EFFECTS OF LOCAL PRESSURE BUMPS ON BEAM LIFETIME AND GAS BREMSSTRAHLUNG

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Abstract

An experimental apparatus permitting to inject various gases (H_2, N_2, CO, Ar, Kr) into the storage ring during machine operation is described, thereby simulating local pressure bumps of the kind that are present in new ID chambers which have no intermediate pumping. Results of lifetime and gas bremsstrahlung at different currents, ID gaps, and with various partial pressure conditions are presented and compared with results obtained during commissioning of new ID chambers.

1 INTRODUCTION

Some extruded aluminum insertion device vacuum chambers have recently been installed in ELETTRA, in replacement of the standard stainless steel vessels. Like a previous stainless steel type these chambers lack lateral pumping. Although an in-situ bake-out at 120° C was performed, the main conditioning of those chambers was achieved by means of the synchrotron radiation. During conditioning the local static pressures were high starting from some 700 pBar and arriving at the end of the conditioning at the nominal pressure of about 0.1 pBar after about 100 Ah of accumulated current[1,2]. The bremsstrahlung related dose reaches its minimum after at least 150 Ah [3].

It is known [4] that high local pressure profiles and heavy gas species can change very drastically the beam lifetime however there are still many unanswered questions such as:

- What is the peak pressure, since the new chambers lack lateral pumping and/or measuring systems.
- What is the dominating gas there (RGA systems exist but are quite distant)
- What is the trend of gas bremsstrahlung as a function pressure.
- What is the trend of gas bremsstrahlung as a function of ID gap.

A controlled gas injection experiment is the best procedure in trying to answer those questions [4].

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1.1 Experimental Apparatus

The drawing of the gas injection system allowing a local pressure increase in the storage ring is shown in fig. 1:

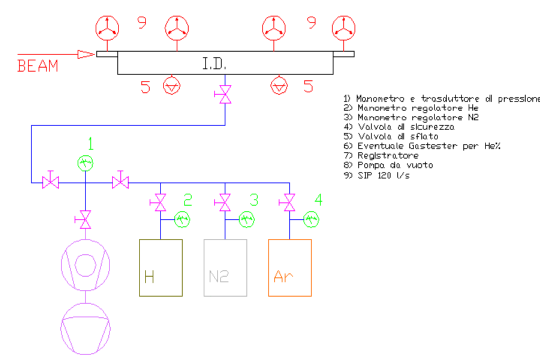

Fig. 1 - Experimental arrangement allowing gas injection into the ELETTRA storage ring

Using this layout 2 different gases (N_2, Ar) were injected through the dosing valve into the insertion device vacuum chamber ID_S3 creating a local "pressure bump" up to 8 e-7 mbar. Using Ar the bremsstrahlung with different gaps of ID_S3 was measured as well as the lifetime, elastic gas scattering lifetime and pressures. With N_2 only lifetimes and bremsstrahlung. were measured. These measurements were compared with the conditioning data.

2 RESULTS AND DISCUSSION

2.1 Lifetime behaviour

In Fig. 2 the lifetime versus the dynamic pressure is plotted for local pressure bumps of N_2 and Ar as well as natural pressure bumps during conditioning of the Aluminum chambers. For comparison old data from H_2 are included. The pressure indicated is read from the lateral pump SIP120_Sn.4 which is the pump at the beginning of the straight low gap chamber. It is very interesting to observe that the conditioning data indicate the existence of gasses with atomic number Z similar to Ar rather than N_2. In the straight low gap chamber S3 used for gas experiment there is one more measuring gauge closer to its center and indicate pressures up to 3 times higher (see fig. 3). It is thus plausible to assume that the maximum pressure amplitude lies within an order of magnitude higher in the center of a long straight section.

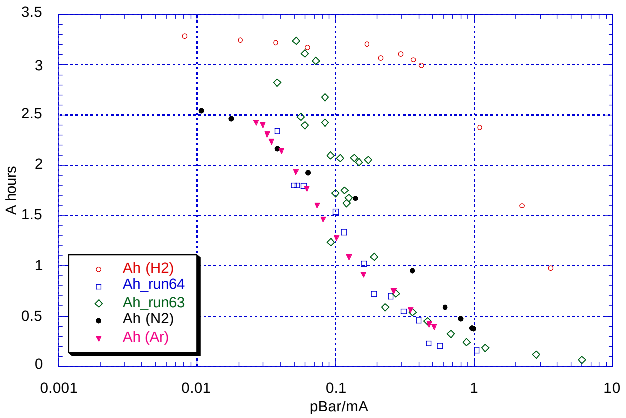

Fig. 2 – Product of lifetime and beam current as a function of local dynamic pressure

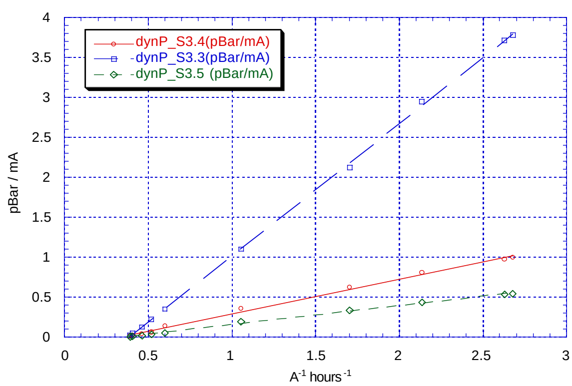

Fig. 3 - Dynamic pressures measured from the pumps at each side (circles, diamonds) and with a Penning head close to the center where gas injection occurs (squares).

2.2 *Elastic Gas Scattering*

Lifetime measurements have been performed with injected Ar and N_2 as a function of the limiting vertical aperture, using remotely controlled scraper blades, in order to determine their elastic scattering constants b:

$$\frac{1}{\tau} = \left(a + \frac{b}{A^2}\right)\left(P_0 + P_1 I\right) + c\,I$$

where a and c are the inelastic and Touschek scattering terms respectively, P_0 refers to the pressure in the absence of beam, P_1 is the gas desorption and A is the vacuum chamber limiting half aperture.

It is already a known fact that at ELETTRA scraper lifetime experiments in a good vacuum do not confirm the usual assumption of H_2 or even N_2 gas prevalence [5,6].

Figure 4 shows the results of the scraper measurements for the injected gasses as well as for a rather high "natural" local bump at the beginning of the conditioning of chamber S2. The normal high vacuum scraper measurement data have been subtracted so that one eliminates the Touschek and other scattering contributions. It is very interesting to observe that the deduced constants b (see table 1) are very close to their theoretically calculated values. The values approach further the theory when the linear fits are made for the smallest apertures or for high pressures where lifetime measurements are more precise.

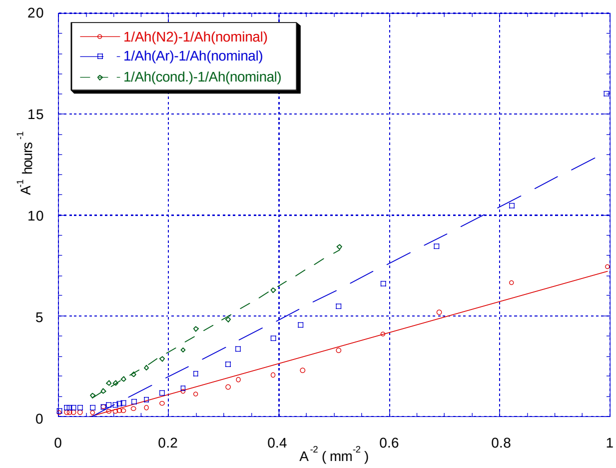

Fig. 4 – Inverse current lifetime product versus inverse square of the vertical scraper blade half aperture.

Table 1: Results of scraper lifetime measurements

Kind of gas	Slope (mm^2/ h)	P1 nTorr	b (mm^2 /h nTorr)	b theory
N2	7.6	75	0.101	0.13
Ar	14	46	0.304	0.39
10 Ah of condit.	16.5	60	0.28	---

The pressures quoted are the maximum measured. For the conditioning data where no central pressure measurements are possible, we have assumed that in the middle of the chamber the pressure is 3 times greater than that at the edges (as indicated in Fig. 3). It is interesting to observe that the measured elastic scattering constant ratio of bs for N_2 and Ar is (b_{Ar}/b_{N2} =) 3.0 very close to their atomic number ratio $r = nZ_{Ar}\;Z_{Ar}(Z_{Ar}+1)/nZ_N\;Z_N(Z_N+1) = 3.05$ (Nitrogen Z=7 and nZ=2, Argon Z=18 nZ=1). Assuming the same confidence level for the aluminum conditioning data, the measured elastic scattering constant seems to correspond to gasses with Z(Z+1) similar to that of Ar, CO_2 being the nearest. RGA analysis however indicates lower levels of CO_2 compared to CO.

2.3 Bremsstrahlung measurements

During the gas injection experiment, bremsstrahlung measurements have been performed placing a standard ionisation chamber inside the front-end hutch of the beam-line. As a matter of fact primary bremsstrahlung emission was not measured, but the secondaries generated in the interaction of bremsstrahlung gamma rays with the switching mirror chamber. The switching mirror itself was removed from the beam path and the gamma rays interacted with a copper block placed at the end of the mirror chamber.

The aim of measurements was to analyze the trend of dose-rate versus pressure and for a fixed gas pressure, the trend of dose-rate vs. undulator gap. As expected the dose-rate/current decreases linearly with pressure since bremsstrahlung emission is proportional to the number of molecules encountered by the electron beam on its path [4].

In the second experiment Argon was injected in the same straight section at two pressures (about $6.5 \cdot 10^{-8}$ mbar and $3.9 \cdot 10^{-7}$ mbar) and radiation measurements were carried out closing the insertion device at different gaps.

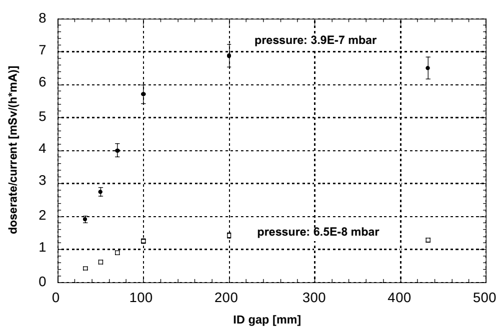

Fig. 5 - Normalized bremsstrahlung rate versus undulator gap with gas injection.

As shown in Fig. 5 a decrease of bremsstrahlung emission was observed while closing the gap: the ratio between the dose measured at ID maximum aperture and at minimum gap was about 3. Similar measurements were performed without gas (during normal machine operations) both at the same section and at another beam-line, where an aluminum vacuum chamber had been installed. It is important to say that the experimental conditions (interaction thicknesses, distances between detector and interaction point of radiation, pressure, etc.) were different for the two chambers. As far as pressure is concerned, in the aluminum chamber there was no possibility of evaluating pressure in the middle of the section because the chamber was lacking lateral pumping points. The average of the pressure values measured at the extremities was about $2 \cdot 10^{-8}$ mbar, an order of magnitude higher than the pressure measured at the various lateral pumping points of the stainless steel chamber (about $1.5 \cdot 10^{-9}$ mbar). Fig. 6 shows the plots of dose-rate/current vs. undulator gap aperture for the two chambers. To allow the comparison of the trends, data are reported using double y-axis.

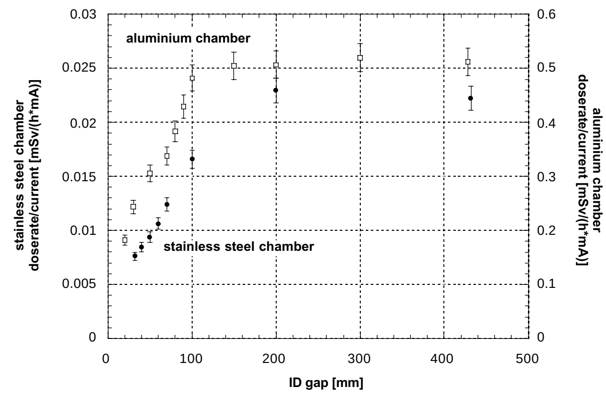

Fig. 6 - Doserate/current as a function of ID gap for the stainless steel and the aluminum chamber.

It can be seen that, the trend of dose versus ID gap found in the gas injection experiment is confirmed also during normal vacuum conditioning [3] and the decrease factor is about the same for both the chambers. This trend could be due to the fact that the increase of the magnetic field with ID closure limits the trajectories of photoelectrons emitted from the irradiated surface and hence reduces the resulting molecular desorption, and consequently also the gas bremsstrahlung rate.

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