EVALUATION AND ATTENUATION OF SIRIUS COMPONENTS IMPEDANCE

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Abstract

The Sirius in-vacuum components have their design improvements, possibilities and choices presented, where wake heating, single-bunch and multi-bunch effects and mechanical aspects were taken into account. The results were finally evaluated and added to the Sirius impedance budget.

INTRODUCTION

In modern light sources, the seek for higher brightness has been pushing accelerators specs for higher currents and smaller vacuum chamber apertures throughout the ring, which intensifies impedance related effects, such as wake heating and instabilities thresholds [1]. Therefore, in new generation light sources all components of the storage ring must be carefully analyzed and any attenuation on the machine impedance is desirable not only to guarantee the machine stability and nominal current specifications, but also to push forward collective effect current thresholds and mitigate the wake heating.

This work summarizes the impedance analysis, focusing on reducing its impact in the collective effects for Sirius, the 3 GeV fourth generation synchrotron light source under construction in Brazil. The impedance analysis regarding the wake heating impact is presented in [2]. The detailed studies regarding Sirius collective effects, together with simulated 2D and analytical impedance evaluation are presented in [3]. The status of Sirius construction and informations about the magnetic lattice and radiation sources can be found in [4–7].

The components were simulated using GdfidL [8] and its recent feature of resistive-wall (RW) – or impedance – boundary conditions is considered in the referred results shown here. The presented multi-bunch (MB) loss factors were evaluated for the simulated natural bunch length σ_s = 2.5 mm, according to Eq. 1:

$$\kappa_{loss}^{MB} = \frac{M\omega_0}{\pi} \sum_{p=0}^{\infty} \Re e Z_{\|}(pM\omega_0)\, e^{-(pM\omega_0/c)^2\sigma_s^2} \qquad (1)$$

where c is the speed of light, M = 864 is the harmonic number, ω_0 = 3.634 Mrad/s is the revolution frequency of Sirius storage ring and $\Re e Z_{\|}(pM\omega_0)$ is the real part of longitudinal impedance sampled at $pM\omega_0$ frequencies. Different filling patterns for M = 432, 216, 1 were also evaluated and the loss factor shown is for the worst configuration among these cases.

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FLANGES

Sirius storage ring has a 24 mm diameter circular vacuum chamber and a keyhole profile in the dipole chambers. Its flange designs [9], as shown by Fig. 1, provides a 50 μm step in the chamber profile, whose impact in the machine impedance is negligible.

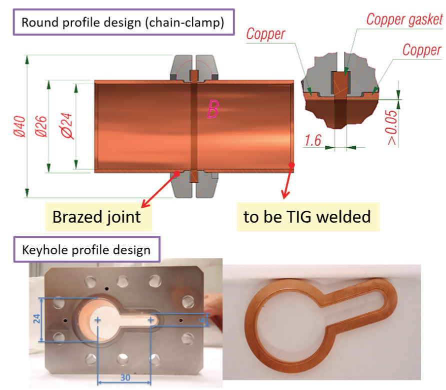

Figure 1: Flange design for round and keyhole chambers.

PUMPING STATION SLOTS

The pumping station and its 2 mm wide slots for round profile chamber are depicted by Fig. 2, presenting low loss factor value. For the keyhole chamber profile, two configurations shown by Fig. 3 with same pumping efficiency were proposed. Concentrating the pumping channels near the chamber nose (blue configuration) have provided a 4 times lower loss factor.

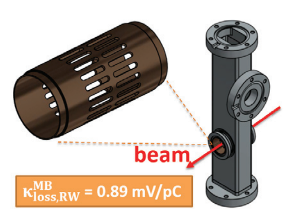

Figure 2: Mech. design for round chamber pump station.

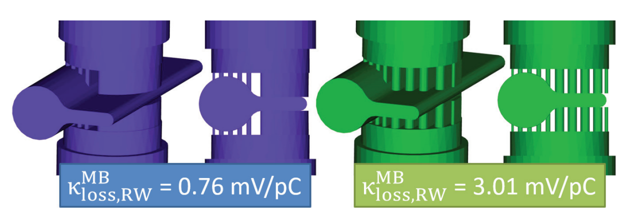

Figure 3: Proposed keyhole chamber pump stations models.

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DIPOLE CHAMBERS

Two nose profile designs were proposed for dipole extraction chambers: Flat Slot and Stepped Slot, depicted by Fig. 4. For infrared (IR) 50 μm wavelength extraction of Imbuia beamline, one special chamber (Conical Slot) is proposed with an extra round profile. Its diameter is increased and its center offset horizontally from the beam path the farther it longitudinally goes from the source.

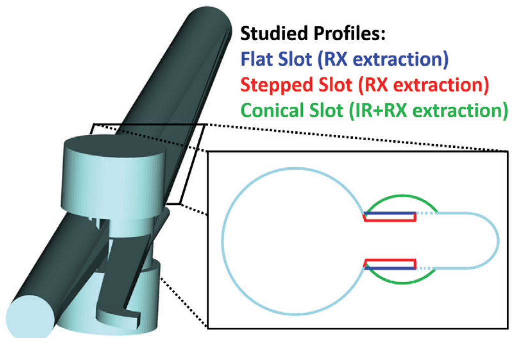

Figure 4: Dipole chamber vacuum profile: 3D base model (left) and the 3 compared slot profiles (right) in a general cross section.

The longitudinal impedance of the three discussed profiles is shown by Fig. 5. The Stepped Slot design has much more higher order modes (HOMs) than the Flat Slot. The latter concept was therefore applied to Sirius dipole chamber mechanical designs. Compared to the Flat Slot design, the Conical Slot for IR extraction only contributes with broadband impedance, with negligible impact to the impedance budget shown in [3]. Although not presented here, the same behavior extents for the transverse impedance.

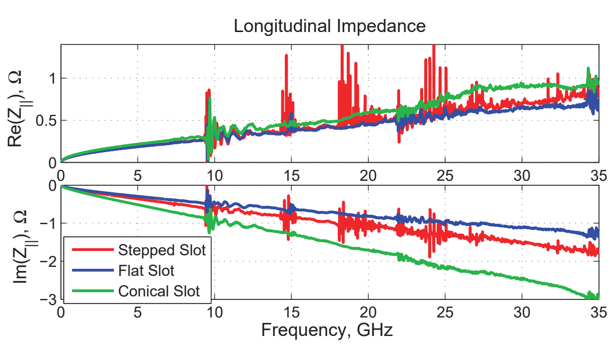

Figure 5: Longitudinal impedance comparison between Flat, Stepped and Conical Slot profiles.

STRIPLINE KICKER

Starting from the models presented in [10], their optimization process was not taking the transverse impedance into account. Later analysis have shown that highly capacitive gap stripline designs trapped strong HOMs, comparable to the narrowband part of the RW impedance of the whole machine (> 1 MΩ), as presented in reference [3]. Furthermore, the Tapered Cavity vertical kicker design has strong HOM in horizontal plane. Table 1 summarizes the strongest HOM peak value for each design, taking into account that many have not enough wakelength (at least 100 m) to solve the peak values (cases marked with the '»' sign). Motivated by these facts, a new design was proposed: Tapered Strip (also in Table 1), which only differs from Tapered Cavity design by the stripline transitions highlighted in yellow in Fig. 6. Such transitions not only improves horizontal narrowband impedance but also the longitudinal broadband impedance, as shown by Fig. 7. Time domain simulation was performed and S1,1 analysis was found below -20 dB within the 250 MHz operation bandwidth.

Table 1: Maximum Transverse Dipole HOM Amplitude for the Studied Vertical Kicker Models

Stripline Model	max(Z_{D_x}), kΩ/m	max(Z_{D_y}),kΩ/m
Comb-type geom 2	not evaluated	»1200
Std Capacitive Gap	15	»200
Hybrid	40	»300
Tapered Cavity	200	none
Tapered Strip	50	none

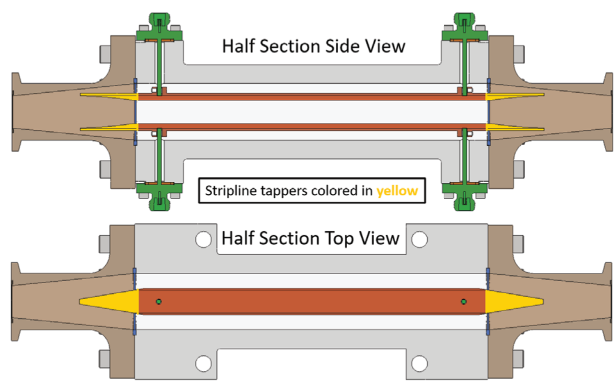

Figure 6: Sketch drawing of Tapered Strip vertical kicker.

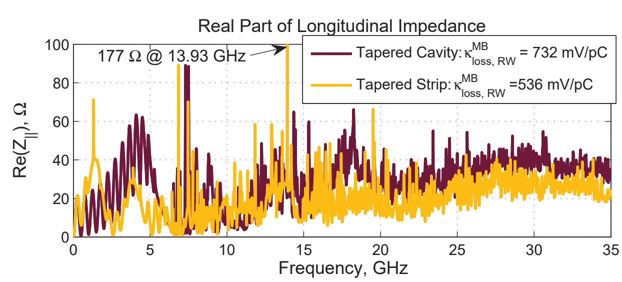

Figure 7: Strip tapers impact in the longitudinal impedance.

SCRAPER

The scraper design is in its final stage and it proposes beam collimation by angular movement, although uses

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linear actuators. As can be seen in the sketch from Fig. 8, with 0.1 mm gap between plunger and shroud and smooth transitions no matter the offset, it is expected a low impedance contribution, which will be evaluated after concluding the design proposal.

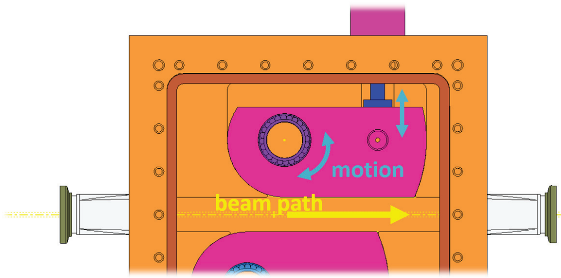

Figure 8: Scraper: top view (removed cover) of the mechanical design sketch.

SYNCHROTRON RADIATION MASK

Several profiles of synchrotron radiation masks were analyzed for Sirius, both in terms of transverse and longitudinal profile. It was found and applied a 1/10 taper-in and 1/1 taper out, 2 mm intrusion lateral iris configuration. As seen in Fig. 9, is worth comparing such lateral profile (blue) with a axisymmetric one (red) with the same longitudinal iris configuration. The former has 5x lower broadband impedance than the later (factor included in the plot). Such factor of 5 would bring down Microwave Instability threshold from 0.75 to 0.55 mA. In a complementary way, the RW impedance (green curve) from long-range wakepotential shows no strong HOMs.

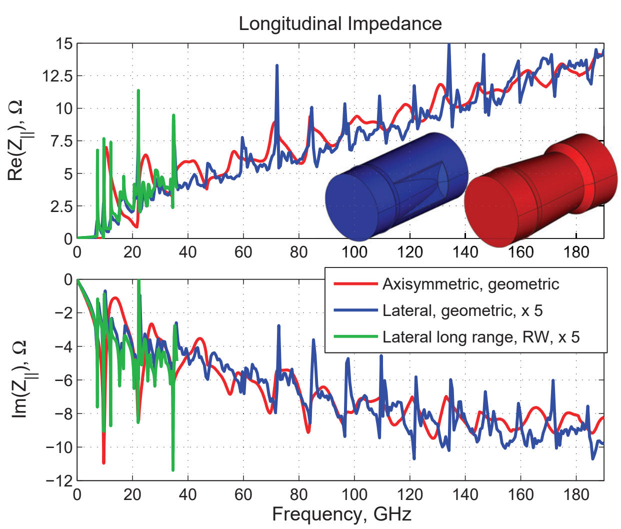

Figure 9: Longitudinal geometric impedance comparison for radiation masks: lateral (blue) and axisymmetric (red), obtained from short range wakefield. RW Impedance from long-range wake (green curve) is also shown for HOM evaluation of lateral profile mask.

VALVE BLOCK

The impedance analysis of Sirius RF-shielded bellows and gate valves were performed focusing on wake heating effects and can be seen on [2]. However, every gate valve is concatenated with a bellows, a BPM block (BPM [11] with bellows on both ends) and a mask, as depicted by Fig. 10. One may find it interesting to see in Fig. 11 that the sum of the separate impedance spectra is not the same as the single model containing the mentioned components.

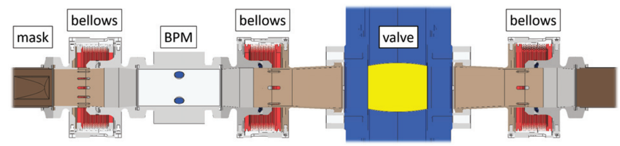

Figure 10: Design sketch of the valve-block assembly, in order: mask, BPM block (BPM with bellows on both ends), gate valve and bellows.

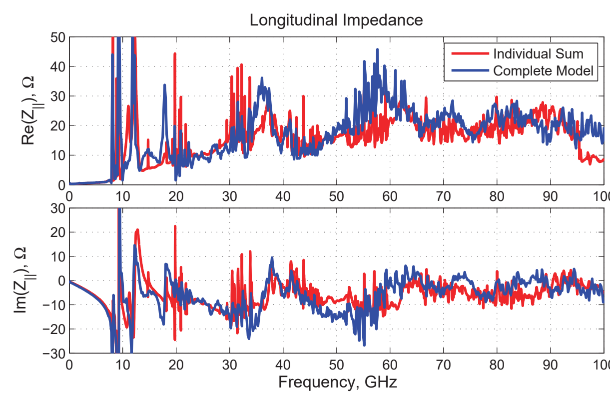

Figure 11: Longitudinal impedance comparison of complete valve assembly model (blue) against the individual sum (red) of: 1 radiation mask, 1 BPM, one gate valve and 3 bellows.

FINAL COMMENTS

Except by the RF cavities, the narrowband and broadband impedance budget for Sirius have been evaluated using 2.5 mm and 0.5 mm driving bunch, respectively. The final component designs were chosen aiming a satisfactory trade-off between electromagnetic performance and mechanical complexity. We are still working to rerun some models with finer mesh in order to obtain an impedance budget as close as possible to the real case scenario.

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