LIFETIME REDUCTION DUE TO INSERTION DEVICES AT BESSY II*

J. Feikes, G. Wuestefeld, BESSY, Berlin, Germany

Abstract

After closing insertion devices at BESSYII to smallest gaps beside appearance of a vertical tune-shift due to the natural focussing of the IDs, it is observed that beam lifetime is considerably reduced, up to 30 %. The reduction neither depends on machine tune nor on the settings of the four BESSY II harmonic sextupole circuits. Here measurements and analytical results to explain and cure this effect are presented.

INTRODUCTION

The 3rd generation light source BESSY II actually has 12 insertion devices in user operation [1]. A few of them have an impact on the machine performance when they are turned on. An important issue is the observed reduction of beam lifetime due to the closing of the undulators to narrow gaps. Typical lifetime values at 250 mA stored current, the standard value at injection, are 5h - 8h with all gaps opened. This can go down by 30-40 % to 3h - 5h when the most harmful IDs are closed. Lifetime reduction leads to the need of shorter injection intervals and subsequent a loss of user beam time as data taking during injection is not possible. Investigating these lifetime reductions we revealed that one has to distinguish between two different phenomena:

– lifetime reduction effects strongly depending on the machine tune

– lifetime reduction effects not depending on tunes but on the optics distortion cause by the ID.

Both effects may occur at the same time. Here it is reported on activities to cure them.

TUNE DEPENDENT EFFECTS

TUNE SCANS

When the UE56 undulator went into user operation at BESSY II it was realized that beam lifetime changed according to gap position. As this was a tune dependent effect, systematic tune scans around the working points had been performed (see also [2]). One scan lasts about 8 hours and data like lifetime, beam loss monitor rates and source sizes at the pinhole monitors were taken at approximately 2000 different pairs of values for the two transversal tunes. As an example in Fig. 1 the product current x lifetime (normalized to the current value at start of the scan) is painted in a colour code vs. the horizontal and vertical frequency shift

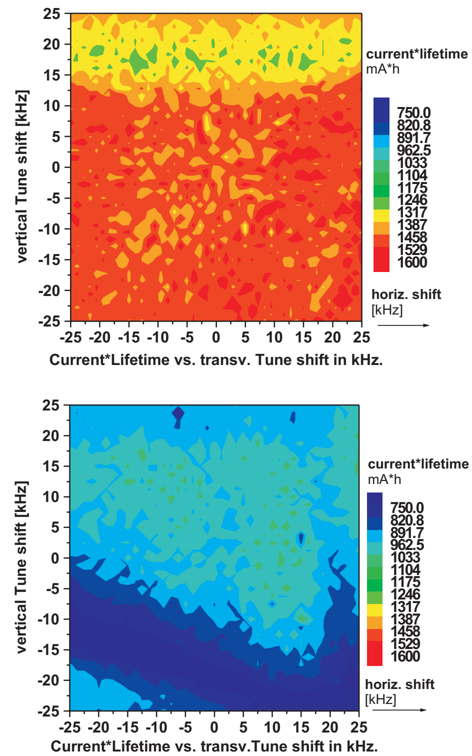

Figure 1: Tune scans with ID UE56 open (above) and closed to 16.6 mm (below). Parameter shown in colour code is current × lifetime in mA*h. Center points mark the actual working point at fx=1060kHz fz=925 kHz (17.848/6.74). BESSY II revolution frequency is 1249 kHz.

of the tune given in kHz. The beam revolution frequency is 1249 kHz, so the total axis range of 50 kHz corresponds to a fractional tune variation of 0.04. With all IDs opened only a vertical fourth order resonance at $fz \approx +20$ kHz corresponding to 4 Qz=27 is present. After closing the UE56 a squew octupole resonance appears (in the lower part of the diagram) with a lifetime degradation of up to 50 % relative to its value at open gaps. Initially the working point was located on that resonance but readjusted now vertically +20 kHz higher, about ΔQ_Z=0.016 away from this resonance. The source of that fields driving this resonance could be identified [1]. and removed. The newly installed apple type IDs excite these resonances to a much less extent.

* This Work is funded by the Bundesministerium fr Bildung, Wissenschaft, Forschung und Technologie and by the Land Berlin.

FEEDFORWARD

When all IDs are closed, their natural focussing induce a vertical tune shift of $\Delta\ f_Z$=+90 kHz (ΔQ_Z=0.072) much larger than the distance to the ID induced resonances. In order to fix the tune, a feedforward program for each ID was installed based on the SDDS toolkit [4] [1] The BESSY II optics consists of 16 double bend achromats and 16 straight sections [3]. Located outside the achromats there are 40 independent tunable quadrupole circuits each consisting of 2 quadrupoles. Standard tune correction is achieved with 32 of that circuits - the resting 8 circuits are used to define the horizontal betafunction in the straights. 16 circuits act focussing (F) and 16 are defocussing (D). Normally the tune is changed in a global way, which means that all F or D quadrupoles are changed by the same amount. Also the standard feedforward corrects in a global way adding the same increment to all F or D quadrupole power supplies with an amount depending on the value of the ID gap under consideration. Fig. 2 shows shifts of the vertical tune with feedforward “on” and “off” while ID gaps are changed. In this example a vertical tune shift of Δf_z=+80 kHz (ΔQ_z=0.064) without feedforward is reduced to +5 kHz, sufficiently small to avoid any resonance. The horizontal tune keeps constant within +/-2 kHz as well. Because the

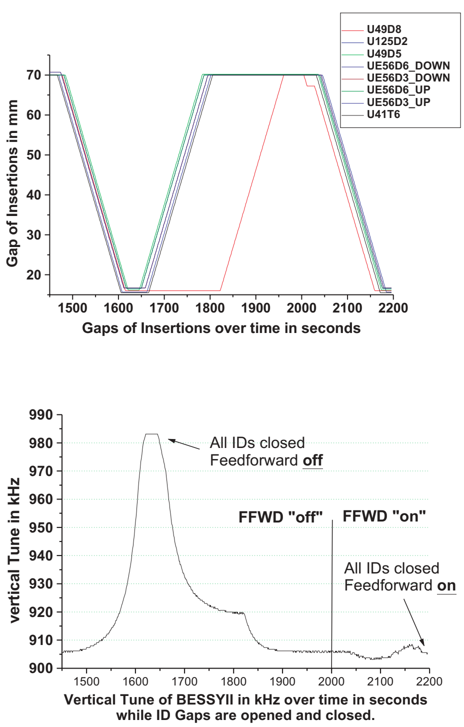

Figure 2: Upper picture: ID gaps in mm over time in seconds lower picture: corresponding value of vertical tune.

reference orbit keeps carefully centered in the quadrupoles routinely aligned by a beam based calibration, orbit stability is not affected despite the permanent changes in the quadrupole strengths due to ID movements.

[1] Now most of the BESSYII feedfoward files operate under a new written program, based on a data bank system

DYNAMIC EFFECTS

OBSERVATIONS

Even with fixed tunes the strongest IDs (like the U125 producing a vertical tune shift of 28 kHz at its minimum gap of 15.7 mm) show considerable lifetime reductions. A tune scan does not reveal any resonance excitation, but the decrease of lifetime is independent of the working point. More observations:
– relative reduction of lifetime as function of gap runs parallel to the vertical tuneshift with gap
– optimum settings for harmonic sextupoles are independent of the value of the undulator gap
– a scraper measurements with gap open and closed does not give any hint on reduction of transversal aperture
– measurement of dynamic aperture using pinger magnets show that it is considerably reduced when ID gap is at closest value
– measurement of lifetime vs. cavity voltage shows that RF aperture is reduced from about 2.4 % (gap at 150 mm) to about 2.1 % (gap at 15.7 mm)
– only Touschek lifetime is reduced. Analysis of lifetime reductions with 100 mA beam current in 50 and 350 bunches and 0.25 -10 mA in a single bunch show that vacuum related lifetime contributions are not notably affected
– the effect depends on the transverse beam size (coupling).

OPTIC DISTORTIONS AND LIFETIME

Beside a tune shift the insertions generate also distortions of the optical functions. In order to compensate them, the strongest (U125) had a modified feedforward compensation (“local compensation”) which beside the tune, also corrected the ID generated beta beat. This was achieved by powering that quadrupoles located in the same straight section as the ID with separate values from the others [2]. Reduction of beta beat was confirmed by direct beta function measurements (using the “golden rule”). But when closing the U125 gap to its narrowest value with this local feedforward, it was observed that life time degradation became worse, now 24 % instead of 16% (value with global feedforward active). As well as the origin of the effect this also had to be explained.

A tracking study (using MAD) of the complete nonlinear BESSY II optics predicts that the optical impact of the U125 reduces the dynamic aperture for off energy particles. Tracking results show that this does not only depend on the beat of the vertical beta functions, but even

[2] Simply compensating the natural tune shift of an undulator by the adjacent quadrupoles would strongly increase the beta beat in that straight. We used another method, adding about the same tune shift with the adjacent quadrupoles as that produced by the ID and then compensating the sum of both shifts in a global way. By this means beta beat keeps small everywhere.

stronger on the beat of the vertical beta phase. As an explanation for the life time reduction effect this is in accordance with all the observations stated above. As a consequence it was searched for a new feedforward scheme were not only the tune and the beta beat were corrected but also the vertical phase jump was kept localized. Fitting runs with MAD result in a feedforward pattern where all 40 available quadrupole circuits had to be used and each of them had a different but modest correcting strength (respecting the symmetry to the distortion). Fig 3 shows the relative change of each quadrupole strength due to the correction from the improved feedforward correction for narrowest gap of U125. The theoretically predicted distortion

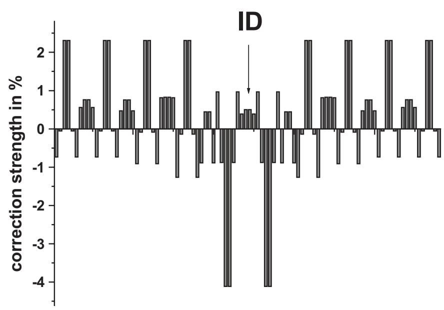

Figure 3: Relative change of quadrupole strength due to action of the improved feedforward scheme.

of optical functions in four different feedforward schemes is shown in Fig 4 and Fig 5.The schemes are:

"no correction" - without feedforward

"improved correction"- scheme shown in Fig 3

"local tune correction" - correction of tune shift by only powering of adjacent quadrupoles

"global tune correction" - uniformly distributed correction.

We tried all these schemes at the U125. The predicted beta beats could be confirmed by direct beta function measurements.

Using the improved feedforward scheme life time reduction caused by the U125 could be improved from 16 % to 10% demonstrating that indeed phase beating is crucial in maintaining the dynamic aperture. Currently a very strong wiggler with a tune shift of Δf_Z=+100 kHz and a accordingly strong impact on dynamic aperture started commissioning. In a first measurement at very low beam currents it was shown that an improved feedforward for this device also recovered considerably life time.

CONCLUSION

Effects **depending on tune** could be cured by:

– proper choice of working point

– fixing the working points using a feedforward.

– removing the resonance source inside the ID

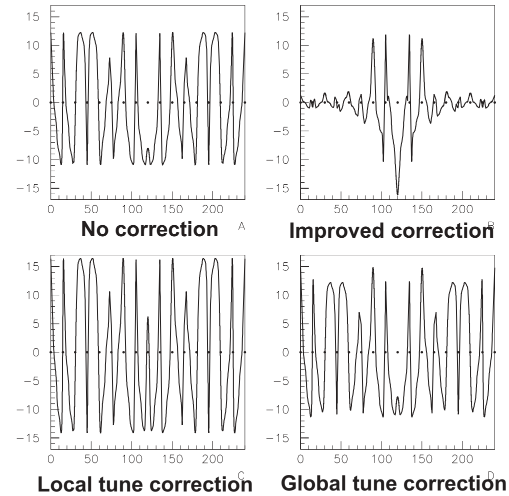

Figure 4: Vertical beta beat in % due to U125

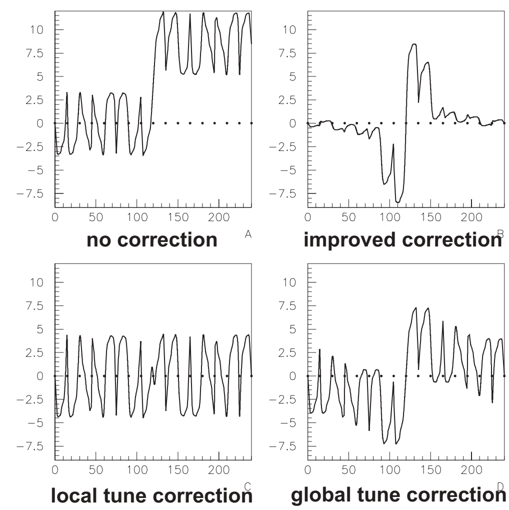

Figure 5: Vertical phase beat in % due to U125

Not tune dependent effects could be traced down to be caused by a reduction of dynamic aperture for off-energy electrons. A cure was found which partially restored lifetime, using a special scheme of distributing the correcting quadrupoles strength used in the feedforward correction.

REFERENCES

[1] J. Bahrdt et al, "Elliptically polarizing insertion devices at BESSY II" Nucl. Instr. and Meth. in Phys. Res. A467-468 (2001) 21-29

[2] P. Kuske et al, Investigation of Non-Linear-Beam Dynamics with Apple II-Type Undulators at BESSY II, PAC2001, Chicago June 2001

[3] G. Wuestefeld et al, Optimization and Tracking Studies for the 1.7 GeV Light Source BESSY II, EPAC 94, London July 1994

[4] M. Borland, Application Programmer's Guide for SDDS Version 1.4, APS LS Note