A NEW MODE FOR OPERATION WITH INSERTION DEVICES AT UVX

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Abstract

UVX is a 1.37 GeV electron storage ring at the Brazilian Synchrotron Light Laboratory (LNLS). The ring is composed of a 6-fold symmetric double-bend achromat lattice with 4 sections reserved for insertion devices. The storage ring was commissioned in 1997 in a mode of operation with high (~12 m) vertical betatron functions in the insertion straights. However, the need for operation with reduced vertical aperture arose with the gradual installation of insertion devices over the years and is particularly important for operation with a 14 mm vertical aperture superconducting wiggler scheduled for installation in late 2009. To cope with this restricted aperture, a new mode with low (~0.8 m) vertical betatron function in all six long straights was deemed necessary and was implemented at the end of 2008. In this report we present the commissioning results of the low vertical beta mode and the advantages in operating in this mode with insertions.

INTRODUCTION

The LNLS UVX is a 1.37 GeV electron storage ring which has been open for users since 1997. The storage ring is composed of a 6-fold symmetric DBA lattice with quadrupole doublets flanking the long insertion straights for betatron function matching. The ring has 6 long straight sections, 4 of which are available for insertion devices (IDs). The storage ring started its operation without IDs in a mode named Standard mode, with classical optical functions for this kind of lattice at the time, specifically, with high betatron functions in the long straight sections. See Figure 1. The first insertion device, a 2 T hybrid multipolar wiggler, was installed in the ring in the beginning of 2005 with a reduced (18 mm) chamber aperture. The second device, an elliptically polarizing undulator, was installed 2 years later, also with the same reduced aperture. To minimize the impact of these devices on the beam we implemented operation modes with low vertical β-function in the straight sections were the devices were installed. Initially a mode with low vertical β just in the wiggler section was implemented and afterwards also in the undulator section. These modes have the same tunes as the Standard mode and thus we can migrate between the modes without losing the beam, with the tunes kept constant. For a long period our approach was to inject and ramp the beam in the Standard mode with the insertions opened and later migrate to the localized low vertical β modes while closing the insertions gap. With the perspective of installing the third device, a super-conducting wiggler with 14 mm vertical beam stay-clear, by the end of 2009, a new mode with low vertical β-function in all 6 straight sections, the BBY6T mode, must be implemented. In this new mode the vertical tune cannot be kept constant, it actually increases significantly and turns out to be separated from the Standard mode by integer resonances. Our migration approach would not work out in this case. In fact, the main anticipated difficulty for commissioning of this new mode was the demonstration of reliable and efficient injection at 500 MeV (the maximum energy of the LNLS booster synchrotron) as well as of the energy ramp from 500 MeV to the 1.37 GeV nominal operating energy. On top of that, a new rampdown procedure must be commissioned to allow recovery of the remaining stored beam at the end of each user´s shift so as to allow topping up of the beam current at the 500 MeV injection current.

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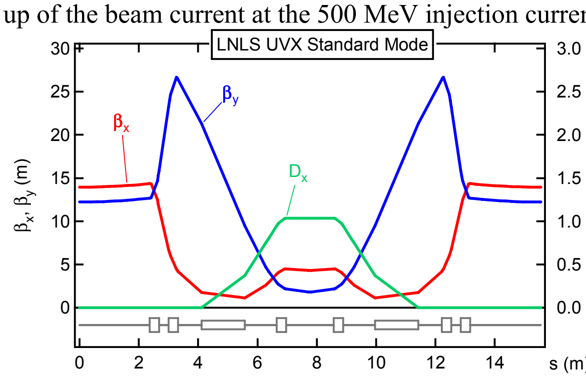

Figure 1: Twiss functions for LNLS UVX Standard mode.

THE LOW VERTICAL BETATRON FUNCTION MODE – BBY6T

After some years operating the LNLS UVX storage ring in the Standard mode (and same tune variations of it), we now moved the nominal operation mode to the BBY6T mode, which has a reduced vertical β-function in all six long straight sections restoring the 6-fold symmetry of the lattice, as shown in Figure 2. The vertical β-function at the centre of the long straight section is reduced from 12.2 m in the Standard mode to 0.77 m in the BBY6T mode. In this mode the impact of insertion devices such as high field wigglers are minimized.

The lower vertical β-function results in larger phase advance and thus in larger vertical tunes. The vertical tune increases from 2.17 in the Standard mode to 4.17 in the BBY6T mode while the horizontal tune has the same value of 5.27. Besides reducing the harmful effects of insertion devices on the beam, the BBY6T mode also allows for the installation of reduced gap devices without limiting the aperture of the ring. Figure 3 shows the measured saturation current at injection energy as a function of the position of a vertical beam scraper. Our present operation current of 250 mA can be reached with the scraper positioned at 5 mm, which scales to a half-aperture of 3.5 mm at the centre of the straight section or to 9.7 mm at the extremities.

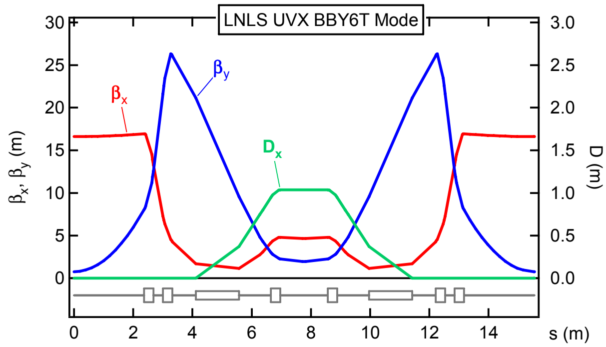

Figure 2: Twiss functions for the BBY6T mode.

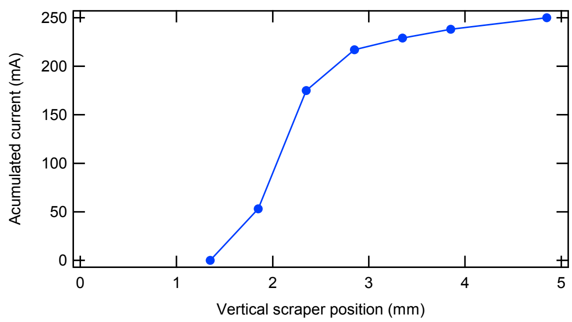

Figure 3: Saturation current at injection as a function of the vertical scraper position (half-gap height).

Effects of insertion devices on beam dynamics

The effects of IDs on beam dynamics include linear focusing effects as well as nonlinear effects. The small vertical β-function at the location of the insertion is beneficial for both kinds of effects. The linear focusing effect can be compensated for locally, within the insertion device straight section, using the two available families of quadrupoles independently from the other quadrupoles. The compensation aims at restoring the original tunes and the symmetry of the β-functions. In Figure 4 we show the effect of the 2 T multipole wiggler [1] installed in the ring on the Standard and BBY6T optics before and after local compensation. The difference between the modes is remarkable: in the Standard mode the compensation is essential, while in the BBY6T mode it is not necessary. This makes the operation of the wiggler much easier since we must open its gap at injection and a compensation scheme would require synchronization of the quadrupoles with the wiggler gap.

The nonlinear effects have been studied for the same wiggler and are shown in the dynamic aperture graphs in Figure 5. The graphs also show the same normalized coordinate $u/\sqrt{\beta_u}$, where u is either x or y for easy comparison. Although the dynamic aperture simulations show a small reduction in the vertical aperture for the BBY6T mode, the measured beam lifetime did not decrease with the implementation of the new mode.

Figure 6 and 7 show measured variations in the tunes and beam-sizes as a function of the wiggler gap in the BBY6T mode.

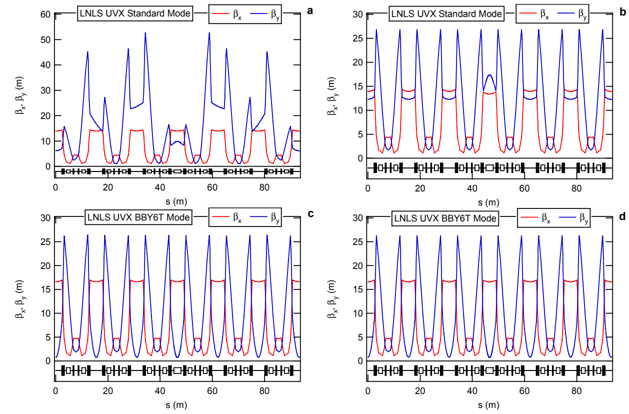

Figure 4: Linear optics perturbation caused by a 2.0 T multipole wiggler on the LNLS ring. (a) and (c) show respectively the Standard and BBY6T modes without compensation and (b) and (d) with compensation.

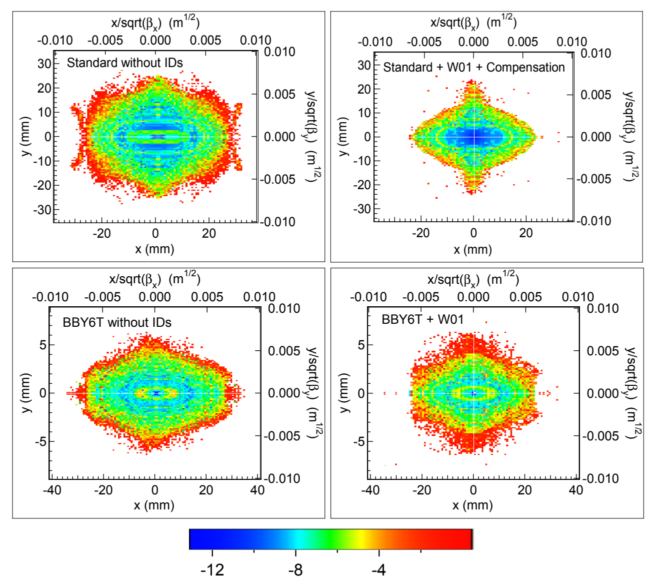

Figure 5: Dynamic aperture for the Standard (top row) and BBY6T (bottom row) modes. From left to right we have the lattice without IDs and with the 2.0 T wiggler with compensation in the Standard mode. The color code indicates the change in betatron tunes in a logarithmic scale.

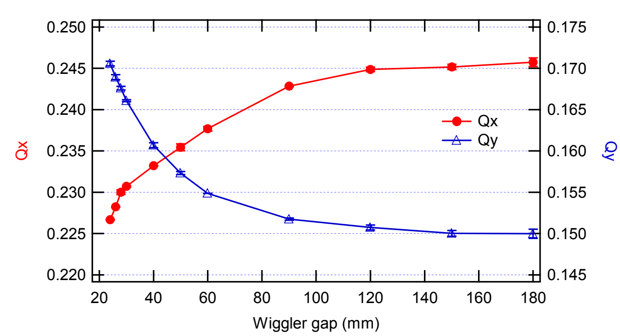

Figure 6: Measured tunes as a function of the wiggler full gap in the BBY6T mode.

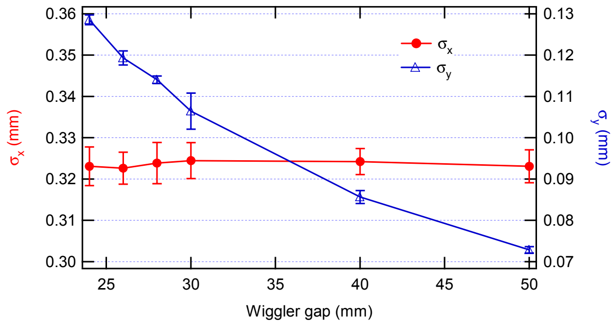

Figure 7: Measured beam-sizes as a function of the wiggler full gap in the BBY6T mode.

Commissioning of BBY6T mode

The commissioning of the BBY6T involved the implementation of the new mode both at the injection and operation energies. Injection in the user shifts consists of three stages: ramp the residual current at 1.37 GeV down to the 500 MeV injection energy, complete it through the accumulation process, and ramp up the refilled beam to the operation energy. Both ramping routes (up and down) had to be commissioned. All these stages have to be pursued sequentially and in a cyclic way in order to achieve overall repeatability of the machine lattice configurations.

The commissioning of the BBY6T mode started by searching for the first turn, which was achieved rather easily. After successfully storing a few milliamps, automated measurement of response matrix for orbit correction and tune scans proved to be very helpful to bring the stored current to some tens of mA. Since the horizontal optical functions have not changed much, the old settings of the transport line and injection kickers could be used. Nevertheless, the nominal injection current of 250 mA could only be reached by careful chromaticity measurement and adjustment as well as by scanning the temperature of one of the RF cavities, which had the temperature set point changed from 40.0 °C to 47.5 °C. The configurations have been perfected over several machine study shifts.

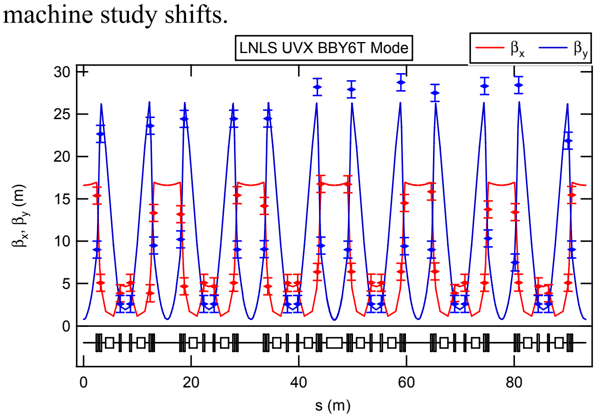

Figure 8: Measured (dots) and calculated (full curves) betatron functions in the BBY6T mode with the wiggler closed. The betatron functions were measured by changing quadrupole strengths.

Experimental characterization of BBY6T

A series of measurements has been performed to characterize the BBY6T mode, including betatron function measurement by changing individual quadrupole strengths and by fitting the orbit response matrix, dispersion function and coupling. A symmetryzation of the lattice [2] was performed with the MATLAB-based LOCO program. A large effort has been made at LNLS in order to automate the measurements. Figures 8 and 9 are some examples of completely automated experiments.

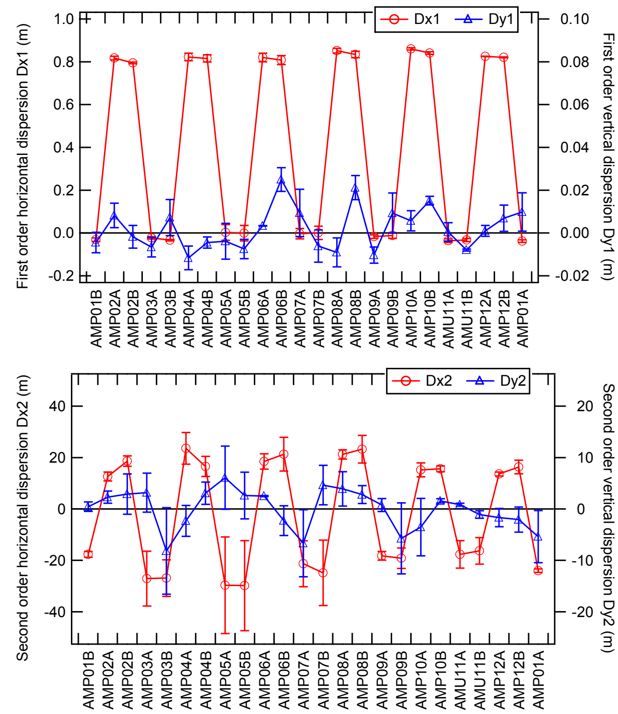

Figure 9: Measured first (top) and second (bottom) order dispersion function.

CONCLUSIONS

The nominal operation mode for the LNLS UVX storage ring has been changed from a variation of the Standard mode to the BBY6T mode, a new mode with a new operation point, in preparation for the installation of the third insertion device, a super conducting multipole wiggler, late in this year. This new mode restores the 6-fold symmetry of the lattice and is less sensitive to the perturbations of insertion devices. The new operation point of mode BBY6T required a new commissioning which occurred at the end of 2008. The BBY6T mode is been routinely employed for users operation since the beginning of this year.

REFERENCES

[1] R.H.A.Farias et al, "Commissioning of the LNLS 2 T Hybrid Wiggler", PAC05, http://www.JACoW.org.
[2] X.R.Resende et al, "Analysis of the LNLS Storage Ring Optics Using LOCO", these proceedings.