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 betafuction (equipped mainly with wigglers and undulators) called D-straight or near a straight with low horizontal betafuction (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...
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 mea-
surement.

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.

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 lifetime 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**