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ADVANCES IN THE SIRIUS DELTA-TYPE UNDULATOR PROJECT

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Abstract

The Delta undulator is a compact adjustable-phase insertion device that provides full light polarization control. Five undulators of this type will be installed in the initial operation phase of Sirius, the new 4th generation synchrotron light source that is being built by the Brazilian Synchrotron Light Laboratory (LNLS). In this work we present the recent advances in the development of Sirius Delta-type undulator, the studies of the effects of this device in the storage ring beam dynamics and assembly and measurements strategies.

INTRODUCTION

The Sirius project is currently in the final construction stage. The Linac is already being commissioned and the storage ring tunnel is ready for installation. For more information, refer to [1].

The Sirius 3 GeV storage ring comprises a 5BA lattice with 5 high and 15 low horizontal beta straight sections, of which 17 will be available for installation of insertion devices (IDs). The reduced beam-stay-clear of the low beta sectors ($BSC_x = \pm 3.2$ mm and $BSC_y = \pm 1.9$ mm in the center of the straight section) [2] allows the use of devices with small aperture in both transverse planes, such as the Delta undulator [3, 4]. This undulator consists of four arrays of permanent magnet (PM) blocks placed around the beam axis forming a diamond shaped beam aperture. Both the radiation polarization and the amplitude of the on-axis magnetic field are controlled with the longitudinal displacement of the magnetic arrays, so the gap is kept fixed. Five Delta undulators are foreseen for the first operation phase of Sirius: two with a period of 21 mm and three with a period of 52.5 mm. The main parameters of these undulators are listed in Table 1 and the calculated brightness is shown in Fig. 1.

Table 1: Parameters of the Sirius Phase-I Delta undulators

	Delta-21	Delta-52
B_0 [T]	1.12	1.19
Period [mm]	21.0	52.5
Length [m]	2.4	3.6
Gap [mm]	6.92	13.85
Maximum K	2.20	5.85

The Delta undulator design can provide a stronger magnetic field than conventional APPLE devices. However, the Delta limited horizontal and vertical apertures makes the measurement and tuning of the undulator more difficult and the fixed gap scheme poses additional concerns in the possible detrimental effects on beam performance. This paper presents an overview of the Delta undulator project and a summary of the simulated effects of this ID on beam dynamics. The assembly and measurement plans for the undulator are also discussed.

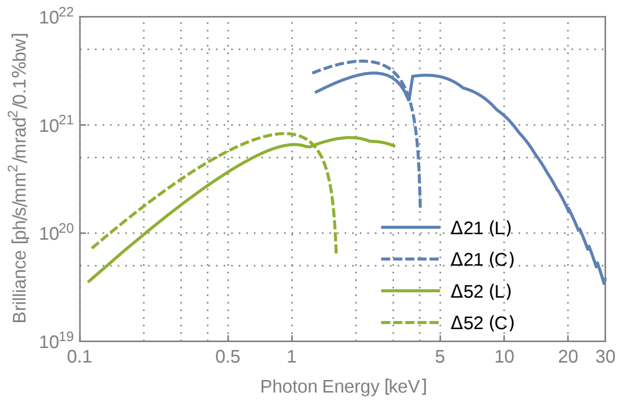

Figure 1: Brightness for the Delta undulators with periods of 21 mm (Δ21) and 52.5 mm (Δ52) for linear (L) and circular (C) polarization modes calculated using Spectra 10.1.2. The calculations were performed for a beam current of 350 mA (Sirius Phase-II).

UNDULATOR DESIGN

The Sirius Delta-type undulator is an out-of-vacuum pure permanent-magnet device composed by four arrays of NdFeB blocks. Figure 2 shows the undulator layout. To facilitate assembly, the PM blocks of each array will be mounted into aluminum block keepers of 12 blocks each. After the alignment, the blocks will be glued in the keepers to provide mechanical stability. These keepers are assembled on a carbon steel base that can be moved independently to control the energy and polarization of the emitted radiation. The linear drive system comprises a preloaded double-nut ball-screw and a servomotor with an absolute encoder, and can provide a positioning precision of 0.2 µm. The undulator will be segmented in modules of 1.2 m to allow NEG coating deposition for a vacuum chamber with such a small radius (less than 5 mm for the Delta-21 case).

The magnetic field calculations indicated forces up to 30 kN between the magnetic arrays. Studies of the effect of these forces in the mechanical structure, as well as modal analysis, were performed with the software ANSYS [5]. The result for the deformation of the cassette for the worst case analyzed (inclined polarization mode) is shown in Fig. 3, which indicates a maximum deformation of 25 µm. This simulation does not take into account the effect of the flexible joint of the double-nut, therefore smaller deformations are expected for the real structure.

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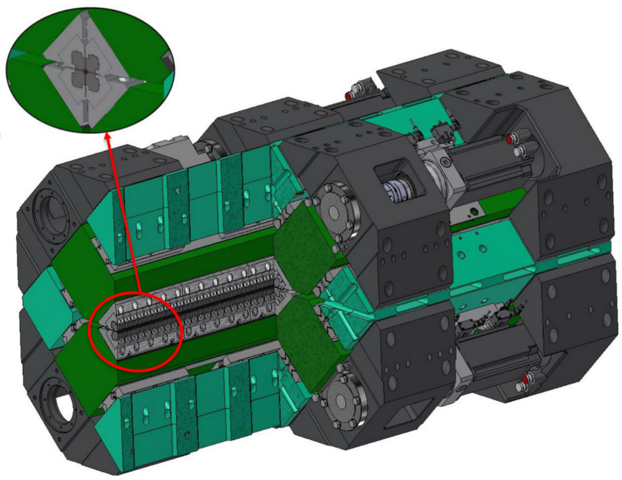

Figure 2: Mechanical layout of the Sirius Delta undulator. In detail are shown the PM blocks and the block keepers.

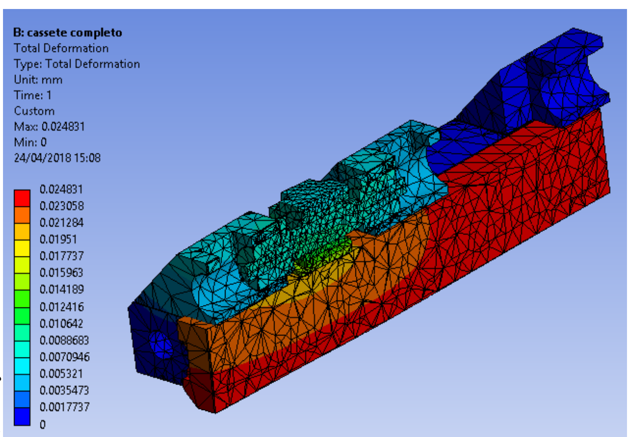

Figure 3: Cassette deformation for inclined polarization mode.

EFFECTS ON BEAM DYNAMICS

The study of the linear and non-linear effects of the Delta undulators in the storage ring beam dynamics was performed using the kick map method. The effects of the IDs in the beam emittance, energy spread and the collective behavior and instabilities are not considered here and can be found elsewhere [6, 7].

The Radia package [8] was used to model the IDs and to evaluate the kick maps for several undulator operation modes. In a previous work [9] a simplified model was used to speed up the calculations. A more detailed model is considered here, which takes into account the correct shape of the PM blocks, as well as their interaction due to the finite magnetic susceptibility of the NdFeB, which is approximately 0.04 in this case.

The linear effects introduced by the IDs in the lattice model were minimized with a local correction of the optics, using only the quadrupoles of the ID straight section, and global corrections of the tune and the chromaticity. Applying these steps the RMS beta beat was reduced from 1.7 to 0.4 in the worst case analyzed and the tune and chromaticity of the lattice were restored to their nominal values in all cases. Feed-forward tables depending on the undulator operation mode will be used to implement these corrections in the real machine.

The dynamic aperture of the lattice with IDs were calculated using particles tracking, as described in [9]. The results for the dynamic aperture are shown in Fig. 4. A reduction of the area from 37 mm^2 to 30 mm^2 is observed for the machine with Delta-21 devices. No significant reduction was observed for the machine with Delta-52 devices. In both cases, the dynamic aperture on the negative horizontal side exceeds the target value of 8 mm and should not compromise the off-axis injection process.

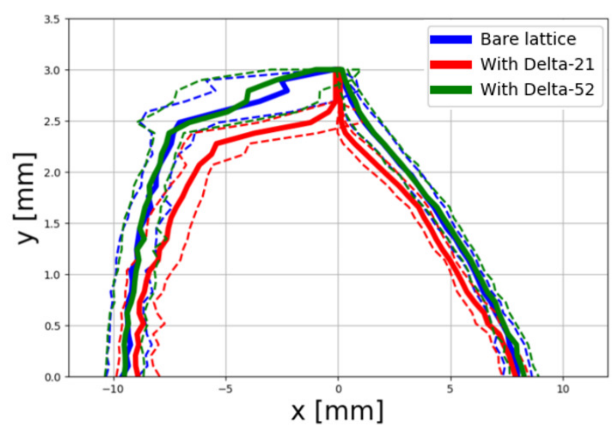

Figure 4: Dynamic aperture for the storage ring bare lattice (blue), lattice with 14 Delta-21 (red) and lattice with 14 Delta-52 (green). The dashed curves indicate one standard deviation from the average (solid curve) over 20 machines with random alignment, excitation and multipole errors.

MAGNETIC MEASUREMENT INSTRUMENTATION

The measurement and tuning of all Sirius Phase-I undulators will be performed in-house. A Helmhotz coil system will be used to check the magnetization measurement data provided by the PM block manufacturer. The magnetization measurement results will be used in sorting algorithms to determine the initial position of each block. The magnetic field of each cassette will be tuned during the assembly using the longitudinal field profile data measured with a Hall probe system. The field correction will be performed with blocks substitution and virtual shimming.

An ultra-thin 3-axis SENIS Hall probe (0.25 mm) will be used for the measurements of the longitudinal magnetic field profile after assembly. A C-shape measurement structure was designed to allow lateral access of the probe to the beam aperture, as shown in Fig. 5. Finally, the field integrals of the assembled undulator will be measure with a stretched wire system.

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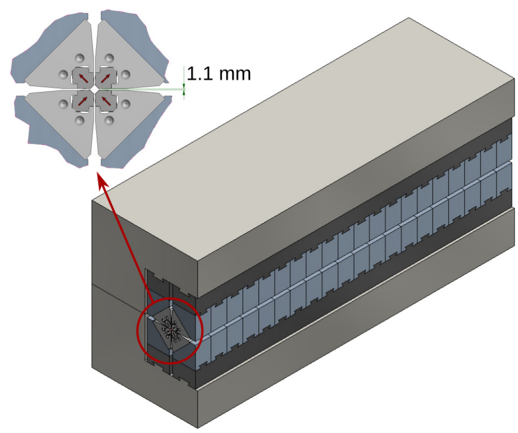

Figure 5: Design of the C-shape undulator structure that will be used for the magnetic field measurements.

UNDULATOR PROTOTYPE

A full scale prototype for the Delta undulator, with a 20 mm period and a 6.92 mm gap, is currently being built to test its mechanical and magnetic performance. Figure 6 shows the prototype structure. The PM blocks will be assembled in the structure after mechanical tests. The prototype NdFeB (48SH) blocks were ordered from “Dailymag Magnetic Technology Limited” with remanent magnetization specification from 1.37 to 1.43 T and intrinsic coercive force > 1590 kA/m. Figure 7 shows a keeper with the assembled PM blocks that was used to test the blocks bonding process.

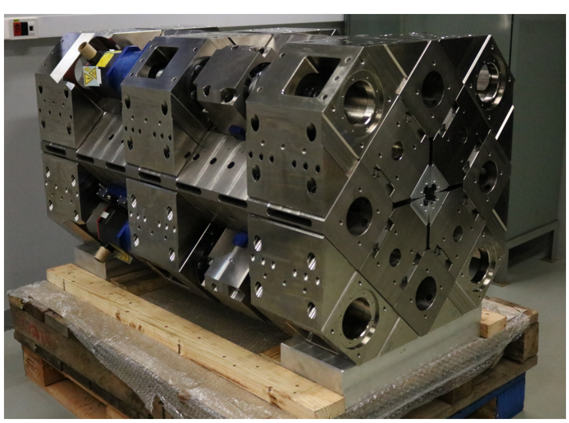

Figure 6: Delta undulator prototype.

NEXT STEPS

The magnetic assembly of the prototype is being performed to validate the control parameters of the servo drivers and the maximum mechanical deformation of the two prototypes available. The mock-up for magnetic assembly, measurements and shimming will be detailed and built, as well as the new stem for the ultra thin SENIS’s sensor. During the mock-up construction, new studies of the shimming method and sorting based in the magnetization will be tested. The

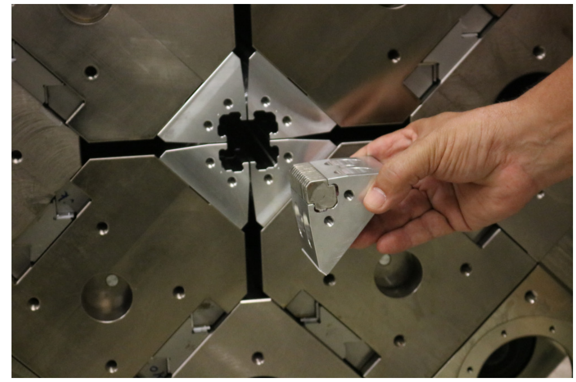

Figure 7: Block keeper with PM blocks.

vacuum chamber mechanical design, the flange brazing and NEG coating setup are being prepared for tests in chambers of 1.2, 2.4 and 3.6 m, as well as the fixing and cooling methods of the chamber.

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