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HIGH HEAT LOAD FRONT ENDS FOR SIRIUS*

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Abstract

Currently under construction on Brazilian Synchrotron Light Laboratory Campus, Campinas/SP, Sirius is a 3GeV, 4th Generation Synchrotron Light Source. In this paper we describe the Front End that has been designed to transmit the intense synchrotron radiation generated by the insertion devices that will generate the most critical thermal stress, with a peak power density of 55.7 kW/mrad² and a total power of 9.3kW at 500mA in the storage ring.

The functions of the main components and their location in the layout are described. Computational fluid dynamics (CFD) and structural simulations, that have been carried out to verify the performance under the high heat loads generated by Sirius, are also detailed along with the limits of temperature and stress that have been employed in the design.

INTRODUCTION

Sirius storage ring uses the multi-bend-achromatic design approach (5BA in this case) to achieve a very low beam emittance of 0.25 nm·rad. The 518 m circumference contains 20 straight sections of alternating 6.5 and 7.5 meters in length, to be used for insertion devices as well as injection and RF systems. The central dipole of the 5BA cells is a permanent magnet with transverse and longitudinal field gradients to reduce the emittance and provide a hard X-ray radiation source. The 3.2 T narrow high field section in its center provides radiation with critical energy of 19 keV. The other low field dipoles (0.58 T), responsible for the main beam deflection, will be electromagnets [1].

A Front End is a group of components connecting the storage ring to the beamline. They are responsible for defining the final aperture, absorbing exceeding beam power, radiation protection, storage ring vacuum protection and photon-beam diagnostics [2]. The first 5 Sirius' beamlines are planned to use in-vacuum and elliptically polarized undulators. An IVU19 front-end was first designed since it is the Insertion Device (ID) that will generate the most critical thermal stress, with a peak power density of 55.7 kW/mrad² and a total power of 9.3kW at 500mA. This paper will present the requirements, design and prototyping details.

FRONT END LAYOUT

The Front End functions are fulfilled by a proposed set of interlocked components, whose locations are shown in Fig. 1. Ion Pumps provide ultra-high vacuum to the Beamline, Front End and Storage Ring, whose level ($\leq 10^{-9}$ mbar) is monitored by vacuum readers placed at strategic locations.

Since for most of the Sirius' Front Ends there is no physical vacuum insulation (such as windows), preserving the pressure levels in the Storage Ring in the case of any event on the Beamline side becomes critical. If a sudden pressure rise is detected, the electron-beam is dumped and the Fast Valve shut to partially seal the vacuum path and stop the pressure wave. It is followed by the Slow Valve, which completely seals the path between Storage Ring and Beamline, preventing a significant pressure rise occurrence in the Storage Ring [3].

Pre-Masks upstream the Front End will be designed restricting the photon beam generated by B1 and protecting the vacuum tubes. Also, a Machine Photon Shutter upstream the Front End will be designed to block the photon beam in maintenance cases.

Table 1 resumes the Front End project, showing the components position, apertures, and the incident/absorbed power. Power values were calculated using Spectra v10.

FRONT END COMPONENTS

Power Absorbers

They are components that absorb the beam power, shape its size and form to the first optical components. The IVU Front End will have a Fixed Mask, a Photon Shutter, and High Power Slits as components responsible for these functions.

There are two materials that are being studied to be used to dissipate the thermal power, Glidcop and Copper Chromium Zirconium (CuCrZr) [4]. The major difference between the two materials is that Glidcop can be brazed and CuCrZr cannot, but CuCrZr can be purchased in the local market and is available in a vast number of suppliers. As CuCrZr is hard enough to be used in flanges, the idea is to make the components without the need of brazing the flanges.

Table 2 presents the design parameters to which the power absorbers are submitted.

Fixed Mask The Fixed Mask (FM) is a static and water-cooled block of high thermal conductivity alloy. It absorbs unwanted or misteered beam, preventing components downstream to suffer from high thermal load effects. It presents an hourglass form orifice, which provides grazing incidence to the beam in order to reduce the power density on its surface, and, at the same time, define the Front End's entrance acceptance. It has four helical water channels for cooling. Figure 2 shows the internal design of the Fixed Mask.

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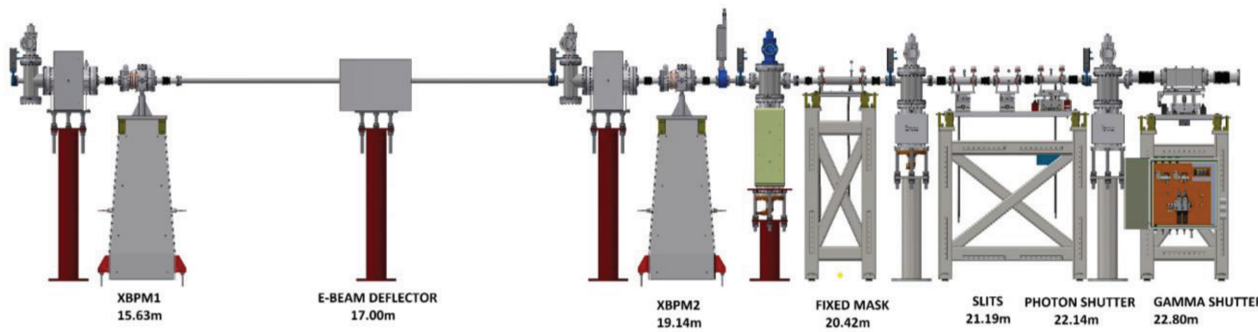

Figure 1: General Front End (FE) layout.

Table 1: IVU19 Front End Aperture Table

Component	Distance from ID source [mm]	Beam Size HxV [mrad]	Beam Size HxV [mm]	Aperture Size [mrad]	Aperture Size [mm]	Incident Power [kW]	Absorbed Power [kW]
XBPM1	15,626	2.00x1.00	31.2x15.6	1.01x0.94	15.8x14.6	9.25	0.18
EBD	17,000	1.01x0.94	17.2x16.0	ø2.35	ø40	-	-
XBPM2	19,143	1.01x0.94	19.3x18.0	1.10x1.02	21x19.6	-	-
FV	19,429	1.01x0.94	19.6x18.3	ø2.06	ø40	-	-
FM	20,417	1.01x0.94	20.6x19.2	ø0.152	ø3.1	9.07	8.11
HPS-1*	21,190	ø0.152	ø3.22	0.38x0.38	8x8	0.96	0.96 max
HPS-2*	21,516	ø0.152	ø3.27	0.37x0.37	8x8	0.96	0.96 max
PS	22,136	ø0.152	ø3.36	0.68x0.68	15x15	0.96	0/0.96
GS	22,803	ø0.152	ø3.47	ø0.44	ø10	-	-

** The set of HPSs will be limited to an aperture of 66x66 µrad^2 (1.42x1.42 mm^2@21.5m), resulting in a maximum of 247W (500mA) exiting the FE.*

Table 2: Design Parameters/Boundary Conditions for the Power Absorbers

Maximum Values	
σ_{VM}	σ_{yield} (370 MPa)
ε	0.2%
T_{max}	300°C
$T_{max\ wc}$	100°C
v_{water}	3 m/s

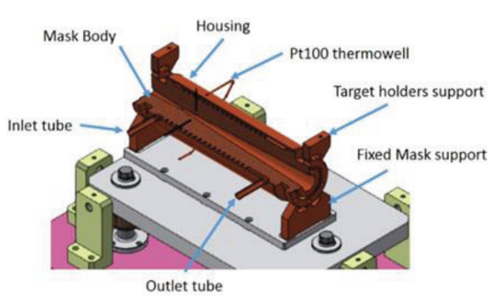

Figure 2: Fixed Mask Design.

High Power Slits A set of High Power Slits (HPS) is placed downstream the Fixed Mask to define the photon beam size exiting the Front End. It is going to be limited for a maximum aperture of 66x66 µrad, which is 110% of the maximum beam size expected by downstream components in the First Optical Enclosure.

The HPS are composed by two L-shaped components that will move by X-Z linear stages in a way to define the exit aperture size, as shown in Fig. 3. The design is similar to the Fixed Mask's, but having only one helical channel and reduced length. The stages specified for this application have an accuracy of 10µm, which results in a movement accuracy, in relation to the beam source, of 0.5 µrad.

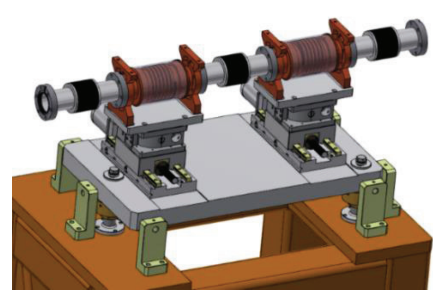

Figure 3: High Power Slits.

Photon Shutter The Photon Shutter (PS) function is to close the photon beam to downstream Front End components and beamline itself.

Its design is the same as the HPS, but having only one helical channel and reduced length. It has a grazing incidence surface with 9° angle that will intercept the photon beam when closed, resulting in a maximum power density of 17.4 W/mm^2. It has an aperture of 15x15 mm^2. One

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thermocouple is placed inside the Photon Shutter to acquire its temperature for the interlock system.

Gamma Shutter

The Gamma Shutter (Fig. 4) uses a block of Tungsten for radiation personal protection. Radiological Safety Group stated that the minimum material thickness to block Bremsstrahlung radiation to a safe level is 244 mm. To close the Gamma Shutter, the block is moved down in 2 seconds with a stroke of 30 mm. There is a hole of 10 mm diameter to permit the photon beam to pass when the Gamma Shutter is open, therefore it also has the functionality of a Collimator [5].

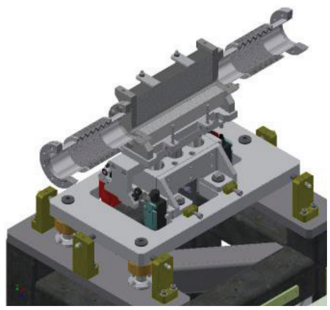

Figure 4: Section view of Gamma Shutter.

E-Beam Deflector

The installation of an e-Beam Deflector (EBD), a permanent magnet dipole, allows directing occasional escaping electron-beam towards the shielding wall.

A 280 mm length 0.6 T magnetic field e-Beam Deflector was specified. Positioned 6.65 m from the shielding wall it can deviate the electron beam down by 50 mm.

XBPM

The X-Ray Beam Position Monitors detect the photon-beam position with micrometric resolution. Two Tungsten-blades XBPMs are foreseen in order to provide both position and steering angle information. The device depicted in Fig. 5 is an improvement of the XBPM used at Soleil and developed in a collaboration to the LNLS [6], it is further addressed in [7].

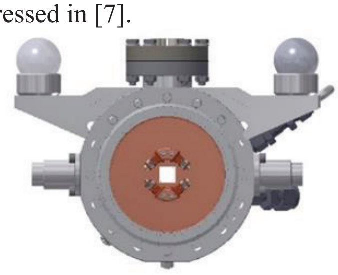

Figure 5: XBPM front-view.

MECHANICAL SUPPORTS

Four key points were attended in the design of the mechanical supports: damping and non-amplification of ground vibration; reduction of displacement due to temperature fluctuations; ease and accuracy of positioning systems; and ease of transport and assembly [8].

Measurements were performed at LNLS indicating 60 Hz as the frequency to avoid. In this direction, having in mind that the special floor already isolates the system from the ground, 75 Hz was adopted as minimum first eigenfrequency for all supports except for the XBPMs. The target sought for the later was at least 100 Hz, regarding future applications relative to diagnostics.

CURRENT STATUS

A first fully equipped Front End prototype is under construction and shall be ready by the end of this year, including all mechanical, vacuum, interlock, controls and diagnostic systems.

Most of the components are being manufactured at local companies and only specialized tasks such as brazing, assembly and vacuum conditioning are executed internally by the LNLS team.

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REFERENCES

[1] L. Liu, F. H. de Sá and X. R. Resende, “A new optics for Sirius”, in *Proc. IPAC'16*, Busan, Korea, May 2016, paper THPMR013, pp. 3413-3415.
[2] C. Benson, *et al.* "Mechanical design of a front end for canted undulators at the advanced photon source", *Synchrotron Radiation Instrumentation*, vol. 705, p. 466-469, May 2004.
[3] “PDR In-Vacuum Undulator Front-ends”, LNLS Internal Documentation, 2016.
[4] S. Sharma, “A Novel Design of High Power Masks and Slits,” in *Proc. MEDSI'14*, Melbourne, Australia, 2014.
[5] W. R. Job, P.K., Casey, “Bremsstrahlung Ray Tracing Guidelines for NSLS II Beamlines and Front Ends,” BNL, Brookhaven, USA, 2006.
[6] N. Hubert *et al.*, “Design of a new blade type X-BPM” in *Proc. IBIC'14*, Monterey, CA, USA, Sep. 2014, paper WEPD22, pp. 687-690.
[7] L. M. Volpe *et al.*, “Blade XBPM Optimization for Sirius”, presented at MEDSI’16, Barcelona, Spain, 2016, paper WEPE08, this conference.
[8] B. N. Jensen, "Managing Vibrations, go to the Source(s)," in *Proc. MEDSI'14*, Melbourne, Australia, 2014.