CONCEPTUAL DESIGN OF AN EPU FOR VUV RADIATION PRODUCTION AT LNLS

G. Tosin, R. T. Neunschwander, J.F. Citadini, M.C. Rocha, X. R. Resende, P.F. Tavares, R. Basílio, M. Potye, LNLS, Campinas, Brazil

Abstract

We describe the magnetic and mechanical design of an elliptically polarizing undulator (EPU) currently under construction at the Brazilian Synchrotron Light Source - LNLS. The device is designed to cover the photon flux in the range from 100eV to 1000eV (124Å a 12.4 Å), allowing linear, elliptical and circular polarizations. With this device it is possible to reach absorption edges of several elements such as Si, S, Br, C, N, O, Fe, F, Cl and to measure magnetic dichroism.

The EPU uses a pure permanent magnet design and field corrections are done by means of virtual shims, with horizontal and vertical displacements. Each one of the four magnetic blocks linear arrays (cassettes) is segmented into seven sub-cassettes. The separate magnetic measurement of each sub-cassette allows corrections of the magnetic field profile to be made before final assembly and makes the verification of mechanical tolerances easier and faster, decreasing the expected time that will be spent in the magnetic tuning of the device.

The mechanical structure is composed of a C-Frame, gap and phase actuators. The two gap actuators as well as the phase actuators use absolute encoders and biasing with springs to eliminate backlash. An apparatus having springs to simulate the magnetic forces was used to test the motion control.

INTRODUCTION

This paper describes the main parameters and concepts related to the EPU undulator under construction, which has been designed to cover the vacuum ultra violet spectra at the LNLS 1.37 GeV electron storage ring. The undulator development was segmented in three specialties: magnetic design, mechanical design and control system. The undulator total length is limited by the size of the long straight section reserved for insertion devices and the magnetic period was found by optimizing the photon flux for the desired spectral range (from 100eV to 1000eV) and polarizations, considering harmonics up to fifth order [1].

Table 1 contains the undulator main parameters and Table 2 the magnetic field quality tolerance imposed for the undulator.

Table 1: Undulator main parameters

Magnetic period [mm]	50
Number of blocks per period	4
Undulator total length [mm]	2773
Number of periods	54
Minimum gap [mm]	22
Magnetic blocks main dimensions [mm^3]	12.3×40×40
Horizontal distance between cassettes [mm]	1
Maximum peak fields (vertical, circular and horizontal phases) [T]	0.53, 0.27 and 0.31

Table 2: Undulator magnetic specifications

Dipole (Normal and Skew) [T.m]	1.5×10^{-5}
Quadrupole (Normal and Skew) [T]	2.0×10^{-3}
Sextupole (Normal and Skew) [T/m]	1.5×10^{-1}
Octupole (Normal and Skew) [T/m^2]	1.0×10^{1}
Roll off [%]	0.01

MAGNETIC DESIGN

The EPU undulator magnetic structure is composed of two pairs of magnet linear arrays (cassettes), two of them above and two below the orbit plane. Each magnetic period contains four blocks in Halbach configuration. The light polarization can be changed by simultaneously displacement of two diagonally placed cassettes (Figure 1). This procedure corresponds to a phase shift. The field intensity is controlled by changing the gap aperture. Magnetic studies have been done with the simulation codes Radia [2] and Magnet [3].

Vacuumschmelze has furnished us the NdFeB magnetic blocks. The remanent field and the coercivity are 1.25 T and 23 kOe respectively. The measurement of the blocks at LNLS showed less than 1% (peak to peak) variation of the remanent field amplitude and less than 0.8^0 for the angular deviation of the remanent field direction with respect to the main magnetization axis.

The magnetic sorting for the blocks placement in the undulator structure is based on simulated annealing algorithm [4]. Parameters optimized are the first and second field integrals and the phase error, for horizontal, circular and vertical light polarizations.

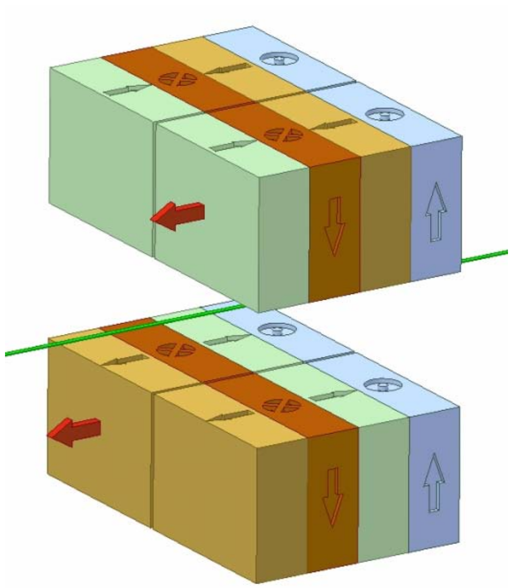

Figure 1: Drawing showing one period of the EPU in the phase corresponding to the vertical field. The symbols on the blocks indicate the magnetization direction. External arrows represent the movements of two cassettes to change the light polarization.

Every cassette is composed of six sub-cassettes having nine magnetic periods each. Sub-cassettes are assembled in a special movable table, machined within ±10 µm of precision, which has Hall probes and digital micrometers attached to it. This setup allows the transverse position as well as the magnetic field profile of every block to be checked. That information is then used to perform a pre-correction in the magnetic field by means of virtual shims [5].

Each cassette has antisymmetric terminations containing magnets with ¼, ½ and ¾ of the main block length. The installation of electromagnets at the undulator extremities for integrated field fine tuning is also probable.

MECHANICAL STRUCTURE

Figure 2 shows the undulator structure, indicating the main parts. Except for the cassettes (strongbacks and blocks keepers) that are made of duraluminum, all other parts are made of carbon steel. The C- frame design is based on the successful mechanical structure of the 2 teslas wiggler bought from STI Optronics in 2003. The mechanical structure was designed to have maximum deformation of 20 µm, considering gravitational and magnetic forces. Such analysis was made using Ansys code [6], and has not taken into account the backlashes between movable pieces. In order to minimize the backlashes, pre-loaded ball screws, high rigid pre-loaded cross roller linear guides and spherical bearings pre-loaded with conventional springs are used (Figure 3). To eliminate the backlash effect on the linear encoders' readings, flexural U joins are employed. Two motors set in motion the vertical gap actuator, allowing for a small vertical misalignment between upper and down cassettes, making possible for the undulator to operate in tapering mode. Also two motors instead of one, for reasons of mechanical complexity, move the phase actuator.

The blocks' keepers (Figure 4) are designed in such a way to allow every block to have vertical and horizontal displacements, used to correct the magnetic field profile (virtual shims).

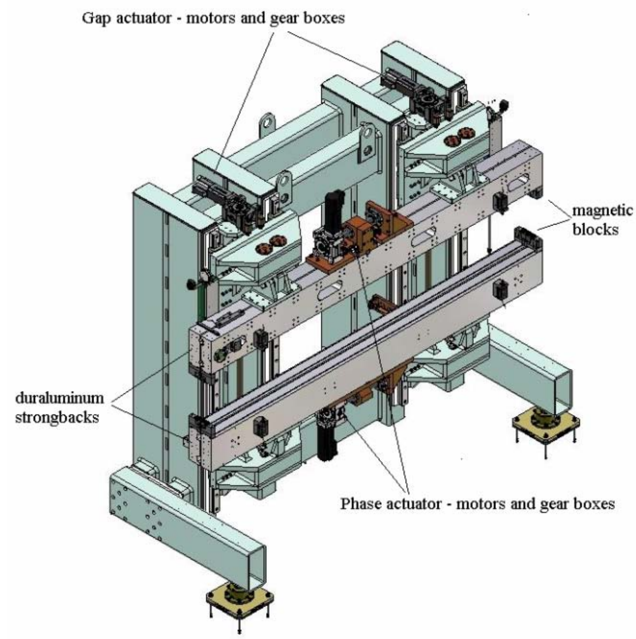

Figure 2: Undulator design and its main parts.

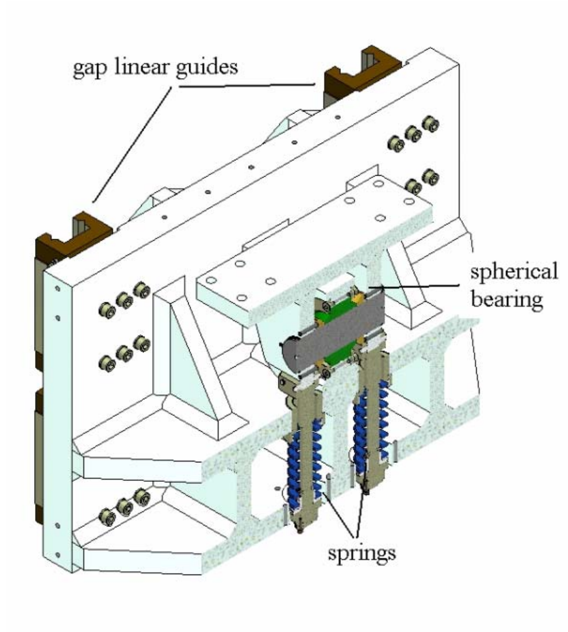

Figure 3: Cut away view showing spherical bearings pre loaded with conventional springs.

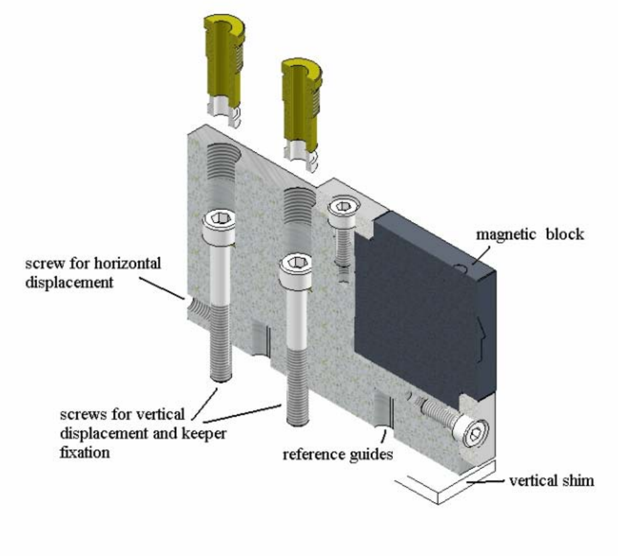

Figure 4: Cut away view of a block's keeper. It is possible to move the keeper in both vertical and horizontal directions to insert shims of calibrated thickness. The two cylinders over the vertical fixation screws are ancillary devices used to insert the shims moving the keepers vertically.

CONTROL SYSTEM

The Undulator movements, as phase or gap displacements are made with servomotors operated by Ecodriver Bosch controller. The Ecodrivers can operate with Absolute Linear Encoders (EnDat protocol) affording more reliability. Another advantage is that absolute linear encoders are not susceptible to electrical noise because it does not count pulses.

The control is divided in two identical blocks: Phase and Gap displacement blocks. Each block is composed of two servomotors with resolvers, two absolute linear encoders (EnDat protocol) and two Ecodrivers (Figure 5).

There are two possible operating modes: Normal Mode and Tapered Mode. In the Normal mode, apart from the blocks, both motors have to move synchronously, in other words, no variation between the absolute encoders is permitted. In the Tapered mode (exclusively in the gap displacement), a little difference between the encoders is permitted, creating a small angle between the cassettes. The Taper possibility is available because the servomotors work unattached from each other and their movements are externally triggered at the same time. The parallelism and the desired angle (Tapered Mode) are guaranteed by the driver's parameters.

Software and Firmware Limits, Limit Switches and Emergency stops were inserted for protection. The biggest risk is the possibility of exceeding the permitted angle between the cassettes in the Tapered Mode, where two limit switches protect the vacuum chamber and the mechanical structure at the minimum gap. Others limit switches are installed close to the spherical bearings, avoiding the difference of the two linear encoders in an established range.

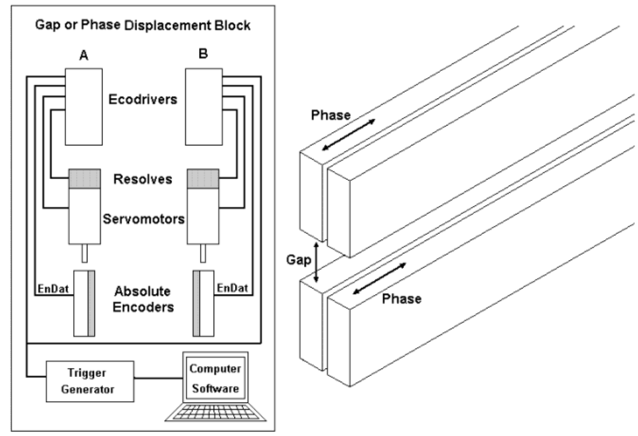

Figure 5: Schematic representation of the control system for gap and phase displacements.

REFERENCES

[1] Resende, X. R. "Period Length Optimization for the LNLS Undulator." Technical Memorandum (MT). nº 3, LNLS, 2003.
[2] Chubar, O.; Elleanume, P.; Chavanne, J. J. **of Synchrotron Rad**., v.5, pp.481-484, 1998.
[3] Magnet. Software for Electromagnetics, Infolytica Corporation. Available in: http://www.infolytica.com.
[4] Ximenes R. Resende and Roberto M. Dias, Proceedings of EPAC 2004, Lucerne, Switzerland.
[5] G. Tosin, J. F. Citadini, R. Basilio and M. Potye, EPU Assembly based on Sub-cassettes Magnetic Characterization, EPAC 2006
[6] Ansys. Software for Finite Element Analyses, Ansys, Inc. Available in: www.ansys.com