COMMISSIONING OF THE LNLS 2 T HYBRID WIGGLER

R. H.A. Farias, J. F. Citadini, M. J. Ferreira, J. G. R. S. Franco, A. F. A. Gouveia, L. C. Jahnel, L. Liu, R. Neuenschwander, X. R. Resende, P. F. Tavares, G. Tosin, LNLS, Campinas, Brazil
N. P. Abreu , LNLS, Campinas and UNICAMP, Campinas, Brazil

Abstract

We present the results of the commissioning of a 28-pole 2 T Hybrid Wiggler at the electron storage ring of the Brazilian Synchrotron Light National Laboratory (LNLS). The wiggler will be used mainly for protein crystallography and was optimized for the production of 12 keV photons. We describe the effects of the insertion device on the storage ring lattice, such as the correction of the linear tune-shift perturbations produced by the wiggler as well as on the reduction of beam lifetime at full energy. Since the injection at the LNLS storage ring is performed at 500 MeV we also focus on the effects of non-linearities and their impact on injection efficiency.

INTRODUCTION

The LNLS UVX synchrotron light source is based on a 1.37 GeV electron storage ring that has been in operation for external users since 1997. The injection system to the storage ring comprises a 120 MeV linear accelerator and a booster synchrotron. The beam is injected and accumulated in the storage ring at 500 MeV and then ramped up to the nominal operational energy. The ring is 93 m long and its magnetic lattice has a 6-fold symmetry with four free straight sections. Each of these sections allows for the installation of up to 2.9 m long insertion devices. The other two sections house the two RF cavities and the injection septa. The machine is operated for users in either multi-bunch or single bunch mode. In the multibunch mode the typical initial stored beam current in the users run is 250 mA.

Up to this moment all the 11 operational beamlines (eight in the X-ray and three in the ultra-violet region of the spectrum) open for external users at the LNLS Synchrotron Light Source are bending magnet based (1.67 T at 1.37 GeV) with critical photon energy of about 2 keV. The beamlines are currently limited in the flux that can be used in the harder part of the X-ray spectrum (above 10 keV). The need to improve the photon flux at 12.4 keV photon energy to meet the demands for a new Protein Crystallography beam line optimized for the Multiple Wavelength Anomalous Dispersion (MAD) technique has led LNLS to build a new high flux beamline based on the Multipolar Wiggler that has just been installed and commissioned. At that photon energy the wiggler beamline yields more than 60 times photon flux compared to a single dipole.

In this paper we present an overview of the main characteristics of the multipole wiggler and some comments about its installation in the storage ring. Moreover, we present the results of the commissioning of the new device in the storage ring, focussing on the effects on the machine optics.

THE MULTIPOLE WIGGLER

The wiggler was manufactured by STI Optronics. The very high field and relatively large gap (22 mm) of this insertion device led to a magnetic design that includes large main and side magnets and heavily saturated poles. The main parameters of the device, a 28-pole 2 T hybrid wiggler, are listed on Table 1.

A few comments are in order concerning the rationale for the choice of these parameters [1]. The magnet gap has been determined from experiments performed with the storage ring at injection energy (500 MeV) as well as from calculations of the impact of the reduction of vertical aperture on beam lifetime. The gap of 22 mm was determined as a compromise between the lifetime/injection efficiency reduction and the increase in wiggler field and reduction in wiggler period made possible by a smaller gap. In setting this value, we have assumed a total of 3 mm for the vacuum chamber (including possibly 2 mm for the chamber walls and 0.5 mm spacing between chamber walls and the magnetic poles on either side), so that the vertical beam stay-clear is 19 mm. The peak field and period of the wiggler

Table 1: Main Wiggler Parameters

Basic Wiggler Parameters		
Type	Hybrid	
Peak Field @ Min Gap	1.97	[T]
Period	180	[mm]
Minimum Gap	22	[mm]
Length	2.70	[m]
Full-strenght poles	28	
Number of poles	30	
Magnet Material	NdFeB	
Pole Material	V Permendur	
Max Gap	300	[mm]
Int. Field @ max gap	< 90	[G.cm]
Transverse roll-off †	0.01	[%]
Parameter K	33.6	
Critical Energy @max field	2.5	[keV]
Total wiggler Power @ 250mA	3.1	[kW]

† at $x = \pm 10$ mm and min gap

were determined by maximizing the flux of 12.4 keV photons on a horizontal phase space area of ± 0.75 mm $\times \pm 0.5$ mrad. This phase space area is representative of the expected typical sample phase space area in Protein Crystallography studies properly transformed (by an optical system with a 2:1 demagnification) to the central plane of the wiggler. This calculation was performed by assuming a perfectly sinusoidal field shape with no transverse variations, except for the end poles where an analytical model was used to allow the exact solution for the electron trajectories to be found. Given these trajectories, the known beam size and divergence was used to add up all contributions to the photon flux at a given position and angle from all parts of the wiggler.

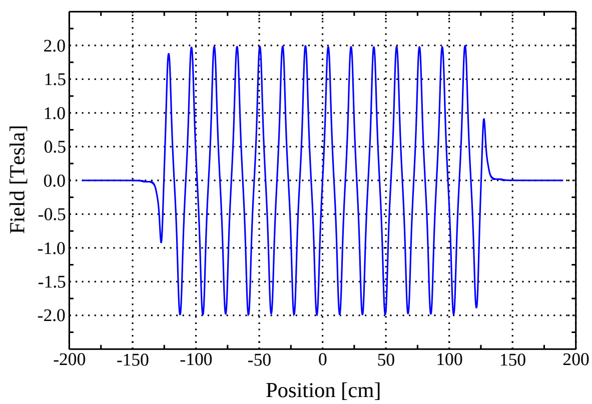

Figure 1: Measured magnetic field along the wiggler magnetic axis.

Besides the main magnetic array the wiggler also has a pair of steering coils used to bring the first and the second field integrals into the tolerances. A magnetic characterization of the wiggler was performed by STI Optronics and repeated at the LNLS magnet lab, complying with the specifications. The measured magnetic field along the magnetic axis of the device is shown in Fig. 1. A measurement bench including Hall probe and rotating coil techniques was developed and will also be used for the characterization of the next insertion device, an EPU undulator which is now under construction at the lab.

THE INSTALLATION IN THE SR

The installation of the wiggler in the storage ring was performed in two stages. The vacuum chamber was installed during the machine shutdown in the last quarter of 2004 together with an upgrade of the injection system. In that opportunity the three "in vacuum" injection kickers of the storage ring were replaced by new kickers with coated ceramic chamber [2]. Afterwards, the NEG coated wiggler vacuum chamber was installed in the machine where it was properly baked in order to activate the distributed pumping [3]. In order to perform the installation of these components one third of the ring had to be vented. As expected, the recovery of the vacuum pressure at the wiggler section was very fast, pointing to a successful activation of the NEG pumping. Modifications in parts of the vacuum chamber upstream the wiggler, with the introduction of additional cooling to account for the wiggler radiation, had already been carried out in a previous shutdown. Also, in order to provide extra orbit control at the wiggler section two pairs of steering coils have been installed in the quadrupoles downstream and upstream the wiggler.

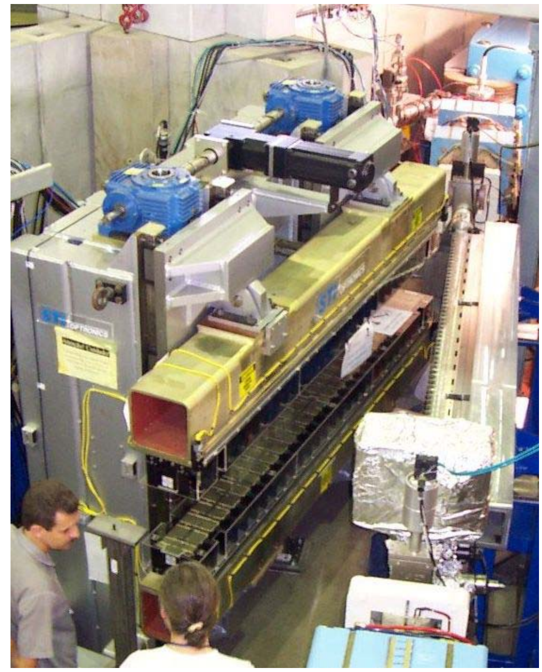

Figure 2: The multipole wiggler being installed in the SR. On the right part of the structure of the vacuum chamber can be seen.

Before the modifications in the ring the typical lifetime at 100 mA was of the order of 25 hours. In order to recover as fast as possible a conveniently long lifetime for the coming users shifts an operation mode was established with low vertical betatron function at the wiggler section. At the time the device was installed in the machine the lifetime at the same current was close to 20 hours at that operation mode.

In March of 2005 the first insertion device was installed and commissioned. The commissioning of the machine with the new insertion device elapsed smoothly. In the low vertical betatron mode it was possible to close the gap of the wiggler without any adjustment in order to compensate for excessive tune shift or orbit distortion. The effect of the wiggler emission was patent since the localized increase of the vacuum pressure in that sector forced a new conditioning of the chamber with beam and it could also be observed as a shift in the synchronous phase with the gap aperture.

The device is remotely controlled through the Ethernet protocol and is fully integrated into the software that controls the whole set of components of the light source.

0-7803-8859-3/05/$20.00

THE EFFECTS ON THE SR OPTICS

A series of measurements has been performed in order to evaluate the impact of the wiggler on the storage ring optics. The symmetrization of the machine optics for the low betatron mode with gap both open and closed was performed as well as tune scans at full energy in order to look for a better operation point. With closed gap the machine still runs at its nominal tunes $Q_x = 5.27$ and $Q_y = 2.17$.

Injection is performed with gap open and with the machine in the normal mode of operation (6-fold symmetry). During the energy ramp the configuration migrates to the low betatron one with a total tune shift in both planes of approximately $\Delta Q_x = 0.02$ and $\Delta Q_y = -0.02$. The ramp to the normal mode requires the establishment of a configuration route so as to compensate for the large tune shifts produced by closing the gap. The tune shift with gap aperture was measured and is shown in Fig. 3. Although it is perfectly possible to close the gap without using the corrector coils they are essential if the gap is to be closed during a users shift.

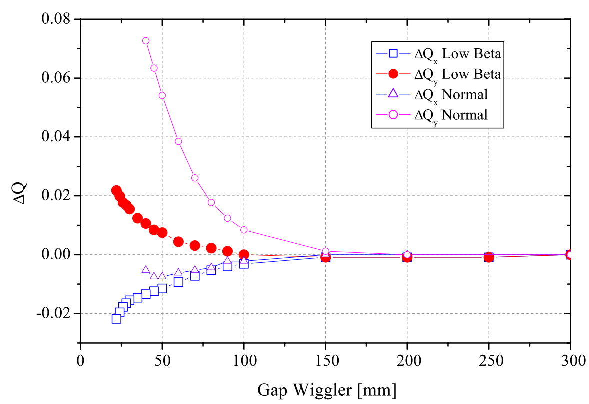

Figure 3: Measured tune shift at different wiggler gaps.

Measurements performed with vertical scrapers show that the presence of the wiggler in the magnetic lattice had no relevant effect on the dynamic aperture (Fig. 4).

The transverse coupling introduced by the wiggler is on the order of 1.5%, close to the coupling intentionally introduced between the horizontal and vertical planes by means of the skew quads so as to increase lifetime during users runs. With gap open the transverse coupling is smaller than 0.3% (Fig. 5).

We established, with the beam, the values for the corrector coils which minimize the first and second field integrals by reducing the orbit horizontal distortion due to the gap closure. The results agree with the measured values both at STI and LNLS.

CONCLUSION

The installation of the first insertion device at the Brazilian Light Source was successful although work still have to be done in order to have it working on a users basis. Further

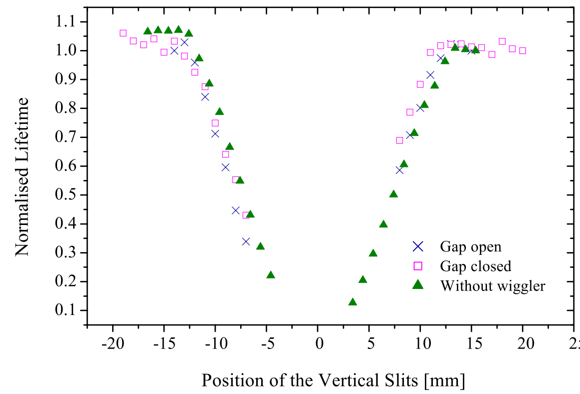

Figure 4: Effect of the wiggler on dynamic aperture.

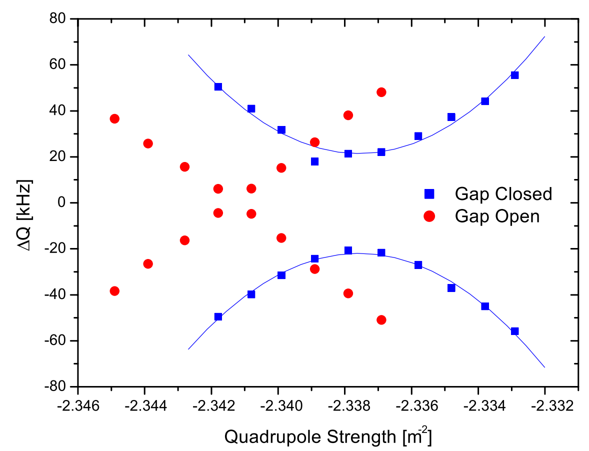

Figure 5: Effect of the wiggler on the beam transverse coupling.

studies are planned concerning the effects of the device in the machine.

ACKNOWLEDGMENTS

This work was supported by the Brazilian funding agencies FAPESP and MCT-CNPq.

REFERENCES

[1] L. Liu and P. F. Tavares, “A Hybrid Multipolar Wiggler for Protein Crystallography at the LNLS Synchrotron Light Source”, LNLS - MeT 01/2003 (2003).

[2] M. J. Ferreira et al, “Design, Construction and Commissioning of a NEG Coated Wiggler Vacuum Chamber for the LNLS Storage Ring”, These proceedings.

[3] M. J. Ferreira et al, “Design, Development, Construction and Installation of a Ceramic Chamber for a Pulsed Kicker at the LNLS Storage Ring”, These Proceedings.