IMPLEMENTATION OF A LOW-EMITTANCE OPTICS FOR THE LNLS UVX STORAGE RING

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Abstract

In this report we describe the theoretical optimization and implementation of a low-emittance optics for the LNLS UVX storage ring. The emittance is reduced by letting the dispersion be distributed everywhere while keeping the low vertical beta feature. The optimization strategy is based on a series of quadrupole strength scans and selection of points satisfying a number of criteria. The new mode reduces the emittance from 100 nm.rad to 40 nm.rad, including the effects of the already installed insertion devices, and keeps the working point in the same quadrant as the present operation BBY6T mode. Tests have shown a reduction of approximately 20 % in the horizontal and vertical beam sizes in the middle of the dipoles, in agreement with the theoretical emittance reduction.

INTRODUCTION

UVX is a 1.37 GeV electron storage ring with a rather large natural emittance, 100 nm.rad. The lattice is composed of six *double-bend* cells and the present optics (BBY6T) sets the dispersion function to zero and the vertical beta function to a low value in the long straight sections. The beam is injected at 500 MeV and ramped to 1.37 GeV after accumulation of 250 mA. The BBY6T mode is kept constant during ramping.

For *double-bend* lattices, it can be shown [1] that the horizontal equilibrium emittance is given by the expression:

$$\epsilon_x = F\frac{C_q\gamma^2\theta^3}{J_x 12\sqrt{15}} \qquad (1)$$

where θ is the deflected angle per bending magnet ,γ is the relativistic factor, J_x is the horizontal partition number, $C_q = 3.83 \times 10^{-13}$ m is a constant and F is a form factor, whose theoretical minimum value is three for achromatic and one for chromatic optics.

Although the theoretical minimum is difficult to achieve, because its derivation does not consider other constraints that must be satisfied, this result shows that breaking the achromatic condition enables lower emittance modes. Thus, in this work, all constraints of BBY6T will be maintained, except the achromatic one.

OPTIMIZATION

The only variables for the optimization process were the three quadrupole families (QF, QD and QFC) strength, because no lattice changes, such as quadrupole positions or families creation were allowed.

The optimization method involved a low resolution scan of the three parameters through a large range (determined by maximum achievable strength values and according to whether it was a focussing or defocussing quadrupole) and the selection of points whose optics satisfied the following constraints:

- $\beta_{x,y}(\max) < 35$ m;
- $\beta_y(\text{straight sections}) < 1$ m;
- $\eta_x(\text{straight sections}) < 1$ m;
- $0 < \epsilon_0 < 60$ nm.rad .

In order to facilitate the implementation of the mode, we were interested in optics in which the tunes were in the same quadrant as those of the BBY6T optics. In this way, the low energy injection configuration could be kept the same. Thus, a new selection was performed, determining an acceptable region ($\nu_x \in [5.10, 5.30]$ e $\nu_y \in [4.10, 4.30]$) in the tune diagram (see Figure 1).

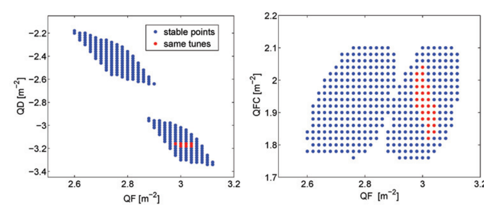

Figure 1: Low resolution scan results projected on QD/QF and QFC/QF planes. Blue dots represent points that satisfy the scan constraints and red dots have the additional tune constraint.

This selection also defined intervals of quadrupole strength for a high resolution scan. Subsequently, considering the effects of the three insertion devices of UVX, one ondulator, one 2 T wiggler and one superconducting 4 T wiggler, it was possible to identify the lowest emittance optics which attended the imposed constraints. Figure 2 shows the emittance dependence with quadrupole strength on QD/QF and QFC/QF planes.

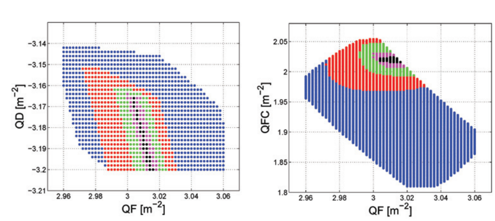

Figure 2: High resolution scan results projected on QD/QF and QFC/QF planes. Black dots represent points with emittance lower than 41 nm.rad.

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Table 1: Main Parameters of LE and BBY6T Optics

Parameters	LE	BBY6T
ϵ_0 [nm.rad]	42	100
ϵ_{ID} [nm.rad]	40	82
α_c	10.5×10^{-3}	8.2×10^{-3}
J_x	0.94	0.96
ν_x	5.28	5.25
ν_y	4.20	4.17
$\xi_{0,x}$	-13.0	-13.2
$\xi_{0,y}$	-9.8	-9.4
σ_ϵ/E_0	0.7×10^{-3}	0.6×10^{-3}
σ_x 4° exit [μm]	258 (27%)	355
σ_x ID sections [μm]	907 (27%)	1200

Figure 3 presents the optic functions of low emittance (LE) and BBY6T optics, where it is possible to note the similarity between the betatron functions, because of the number of constraints that both optics satisfy, and the difference between the dispersion functions on straight sections. Also, Table 1 compares the main parameters of both optics.

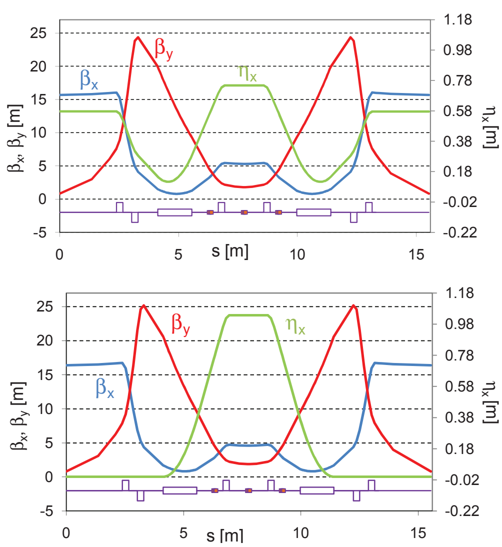

Figure 3: Optics of LE (top) and BBY6T (bottom). In red, β_y, in blue β_x and in green η_x.

IMPLEMENTATION

The main reason to maintain the tunes of the low emittance optics in the same quadrant of BBY6T is the capability of migration from one mode to another without crossing dangerous resonances.

Thereby, to implement the operational mode, we injected the beam in BBY6T mode, and changed QFC strength in five steps, maintaining the working point fixed with QF and QD families. The parameter used to confirm that the migration was complete was the ratio between the measured

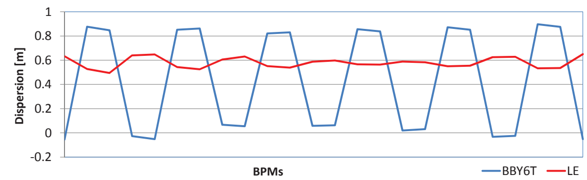

Figure 4: Measured dispersion function for BBY6T (blue) and Low Emittance (red) modes.

dispersion function on long and short straight sections, due to its independence on other lattice parameters, such as momentum compaction factor. Figure 4 shows the dispersion function for both optics.

After the symmetrization of the mode and a preliminary lifetime and coupling optimization through skew quadrupole strength and working point variations, low current (90 mA) horizontal beam size measurements revealed a decrease of 20 % with respect to BBY6T value at the four-degree exit of the bending magnet. This beam size reduction is 7 % lower than expected (see Table 1) probably due to the phase modulation used in UVX RF cavity and the non-zero dispersion function in this region.

However, high current beam size measurements (see Figure 5) have shown a strong transverse coupling and instability, also present in BBY6T mode but weaker, with a current threshold near 115 mA. In order to understand and solve these problems, we are studying collective instabilities and characterizing the operational mode.

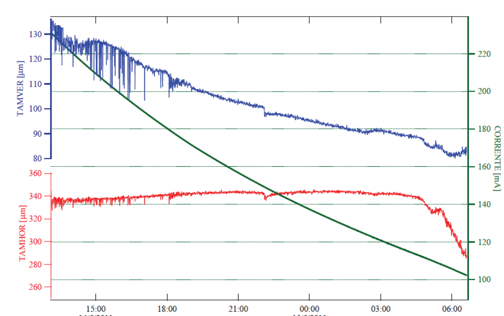

Figure 5: Horizontal and vertical beam sizes in function of current for LE operational mode.

CONCLUSION

A low emittance mode was theoretically determined, simulated and implemented in UVX storage ring. Problems related to instabilities are under further study and characterization and must be understood and solved before used for beam line experiments.

REFERENCES

[1] J.J. Bisognano, "Approaches to lowering emittance in existing light sources", Nuclear Instruments and Methods in Physics Research A, 467-468, (2001) 42-46.