LSB it is an ellipse of 80mm x 40mm. Assuming a momentum acceptance of 2%, figure 3 shows the dependence of the lifetimes for the four distinct processes as a function of pressure for N_2 equivalent gas. As can be seen the most limiting effect is the Bremsstrahlung. The elastic scattering lifetime is not shown because it is more than one order of magnitude greater than the others.

The residual gas in the vacuum pipe will be a mixture of different compounds, and this mixture will be different depending on the conditioning. At the beginning of the conditioning one expects to have a mixture of H_2, CO, CO_2 and CH_4, which globally is well reproduced by considering $\langle Z^2 \rangle = 50$, or N_2 equivalent. Providing the vacuum system keeps a pressure of 10^{-9} Torr of N_2 equivalent the total beam-gas lifetime is around 37 h.

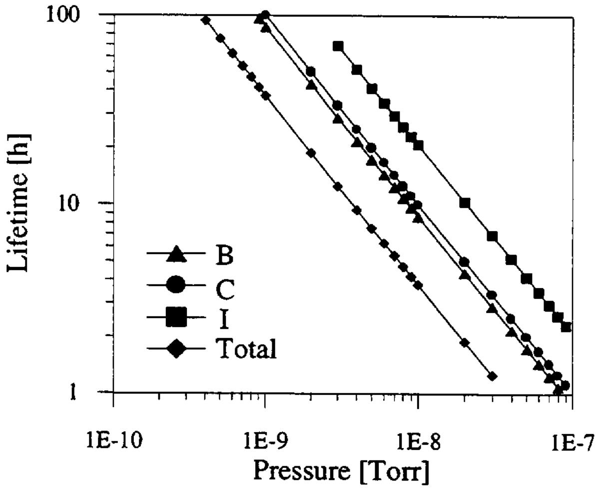

Figure 3. Beam-Gas lifetimes

On the other hand, after the self cleaning conditioning one expects to find mainly two compounds, H_2 and CO. Figure 4 shows the beam-gas lifetimes as a function of the different proportion between these two compounds for a pressure of 10^{-9} Torr.

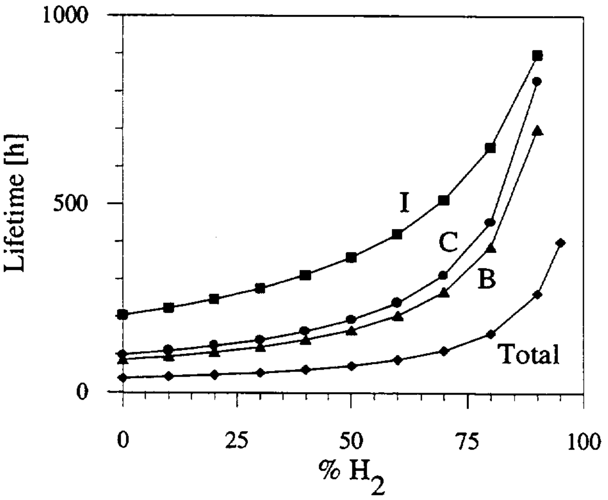

Figure 4. Beam-gas lifetimes as a function of the mixture of H_2 and CO

The lifetime increases with increasing the H_2 proportion. For an expected composition, after a good conditioning, of 80% H_2 and 20% CO, the beam-gas lifetime is around 150 h. That means that a good conditioning procedure will improve the beam lifetime, as it is well demonstrated in the existing machines [4].

5. LIFETIME

Table 1 gives the lifetime obtained for the different processes a vacuum pipe of 80 mm x 40 mm, for a pressure of 10^{-9} Torr of N_2 equivalent, and for a 2% (MB) and 2.8% (SB) of energy acceptance.

Table 1. Lifetime for the different phenomena

Scattering Process	Lifetime [h] MB - SB
Touschek	55 - 11
Bremsstrahlung	86 - 96
Coulomb	100 - 100
Elastic	4100 - 5750
Inelastic	206 - 236
TOTAL	22 - 8

The total expected average lifetime for the MB operation is around 22 h, which is slightly below our design goal. However, after the conditioning we hope to increase the beam-gas lifetime by reducing the average atomic number of the residual gas composition. Then, the expected lifetime for the operating machine will be well above 24 h.

The evaluation of the lifetime as a function of the position in the cell is interesting in order to determine the critical points around the machine. Figure 5 shows the loss rate, the inverse of the lifetime, as a function of the co-ordinate s through the cell.

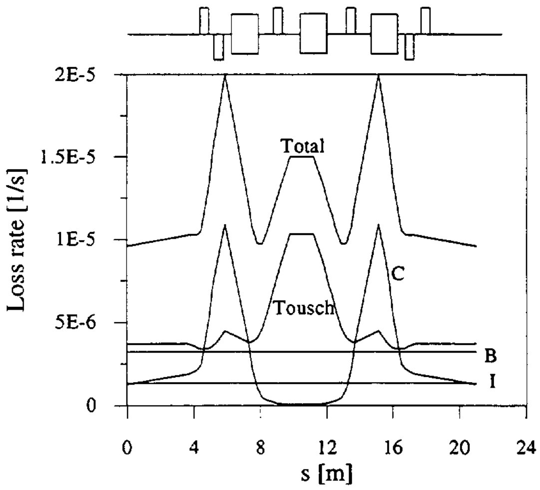

Figure 5. Lifetime in a cell

The Inelastic and the Bremsstrahlung effects do not depend on the optical function, whereas the Coulomb and the Touschek effects follow the betatron functions.

The Coulomb scattering is the limiting effect at the defocalizing quadrupoles, where the vertical beta function is maximum, that is where a small deflection can take the electrons out of the physical acceptance. Therefore, to minimise the Coulomb loss of electrons it is convenient to enhance the vacuum pressure near the quadrupoles, which is accomplished by locating the vacuum pumps at these positions.

6. SMALL GAP FOR ID

The LSB storage ring is designed with the aim of incorporating the new micro-undulators with a millimetric gap. The influence on the lifetime of having straight sections with small vertical dimension is analysed.

In this section we assume that the vacuum level is maintained at 10^{-9} Torr and that the Touschek is limited by the RF acceptance. Then, the only phenomenon that depends on the vertical acceptance is the Coulomb scattering. Table 2 gives the Coulomb and the total lifetime for different gaps.

Table 2. Lifetime for ID gaps

GAP [mm]	Coulomb [h]	Total [h]
40	100	22
30	98	22
20	92	21
10	67	20

From these results, the insertion of small gap ID will not reduce significantly the total lifetime of the machine. However, it is worth to notice that the pressure in the small vacuum chamber of the ID will fall down due to the smaller conductance of the tube. That effect will reduce the beam-gas lifetime. Moreover, if the coupling between the horizontal and vertical planes induces dispersion in the vertical direction, the small gap can limit the momentum acceptance, and then the Touschek lifetime will decrease. Calculations of this effect are under way.

CONCLUSIONS

The phenomena that affect the lifetime of the beam have been analysed and calculated for the LSB. A good bake-out conditioning and a good strategy to place the vacuum pumps will ensure a lifetime greater than 24 h for the multibunch operation with 250 mA beam. The lifetime for the single bunch mode is limited by the Touschek scattering, with a comfortable lifetime of 8 h. A priori, the introduction of ID with small gaps will not significantly reduce the beam lifetime.

REFERENCES

[1] M.Muñoz. *Linear lattice for the LSB Storage Ring.* These proceedings.

[2] M.S.Zisman, S.Chattopadhyay and J.J.Bisognano. *ZAP Code.* Lawrence Berkeley Laboratory (1986).

[3] F.Pérez. *A proposed RF system for the LSB.* These proceedings.

[4] R.P.Walker et al. *Beam Lifetime in ELETTRA.* Proceedings of EPAC'94 (1994).