EVOLUTION OF OPTICAL ASYMMETRIES IN THE ELETTRA STORAGE RING

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Abstract

In order to evaluate the evolution of the storage ring optical asymmetries with respect to magnet alignments, diverse orbit response matrix and betatron function measurements were performed before and after magnet realignments. The asymmetries have been analyzed comparing the theoretical model to the measured, and comparing the measured data itself at identical optical positions.

BETATRON FUNCTION MEASUREMENTS

The ELETTRA storage ring is an expanded Chasman Green lattice with 12 achromats. Each achromat has two focusing quadrupoles (QF) and one defocusing quadrupole (QD) in the arc, and three families of quadrupoles in the straight section, two Q1 (defocusing), two Q2 (focusing) and two Q3 (defocusing). Each family QF and QD is powered in series by one common power supply. Each pair Q1, Q2 and Q3 of an achromat is powered by a single power supply. As we have no backleg windings nor shunt resistors, the measurements of the beta functions were performed only at quadrupoles Q1, Q2 and Q3, so allowed only the average beta function over each pair of magnets of each achromat. The nominal working point is 14.3 horizontal and 8.2 vertical. The measurements were performed at 2 GeV with tunes equal to 0.294 horizontal and 0.174 vertical. The excitation variations were $\Delta KL = + 0.015*0.26\ m^{-1}$ for quadrupoles Q1 and Q3 and $\Delta KL = +0.01*0.498\ m^{-1}$ for quadrupoles Q2. These values are a compromise between the resolution of the tune measurement system and the feed down effects of the closed orbit variation in the sextupoles. Furthermore, it was not possible to increase the current in the quadrupoles QF, i.e., $\Delta KL = -0.01*0.498\ m^{-1}$, as the horizontal tune crosses the 3rd integer resonance. These measurements are performed by a new program [1], which measures the tunes and the closed orbit before and after each quadrupole variation. The program writes out in a file the tunes and the closed orbit, before and after, the difference between before and after, together with the r.m.s. of each BPM. If the difference orbit is lower than three times the r.m.s. at the BPMs, which are close to the sextupoles, the feed down effects from the sextupoles are assumed to be negligible. The program then extracts the measured average beta functions at the quadrupoles from the measured tunes, using the well known formulae:

$$\beta = \frac{\pm 2 * [\cos(2\pi Q_{before}) - \cos(2\pi Q_{after})]}{2 * \Delta K * L * \sin(2\pi Q_{before})}$$

where + and – are for the vertical and horizontal planes, respectively and the factor 2 in the denominator comes from the fact that we have two magnets per power supply. From a read nominal optics file, it calculates the nominal average betatron functions at the quadrupoles Q1, Q2 and Q3 with:

$$< \beta >= \frac{1}{L}\int_0^L \beta(s)ds$$

If the initial measured tunes are different from the ones of the nominal optics file, the program matches the tunes of the nominal optics file to the measured ones, before calculating the average betatron functions at the quadrupoles and the sensitivity matrix $\Delta\beta_i/\Delta k_j$. The asymmetries are computed comparing the measured betatron functions of each pair of quadrupoles of each achromat, and the measured to the nominal. The nominal twiss functions along one achromat, are shown in fig.1, The betatron functions are maximum in the horizontal plane at the center of the quadrupoles Q2 and in the vertical plane at the center of the quadrupoles QD. The nominal average betatron functions are 9.8 m horizontal and 6.5 m vertical at Q1, 18.9 m horizontal and 4.3 m vertical at Q2, 7.9 m horizontal and 8.4 vertical at Q3.

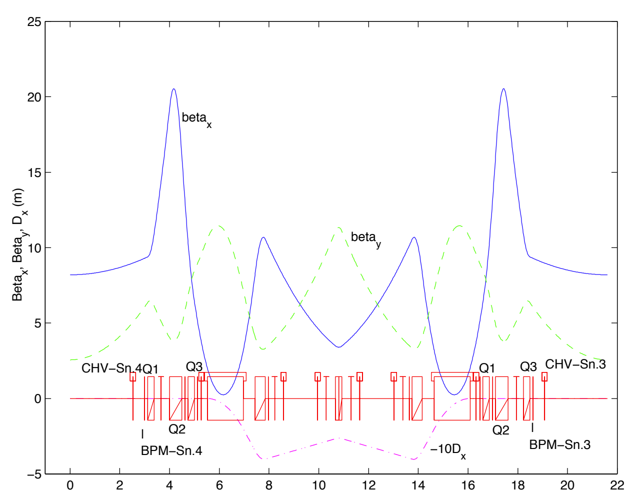

Figure 1: Nominal optics along one achromat

Figures 2, 3 and 4 show the measured and the nominal betatron functions at the quadrupoles Q1, Q2 and Q3, respectively. Beta_H_M (blue) and Beta_V_M (yellow) are the measured while Beta_H_T (maroon) and Beta_V_T (cyan) are the theoretical horizontal and vertical values, respectively.

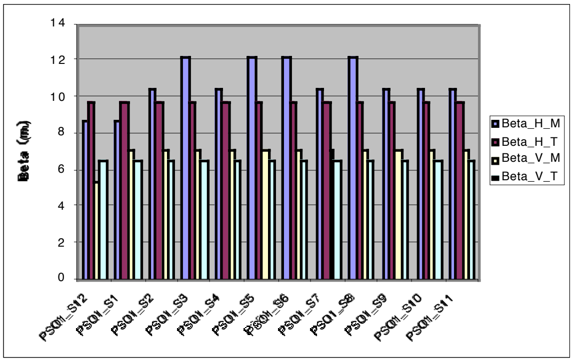

Figure 2: Measured and nominal betatron functions at the quadrupoles Q1.

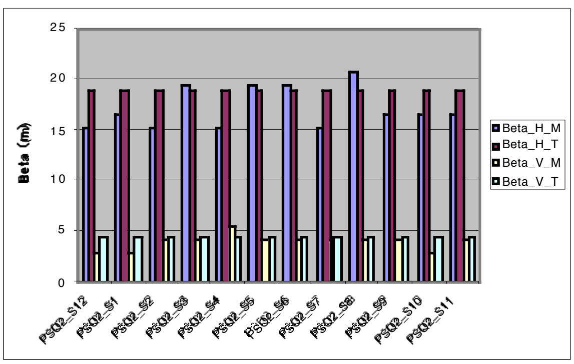

Figure 3: Measured and nominal betatron functions at the quadrupoles Q2.

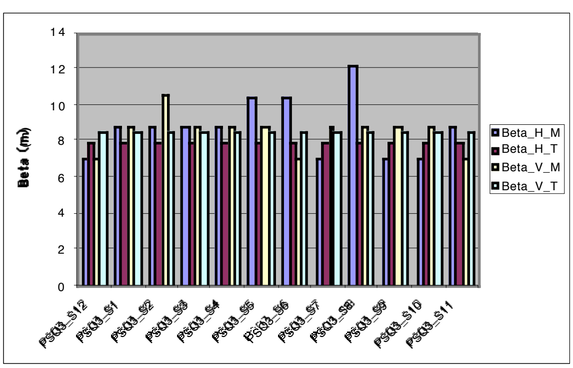

Figure 4 : Measured and nominal betatron functions at the quadrupoles Q3.

The r.m.s. beta beating of the measured beta functions is 14% horizontal and 13.7% vertical.

ORBIT RESPONSE MATRIX

In the storage ring there are 82 lumped horizontal and vertical correctors, and 95 BPMs as the 59th (BPM_S7.6) is now used for the transverse feedback. In the uncoupled case, the measured orbit response matrix is thus 95*82, for each plane. The orbit response matrix has lately been measured using the application program TOCA[2]. As the data is analyzed offline, the measurements are saved in a file together with the status "bad" or "good" or "discarded by the user" of both the BPMs and correctors, the measured tunes, the beam current and lifetime. The measurements have been performed at 2GeV. When the sextupoles are turned ON, the beam current is usually chosen above 100mA, while for the sextupoles switched OFF, the obtained beam current is usually below 90mA and at the end of the measurements, it's 40mA, maximum. Unfortunately, at currents below 50mA, some BPMs were found not to function properly. To get a large signal to noise of the BPMs, one would vary by a large amount each corrector, but then the beam would be in the nonlinear calibration zone of the BPM, or it might get lost for physical or dynamic limitations. So the variation has been chosen in order that the difference is at least ten times the r.m.s. of each BPM.

The closed orbit distortion z_{ij} created at an ith BPM by a kick δ_j of a jth corrector is given by:

$$z_{ij} = \delta_j \frac{\sqrt{\beta_i \beta_j}}{2 * \sin(\pi Q)} \cos(\pi Q - | \mu_i - \mu_j |)$$

where:

β_i and β_j are the betatron functions at the ith BPM and the jth corrector, respectively, μ_i and μ_j are the phase advances at the ith BPM and the jth corrector, respectively, Q is the betatron tune.

The two methods used to extract the asymmetries are:

1) In all the 11 straight sections housing the insertion devices, there are corrector and BPM pairs (CHV_Sn.3, BPM_Sn.3), where n is the achromat number, which are close enough to assume that μ_i - μ_j is zero and that β_i and β_j are equal. The same holds for the pair's corrector CHV_Sn.4 and the BPM BPM_Sn.4, as shown in figure 1. If the lattice were symmetric, the effects of a corrector Sn.3 on the BPM_Sn.3 would be the same in each achromat. The same arguments can be used for the pairs Sn.4. This analysis can be used as a figure of merit for the evaluation of the asymmetries in the storage ring lattice. The results obtained after the partial realignment performed on January 2004, show an improvement with respect to the measurements performed in 2003, mainly in the horizontal plane. The overall maximum asymmetries were 24% horizontal and 12% vertical in 2003, and now are 19% horizontal and 11% vertical in February 2004.

2) The asymmetries are also extracted from a disturbed model optics constructed from the programs LOCO[3] and MAD[4] as in [5]. The coefficients:

$$A_{ij} = \frac{\sqrt{\beta_i \beta_j}}{2 * \sin(\pi Q)} \cos(\pi Q - | \mu_i - \mu_j |)$$

are measured by TOCA and calculated by LOCO and MAD. The model optics obtained minimising the χ^2 deviation between the measured orbit response matrix of June 2004 and the model orbit response matrix is shown in figure 5. With respect to 2001, the model is improved by a factor 2 and 1.4 in the horizontal and vertical planes, respectively. The maximum beta beating is 1.6% and 1.5% for the horizontal and vertical planes, respectively, while in 2001, it was 33% and 22%, respectively. The beta beatings for June 2004 are shown in the figures 6 and 7, for the horizontal and vertical planes, respectively.

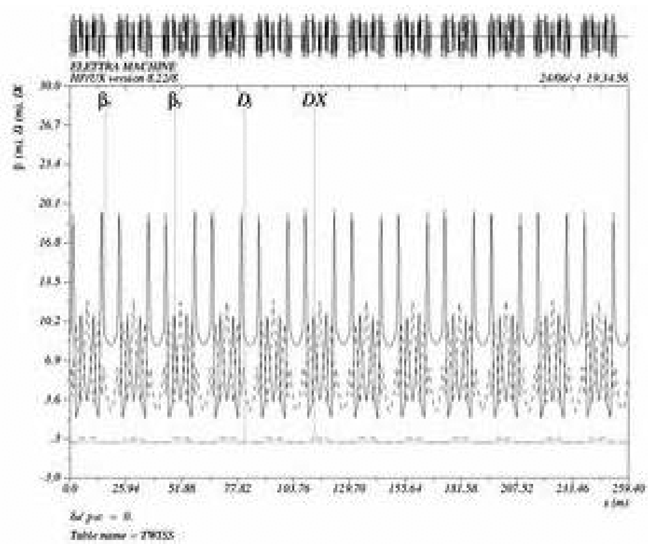

Figure 5: Model optics for June 2004 measurements

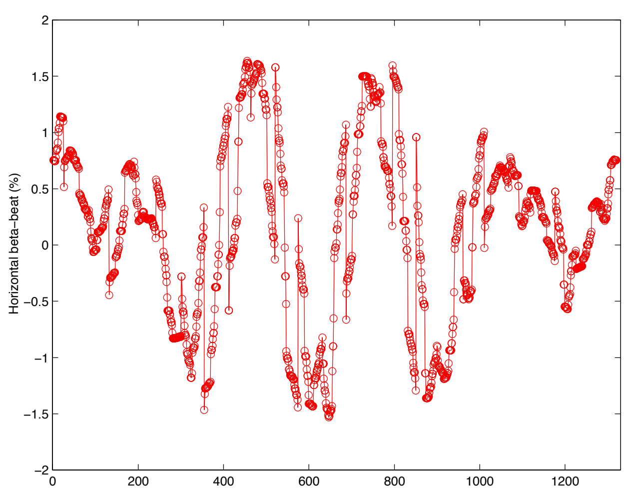

Figure 6: Horizontal beta beating in (%) for the June 2004 model optics.

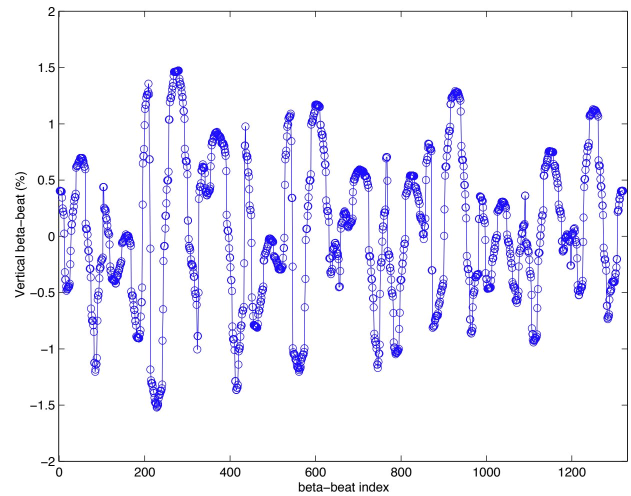

Figure 7: Vertical beta beating in (%) for the June 2004 model optics.

CONCLUSIONS

The measurement of the optical asymmetries performed before and after the partial storage ring magnets realignment has shown a slight improvement of the lattice symmetry. The model optics is also improved. However, the asymmetry evaluated from the measured betatron functions and the orbit response matrix shows that the model optics is rather optimistic. The second point is the symmetry restoration. The new application program developed for the betatron function measurements calculates also the correction of the asymmetries. The first test has given an increase of the lifetime of 1.4 hours.

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