DORIS III AS A DEDICATED SOURCE FOR SYNCHROTRON RADIATION

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Abstract

In May 93 the operation of DORIS for high energy physics was discontinued and the ring became a dedicated source for synchrotron radiation operated at 4.5 GeV. Meanwhile a multibunch feedback system to control beam instabilities had been installed and positrons were stored instead of electrons. The resulting improvements and also the present status are described by discussing some important parameters and their limitations. These parameters include the beam lifetime, the maximum stored currents, the number of bunches, the beam dimensions and aperture, orbit distortions, position control of the photon beams, the reliability and the influence of the 10 insertion devices on the stored beam.

INTRODUCTION

DORIS has been in operation for high energy physics and synchrotron radiation (SR) since 1974. During this period it was rebuilt several times, the last time in 1991. The new ring is called DORIS III and has been described elsewhere.[1] In 1993 it became a dedicated source for SR which now operates with 10 insertion devices (ID). As there have only been minor changes in the magnetstructure in the arcs since 1974, the horizontal emittance is rather large (ϵ_x = .4 $\pi\mu$m at 4.5 GeV) . Thus DORIS cannot be a high brilliance ring, but the photon flux is large. The performance of the ring will be described by discussing some important parameters.

I. BEAM LIFETIME

In Fig. 1 the current of 5 almost equally spaced e^- -bunches is plotted vs time. The lifetime is in general shorter than it would be expected from the vacuum pressure and is also subject to sudden changes. It cannot be increased by varying any machine parameter and the average lifetime of a fill becomes shorter when more current is injected. This limits the maximum current to about 80 mA. The behaviour of the lifetime may be explained by positively charged particles that are captured by the e^- - beam.

According to this hypothesis the polarity of DORIS and of the preaccelerators has been reversed and positrons are now stored instead of electrons. The result is shown in Fig. 2. The lifetime now is in agreement with the vacuum pressure and after some cleaning by beam varies between 15 h and 24 h for currents between 110 mA and 70 mA in 5 bunches.

The lifetime critically depends on the tune for synchrotron and betatron oscillations, especially if the IDs are closed. The maximum field of a 4 m long wiggler is 1.8 T. If the tune variation from the optimum values is larger than .01 for betatron- and .002 for synchrotron oscillations the lifetime is reduced to about 1 h. This is uncomfortable but can be handled. It is not surprising that the area in the tune diagram free from resonances is so small, as the superperiodicity of DORIS III is only 1 and as the IDs generate additional resonances. [2] Moreover satellite resonances

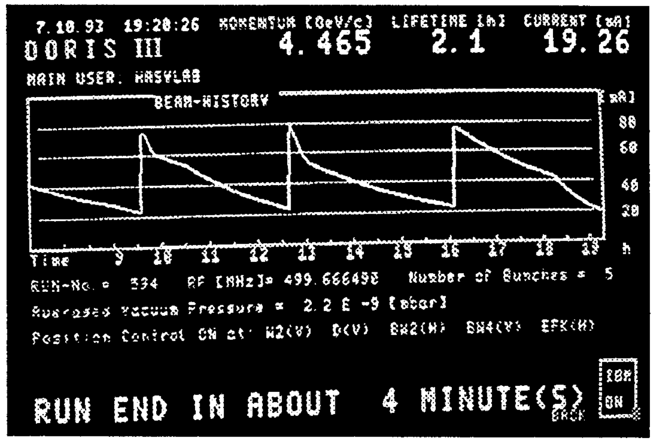

Figure 1. Electron current versus time

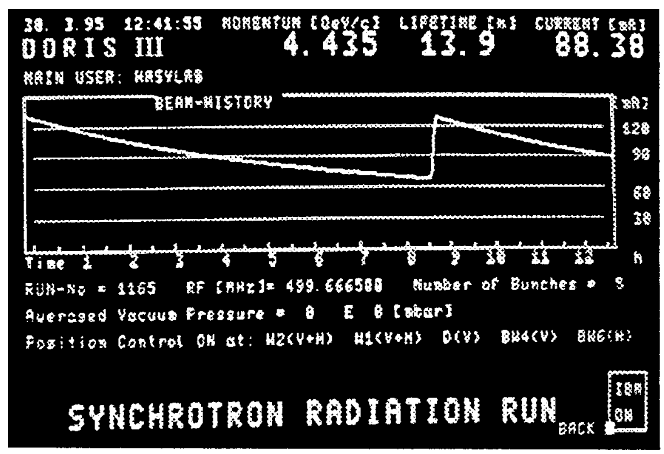

Figure 2. Positron current versus time

are also excited by the horizontal dispersion of about 1.5 m at the cavities and the vertical dispersion of about .15 m at the sextupoles. [3]

II. MAXIMUM CURRENTS AND NUMBER OF BUNCHES

The threshold current for beam instabilities in DORIS III is nearly independent from the number of bunches about 40 mA without feedback system. Therefore a multi-bunch feedback system (MBFB) [4] has been installed that stabilises all focussing oscillations. The distance between successive bunches must be larger than 96 nsec. So a maximum of 10 bunches can be filled out of the possible 482. In table 1 the number of bunches n is given that may be used together with the target and achieved current.

Table 1: Number of bunches and current

n	target [mA]	achieved [mA]
1	35-40	40
2	70-80	80
5	150	160
10	200	-

The target current is limited either according to the MBFB or to higher order mode losses or to the heat load by SR. At 200 mA and 4.5 GeV the vacuum chamber will be loaded by 600 kw, corresponding to a power density of 8 kw/m in the arcs.

At about 150 mA there is at present a current limit due to beam loading. Therefore 10 bunches have not yet been tried seriously. For users 5 bunches are normally filled. That allows high current and time resolved measurements as well.

III. PARASITIC BUNCHES

For time resolved measurements it is important that only the designated RF-buckets are filled. If other buckets contain particles they are called parasitic bunches and may disturb the measurements considerably, at least if their intensity is larger than 10^{-4} of the main bunch.

In DORIS III parasitic bunches have been observed up to 70 nsec, or 35 buckets, behind the main bunch. Their relative intensity varied between 10^{-2} and 10^{-5}. Basically they are generated by an energy mismatch between PIA and DESY II:

Positrons from LINAC II are accumulated in the 450 MeV-storage ring PIA and than injected as single bunches into the 7 GeV synchrotron DESY II. [5] In DESY II they are accelerated to the working energy of DORIS III. [6]

450 MeV is a rather low energy for DESY II. Therefore the dipole current and correspondingly the energy may vary by nearly 1 % from injection to injection. As a consequence there are cycles in DESY II for which the energy deviation of the positrons is so large that they are outside the separatrix, but inside the energy acceptance. Due to their small relative energy loss per turn of 3×10^{-7} [6] these positrons may drift over several buckets until they are finally captured, either by emitting a photon or by the increasing magnetic field of DESY II.

By avoiding the injection of those cycles into DORIS and by setting optimum injection conditions for the other cycles in DESY II, the intensity of parasitic bunches can be made smaller than 10^{-6} of the main bunch. This is shown in fig. 3 [7] which displays the intensity of bunches (arbitrary units) vs time in DORIS. The main bunch is located at t=0. Other bunches are possible every 2 nsec. The intensity extends to about 5 nsec because of the detector's limited time resolution.

IV. ACCEPTANCE AND BEAM DIMENSION

In table 2 the geometrical, horizontal and vertical acceptances of DORIS III are given together with the measured values.

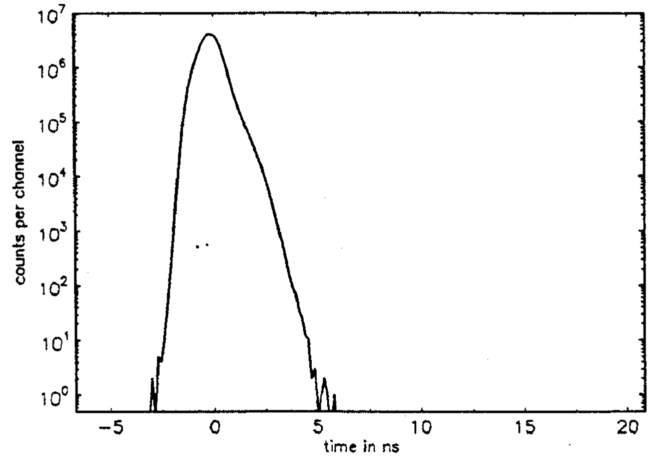

Figure 3. Parasitic bunches

Table 2: Acceptance of DORIS III

	hor [$\pi\mu$ m]	vert [$\pi\mu$ m]
geometrical	80	5
measured without IDs	57	2.4
measured with IDs	43	2.8

The geometrical vertical acceptance is diminished by a factor of 4, compared to the rest of the ring, by the vacuum chamber of the IDs. The free height of the flattest one is 11mm, extending for a length of 4 m. The measured horizontal acceptance is reduced slightly by the IDs whereas there is no influence on the vertical one, which is already small.

Table 3: Beam dimension over aperture

	hor	vert
without IDs	65 %	40 %
with IDs	73 %	63 %

In order to demonstrate that the stored beam needs a great part of the aperture, the ratio of the beam dimension (including the tails required for a lifetime of 1 h) to the measured aperture is given in table 3 instead of the beam dimension itself. With IDs this ratio is increased in the horizontal because the acceptance is reduced, and in the vertical because the beam is enlarged.

V. POSITION STABILITY OF THE PHOTON BEAMS

It has been observed that the position of the photon beams changes typically by $\pm$ 1000 μ horizontally and $\pm$ 150 μ vertically without outside influences in a distance of about 15 m from the source point. This leads to unwanted variations of the photon intensity at the experiments. The reason for the movement is as follows:

The vacuum chamber is heated by SR at the outside and is deformed by the corresponding gradient in temperature. As there are undesirable mechanical contacts with the magnets, especially the quadrupoles are moved by a distance of up to .4 mm. This changes the magnetic fields and causes orbit distortions. For the difference orbit rms-values up to 1 mm have been observed. This may be compared with the rms-value of a well corrected orbit, namely .8 mm for the vertical and 1.5 mm for the horizontal plane. Orbit distortions finally cause the movement of the photon beam.

To counteract this problem a position control system for the most important beamlines has been installed for frequencies lower than .1 Hz. Out of a total of 22 beamlines, 3 are stabilized horizontally to $\pm$ 50 μ and 4 vertically to $\pm$ 10 μ. In addition the decoupling of some quadrupoles from the vacuum chamber has been improved. By this and similar measures the movement of the photon beams has been reduced to typically $\pm$ 2 % of the beam dimensions (1 STD) for the controlled beamlines and $\pm$ 20 % for the uncontrolled ones.

VI. RELIABILITY

The operational statistics for 1994 are given in table 4:

Table 4: Operational statistics for 1994

Scheduled time for users	4200 h $\hat{=}$ 100 %
usable time	3608 h $\hat{=}$ 85.9 %
time for injection	184 h $\hat{=}$ 4.4 %
time for readjustment	71 h $\hat{=}$ 1.7 %
breakdown time	337 h $\hat{=}$ 8.0 %

During more than 85 % of the scheduled time beam could be delivered to the users. The breakdown time of only 8 % includes the breakdowns of the preaccelerators and also the time without beam that was requested by the users.

References

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