STATUS OF SIRIUS – A NEW BRAZILIAN SYNCHROTRON LIGHT SOURCE

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Abstract

We present an overview of the new synchrotron light source project Sirius, currently being designed at the Brazilian Synchrotron Light Laboratory (LNLS) in Campinas, São Paulo. Sirius will consist of a 480 m circumference, 3.0 GeV, 20 TBA cells, 1.7 nm.rad emittance storage ring. The dipoles will be based on the use of permanent magnet technology and will combine low field magnets (0.5 T) for the main beam deflection with a short slice of high field magnet (2.0 T) to generate high energy photons (the critical energy is 12 keV) from dipoles with a modest total energy loss. There will be 18 straight sections for insertion devices. In this report we describe the current status of the magnet lattice design and some of the subsystems.

INTRODUCTION

Sirius is a new 3rd generation synchrotron light source proposed to meet the demand for a high brightness and high flux photon source in Brazil and Latin America. The new facility will be constructed at the LNLS (Brazilian National Synchrotron Light Laboratory) site, in Campinas, São Paulo, where a soft x-ray source (UVX) is already in operation for users since 1997. We are currently starting the detailed design and R&D phase, following a previous phase for definition of the main parameters and initial lattice design study [1]. Since 2009, the funding for the conceptual design phase was mostly used to equip the technical laboratories and the machine shops, as well as to start R&D of the most critical subsystems, especially the permanent magnet dipoles. For this and the next year extra funding is foreseen, but the budget for Sirius has not yet been approved by the Brazilian Federal Government.

The activities related to Sirius over the last year comprise mainly optimization of the lattice design and prototyping of the high and low field permanent magnet dipoles, quadrupole and combined sextupole magnets. In addition, designs studies for several subsystems have started, including the injector, vacuum, diagnostics, RF, alignment and control systems. Also, the layout of the accelerator complex (Figure 1) and civil engineering are being made. The experimental hall will be able to accommodate beamlines up to 70 m in length. The requirement for longer beamlines (up to 250 m) is also anticipated and the possibility of a future extension of the building is left open.

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THE NEW LATTICE

A new lattice is proposed for Sirius in which we keep the modified TBA structure with a high field slice in the middle of the center dipole, but replace the straight section matching quadrupole doublets by triplets in order to reduce the horizontal beta function in the insertion sections. In addition, the length of the straight sections was optimized so that the total circumference of the machine would not increase too much. We reduced the number of 9 m long straight sections from 10 to 4 and introduced four 7 m medium straights. The number of 5 m short straights was increased from 10 to 12, so that the total number of 20 straight sections is maintained. The circumference of the machine increased to 479.7 m, 4% larger than the previous design. The 10-fold symmetry has been reduced to 4-fold. Of the four long straight sections, one is reserved for injection with kickers and a second for the RF cavities, either normal or super-conducting.

The lattice has been optimized for an achromatic optics with zero dispersion in the insertion straights. The bare machine emittance is 2.8 nm.rad and it decreases with the

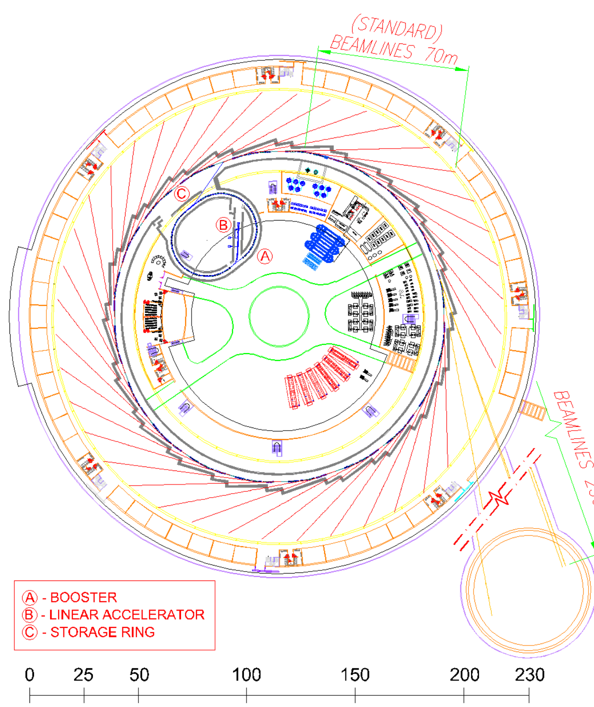

Figure 1: Layout of Sirius.

addition of wigglers. We have also calculated a low emittance mode with distributed dispersion. In this case the bare machine emittance is 1.7 nm.rad but it increases with the addition of strong wigglers. An intermediate hybrid mode is also proposed in which the dispersion is zero in only 4 straight sections. In this case the emittance of the bare machine is 2.1 nm.rad and it decreases if wigglers are installed only in these sections. Figure 2 shows the optical functions for the low emittance mode and Figure 3 shows the effects of wigglers on the emittance for these 3 modes. We consider in this example one 4 Tesla super-conducting wiggler and three 2 Tesla wigglers. Table 1 shows Sirius main parameters. Studies on the optimization of dynamic aperture and orbit correction in the presence of multipole and alignment errors for these modes are being done using the codes OPA, Tracy3 and AT. Figure 4 shows one example of frequency map analysis in the low emittance optics with multipole errors in all magnets and physical limitations. Studies on closed orbit and coupling correction show the orbit can be corrected to residual rms values of 12 μm (8 μm) in the horizontal (vertical) plane in a configuration with 180 BPMs, 160 horizontal, 160 vertical and 40 skew correctors. All corrector coils are integrated into the sextupoles. The optimization of non-linear effects, the analysis of alignment and multipole errors, effects of insertion devices and study of beam instabilities are among ongoing main accelerator physics tasks.

The magnetic measurements and simulations of the high field slice dipole show significant edge effects, as expected. These effects have been incorporated into the lattice optics optimization. The longitudinal field profile is simulated by a sequence of thin dipoles with multipolar components. The model was calibrated by fitting the transfer maps to trajectories calculated by tracking. The strong sextupole component was also incorporated into the lattice non-linear optimization. The peak field and deflection angle were adjusted (from 2.0T/1.0° to 1.95T/1.24°) to accommodate feasible dipole prototype fields.

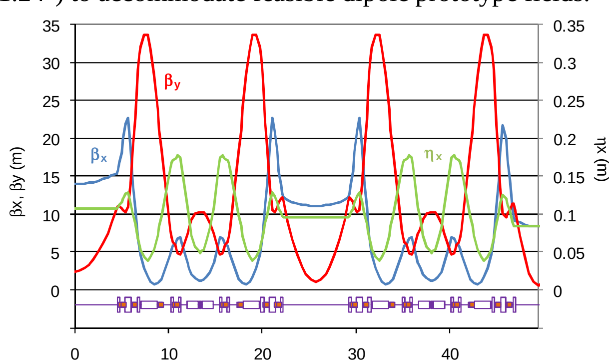

Figure 2: Optical functions of 1/10 of Sirius low emittance mode with distributed dispersion.

INJECTION SYSTEM

The injection system being considered is composed of a 150 MeV Linac and a 3.0 GeV full energy booster synchrotron. Whereas we are planning to purchase a turn-key Linac, the booster synchrotron is being designed at LNLS. The initial design consists of a FODO lattice booster with 120 m in circumference and two 7.4 m long straight sections. The optics has a nominal emittance of 40 nm.rad at 3 GeV.

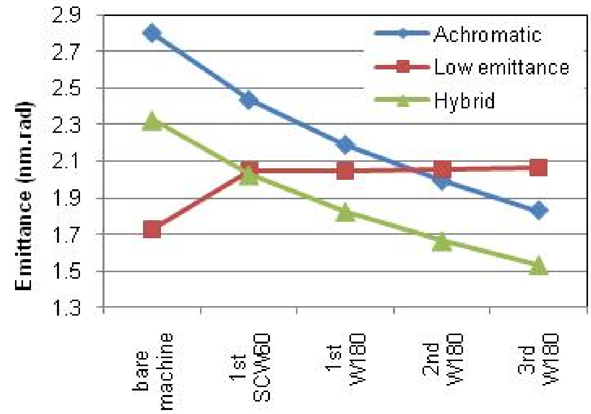

Figure 3: Effect of insertion devices on the natural emittance for Sirius three operation modes.

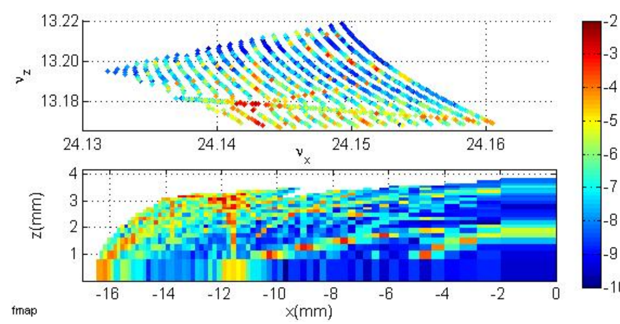

Figure 4: Frequency map analysis for the low emittance mode with multipole errors and physical limitations.

Table 1: Sirius Main Parameters (Low Emittance Optics)

Energy (GeV)	3.0
Beam current (mA)	500
Circumference (m)	479.7
Nat. emittance, bare lattice (nm.rad)	1.7 / 2.8
Cell / symmetry / structure	20 / 4 / TBA
Main dipole field (T)	0.5
Slice dipole field (T)	1.95
Total deflection by main dipoles	335.2°
Total deflection by slice dipoles	22.8°
Critical energy, slice dip. (keV)	11.7
SR loss/turn, dipoles (keV)	430
Betatron tune (h/v)	24.15 / 13.22
Nat. chromaticity (h/v)	-35.2 / -41.4
Nat. energy spread (%)	0.08
Momentum compaction	7.4×10^{-4}
Harmonic number	800
RF frequency (MHz)	500
Damping time (ms) (h/v/s)	17.1 / 24.7 / 15.9
Straight sections	4*9m, 4*7m, 12*5m
Beam size (k=0.5%) @ slice (μm^2)	59 x 9
Beam size (k=0.5%) @ SS (μm^2)	135 x 2

STORAGE RING MAIN SYSTEMS

For some systems we are already producing prototypes and testing concepts while for others we are still at very early stages. In short, we are still exploring ideas and possibilities, comparing solutions adopted elsewhere in terms of the local conditions. We aim of course, at achieving the very demanding specifications for all equipment so that the best performance expected from this light source can be reached. Our approach includes using the existing UVX accelerator as a test bench for new ideas whenever possible. This includes using the solid state amplifiers for the RF system, testing single board computers for the control system, implementing orbit and bunch by bunch feedback loops, testing injection with pulsed sextupole [3], etc.

Magnets

The proposal to use permanent magnets for the storage ring dipoles is a critical point of the Sirius project. An R&D program on this subject was thus given high priority [2].

The first prototype for the low field dipoles used ferrite permanent magnets. The achieved dimensional and magnetic tolerances of such permanent magnets proved to be insufficient for this application. Although the price of NdFeB is higher than ferrite, considering the technical advantages (dimensional and magnetization tolerances, temperature stability) and the lower volume needed to build the dipoles, we have decided to abandon ferrite. A much more compact prototype based on NdFeB has then been developed. The approach is to use permanent magnets to drive the magnetic field. The field quality is determined by the shape of the iron poles, which will also serve to shield the permanent magnets from radiation. The design also allows for field trimming by an adjustable shunt of the return flux. The first prototype for the 2 Tesla slice dipole, which also uses NdFeB permanent magnets and 1010 steel, resulted in a peak field slightly higher than 2 T but also in a higher integrated field. For the next prototype we are aiming at a peak field of 1.95 T and 1.24° deflection. The use of FeNi tapes to reduce field variation with temperature is also being studied for the next prototype. Figure 5 shows pictures of the first low and high field NdFeB permanent magnet prototypes.

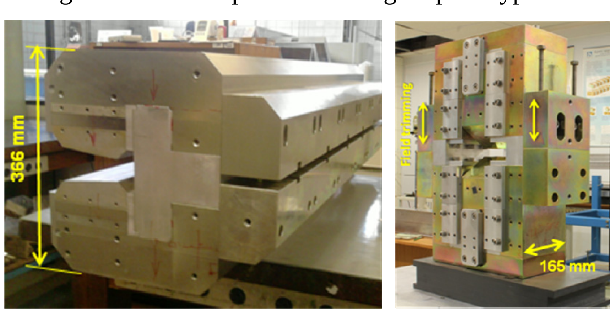

Figure 5: Prototypes of the 0.5 Tesla (left) and the 2.0 Tesla (right) permanent magnet dipoles, based on NdFeB.

A combined function electromagnet sextupole was designed and assembled. The sextupole also includes vertical and horizontal correctors and skew quadrupole. Magnetic measurements show the necessity for further improvements of the magnet multipole content.

Vacuum System

The Sirius vacuum system will be based on stainless-steel chambers with pumping provided by ion pumps and titanium sublimation pumps. We are not planning to use NEG pumps since the use of permanent magnets prevents in-situ activation. The present design of the chamber contains an ante-chamber with a linear array of grazing incidence absorbers electrically hidden by an attenuation channel separating both chambers. The ion pump cells will be installed inside the ante-chamber increasing the effective pumping speed. Also the pump magnets will be mechanically decoupled from the chamber in other to facilitate alignment. Prototyping tests have shown an increase of up to 70% in the effective pumping speed per cell. The geometry shown in Figure 6 is being proposed for all storage ring sections except the insertion straights. This solution will require C shaped magnets. This proposal is being studied.

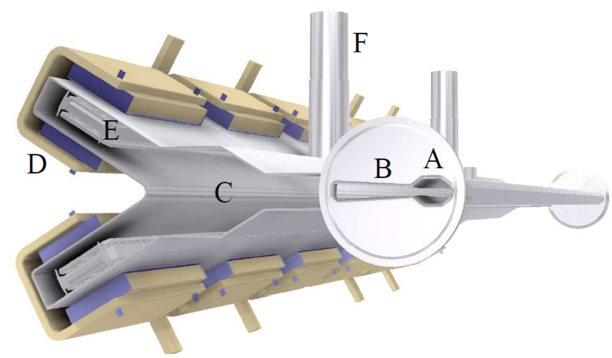

Figure 6: Proposed vacuum chamber for Sirius. A) electron beam chamber. B) Attenuation channel. C) Ante-chamber. D) Ion pump magnets. E) Ion pump cells. F) Ti sublimation pumps.

CONCLUSIONS

A major updating of the LNLS physical infra-structure has been made since 2009 in preparation for the construction challenges of Sirius components. LNLS is now equipped to start the R&D phase. Prototypes can be quickly produced and tested in-house. Over the last year, the magnetic lattice design has been modified in order to optimize its optical configuration and calculations of non-linear dynamics have started. The development of prototypes for the most critical subsystems has started and is in progress.

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