BEAM LIFETIME OPTIMISATION OF BESSYII BY SYSTEMATICALLY ADJUSTING THE HARMONIC SEXTUPOLES*

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Abstract

The BESSY II [1] low emittance storage ring is based on 16 double bend achromats paired in groups of two. There are two sextupole families for chromatic optics corrections. Additional two pairs of two sextupole families are used for the harmonic sextupole correction. To find an optimum field excitation scheme a scanning routine was set up, to vary the field strength of the harmonic sextupoles and to record the corresponding lifetime and transverse beam dimension. The harmonic sextupoles could be readjusted yielding an increase of beam lifetime of about 30 %. We report on the experimental results compared with numerical simulations of the dynamic aperture for different settings of the harmonic sextupoles.

1 SEXTUPOLES AT BESSY II

Because the BESSY II optics has a DBA structure the two chromatic sextupole families for adjusting the chromaticity are located between the two dipoles of the achromat. Here the dispersion grows up to 0.44 m and the values of the betafunctions at the location of chromatic sextupoles allow an easy adjustment of the transverse chromaticities to values of typically 2-3 in both planes. Due to the modest value of the dispersion the chromatic sextupoles have to be strongly powered leading to a small dynamic aperture and poor lifetime without compensating their nonlinear effects by harmonic sextupoles. There are two families at positions without dispersion and with high horizontal (named S4) respectively high vertical (named S3) betafunctions. Each family is divided according to whether the magnet is located near a straight with high horizontal betafunction (equipped mainly with wigglers and undulators) called D-straight or near a straight with low horizontal betafunction (used to put in superconducting wavelength shifters) called T-straight. So there are actual four differently powered harmonic sextupole circuits: S4D, S4T, S3D, S3T. Adjusting their strengths towards best lifetime results in a four dimensional optimisation problem.

2 DYNAMIC APERTURE CALCULATION

In order to prove the existence of a sufficiently large dynamic aperture the values of the harmonic families were adjusted in such a way that the global detuning with amplitude in both planes becomes small. This was done analytically in the framework of distortion functions [2]. Then a tracking code was set up scanning the four dimensional parameter space in the vicinity of small detuning. For each setting of the sextupoles the area of a triangle shaped aperture (width and height) was determined.

In Fig. 1 the aperture is shown as function of the settings of two out of the six possible pairs. The aperture vs. the sextupole strength in the low-beta (S3T/S4T) and the high-beta (S3D/S4D) straight sections show a similar behaviour: the largest aperture is maintained if varying the two sextupoles at a certain fixed ratio. The analytical result indicates that along this line the detuning coefficients remain small.

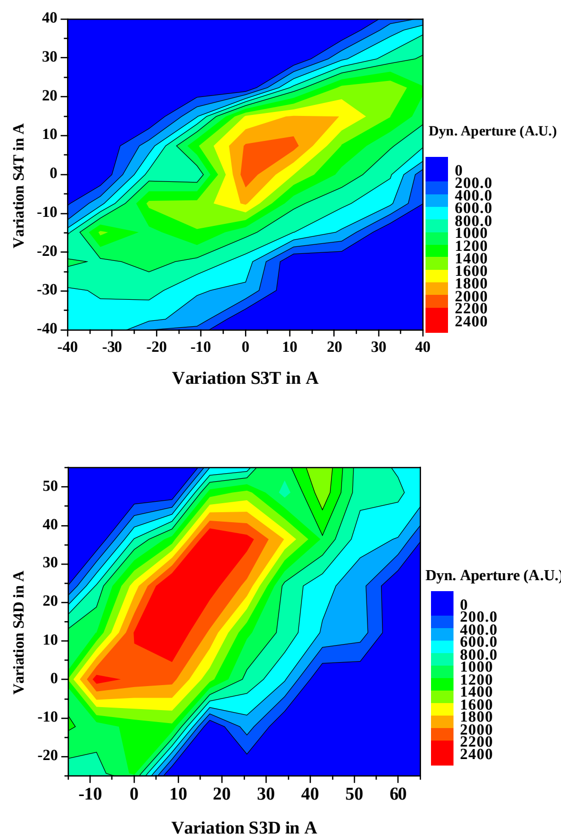

Figure 1: Numerical calculation of the dynamical aperture in BESSY II (A.U., colour plot) scanning the settings of a pair of harmonic sextupoles (in Ampere). During one scan the other pair remains fixed in strength.

Around some combination of sextupole fields on this line there is an area of highest aperture. These were the

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starting values for the harmonic sextupole setting during the machine commissioning.

3 MEASURING LIFETIME AS FUNCTION OF HARMONIC SEXTUPOLES SETTING

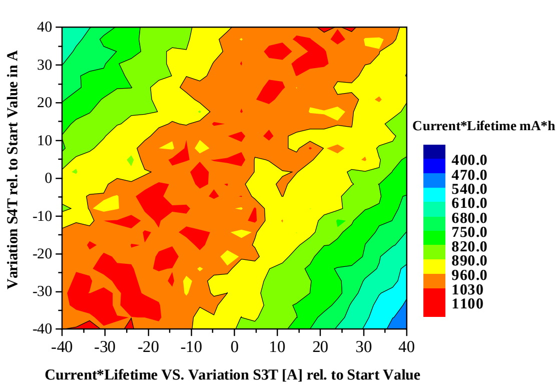
After going into user operation with sextupole settings close to the starting values (although not systematically adjusted) the lifetime had to be further optimised. A scanning routine was written using a LabView code running on an WindowsNT-PC. Data exchange runs via an ActiveX channel access client (written by K. U. Kasemir). This routine had access to the EPICS control system capable of changing the sextupole values and monitoring the resulting changes in the relevant data channels.

Scans were done during night shift automated without any operator present. During each scan the currents of a pair of harmonic sextupole were changed against each other and the resulting lifetime, beam loss rates, source size at the pinhole monitors were written to a file and analysed offline. All six possible pairs were scanned.

The variation of the sextupole currents was about +/- 40A in steps of 4A - 6A. This has to be compared to the typical sextupole currents of 60A - 100A in the standard user setting. One single scan consists of about 1600 different sextupole settings with a scan rate of about 10 seconds – the update rate of the BESSY II lifetime measurement.

4 RESULTS

The most direct information is the lifetime as function of the harmonic sextupole settings (in Ampere). The product of lifetime and beam current (I x τ) is not current independent but varies about 10% - 20% between 100 mA and 250 mA, which is the typical current variation during one scan. To make different scans comparable we fitted the dependence of I x τ on beam current and normalised them to a value of 250 mA.



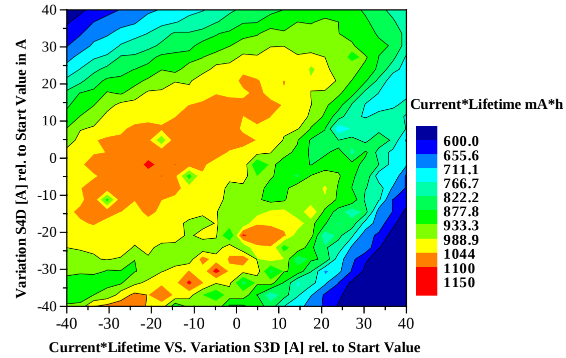


Fig 2: Measured product Lifetime x beam current normalised to a beam current of 250 mA.
While the S3T/S4T strength were changed the other sextupole currents remained constant and vice versa.

The measured lifetime behaviour qualitatively reflects the simulation results. Along a straight line with fixed angle there is a clear crest of best lifetime. On this crest one finds a well-defined area of values for each circuit giving optimum lifetime. The side crest seen in the lower part of the S3D/S4D scan (Figure 2) is strongly tune-dependent and vanished after a small readjustment of the working point. We believe that in the area between that two lines the detuning was such, that some particles hit a nearby resonance leading to beam loss and reduced lifetime. As that loss region goes parallel to the main crests there is another hint that this is the direction of similar detuning values.

Adjusting all harmonic sextupoles to their best values (obtained after 2 iterations of scans) increased the BESSY II lifetime in standard user optics by 30%. The difference between their calculated and their real optimum settings was 10%-30% of their absolute strength. This could be explained partly by differences between the model sextupole strengths (derived from field measurements and theoretical considerations) and their real value in the machine surrounding (saturation effects, fringe field effects etc.). A more careful tracking scan should also take into account the momentum dependence of the dynamic aperture. On the other hand the optimum sextupole setting is not unique and one may vary harmonic sextupole currents in a correlated way by 30% without affecting lifetime. Even switching off the S3T circuit could be compensated by properly adjusting the S4T family.

The source size or source stability did not depend very much on sextupole settings and kept the same after readjustment of the user optics.

It was not possible to reconstruct the lifetime scans from loss rates of the beam loss monitors (BLM). As there are only 11 BLMs at BESSY this seems not a surprise.

CONCLUSIONS

- largest apertures were calculated for small (but not zero !) detuning. The detuning can be approximately calculated analytically in the framework of distortion functions.
- a local optimum value could be determined empirically by iterated scanning and adjusting the two-dimensional projections of the four-dimensional life time curve. This means it had a simple topology. Along lines of similar detuning one can reduce the sextupole strength without strong effects on lifetime.
- in presence of nearby resonances the four-dimensional topology of the lifetime curve may be much more complicated. There is a strong dependence on the working point.

REFERENCES

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