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LONGITUDINAL KICKER DESIGN FOR SIRIUS LIGHT SOURCE

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Abstract

An overloaded cavity kicker for the Sirius longitudinal bunch-by-bunch feedback system will be presented in this contribution. 4th generation light sources' lower aperture of vacuum chambers lead to higher cutoff frequencies, jeopardizing the electromagnetic performance of cavities by trapping higher order modes (HOMs) inside the structure. With the objective of damping longitudinal and transverse HOMs without compromising the kicker shunt impedance, solutions as cavity radius reduction, tapered transitions and other geometry changes are discussed herein.

INTRODUCTION

Sirius, the new LNLS 3 GeV fourth generation synchrotron light source under construction in Brazil, is approaching its commissioning stage. In this stage, called Phase 0, a normal conducting (NC) PETRA 7-Cell RF cavity will be employed in the storage ring and a maximum average current of 100 mA is expected. The following operation stages comprise two superconducting (SC) RF cavities replacing the PETRA cavity and a 3rd harmonic passive Landau Cavity (LC) added to increase the beam lifetime and allow the nominal 350 mA average current to be reached.

However, during Phase 0, achieving the desired average current of 100 mA might be extremely challenging or even impossible without a bunch-by-bunch (BbB) feedback system. On both transverse and longitudinal planes, several higher order modes of the NC cavity are expected to drive coupled-bunch mode instabilities (CBMIs) [1]. Whereas stripline kickers were designed for the transverse plane [2, 3], an overloaded cavity, subject of this contribution, was designed to perform as longitudinal plane BbB kicker.

The correction signal of the Sirius BbB feedback system is modulated at 2.5 times the RF frequency f_{RF} of 500 MHz. In order to correct all CBMIs, a bandwidth (BW) of $\frac{1}{2}f_{RF}$ (250 MHz) is enough for a cavity fundamental mode centered at $f_c = 2.25f_{RF}$ (1.125 GHz) or $f_c 2.75f_{RF}$ (1.375 GHz). The later is preferable for a higher shunt impedance and shifting higher order modes (HOMs) up in frequency. Another design goal was to damp all the HOMs by solutions in the geometry without significantly increasing the mechanical complexity already demanded by an overloaded cavity design.

CONCEPTUAL ASPECTS

The longitudinal kicker design is basically a pillbox cavity with radially attached coaxial feedthroughs that couple the signal by ridged waveguides placed around the vacuum chamber profile, therefore lowering the quality factor of the cavity. Whereas the correction signal is applied at one end of the cavity, the other end is terminated with matched loads. The design was proposed at DAΦNE [4] and later modified at PLS [5]. Based on these studies, a longitudinal kicker was designed in 2013 for UVX [6], the currently operating LNLS light source.

Initially the UVX design was taken as starting point for Sirius kicker, since the center frequency of the former being 65 MHz lower than the 1.375 GHz required for the later would demand a slight cavity radius reduction. However, the difference in the vacuum chamber diameters – 58 mm for UVX and 24 mm for Sirius – and the corresponding difference between their cutoff frequencies – ~3.96 GHz against ~9.56 GHz, respectively – is enough to trap several HOMs in the cavity with the Sirius beam pipe. This problem has motivated the study to incorporate recent design modifications, such as tapered transitions proposed at DIAMOND [7] and nose cone lengthening at MAX-IV [8].

Lengthening the nose cones lowers the center frequency of the cavity, which can be brought back up by reducing the pillbox radius, shifting HOMs upwards as a beneficial consequence. The HOMs still below the chamber cutoff could now be damped by tapered transitions between the nose cone edge and the beam pipe profile. These premises will be the focus of this contribution, which will not detail the ridged waveguide optimization.

DESIGN EVOLUTION

After the conceptual review, the design evolution can be divided into three stages, each one represented by a geometry depicted by Fig. 1. GdfidL [9] was used for the wakefield simulations, whose impedance results for the respective stages are depicted by Fig. 2.

First attempts aimed at lengthening the nose cones until achieving a geometric configuration for a compact 112 mm diameter cavity. This would allow its vacuum sealing by a DN100CF flange. Geometry 1 represents this stage, but reasonably strong longitudinal and transverse dipole modes were still trapped in the cavity, as shown in Fig. 2 (blue curve).

By employing a tapered nose cone and adjusting the length of both ridged waveguides and tapers, Geometry 2 (green curve in Fig. 2) had all of its HOMs damped except for a TE_{111} mode centered at ~9.56 GHz. Diagnosing this mode using ANSYS HFSS [10] eigenmode simulations, it was trapped in the tapered cavity shape formed by the nose cones, as depicted by Fig. 3.

The remaining HOM was damped in Geometry 3 by machining 4 slots across the nose cone (see Fig. 1), in order to cover both vertically and horizontally oriented HOMs. The 8 mm slot width is narrow enough to trap the fundamental mode, but wide enough for coupling the HOM to the ridged waveguides. As minor adjustments in the nose cone

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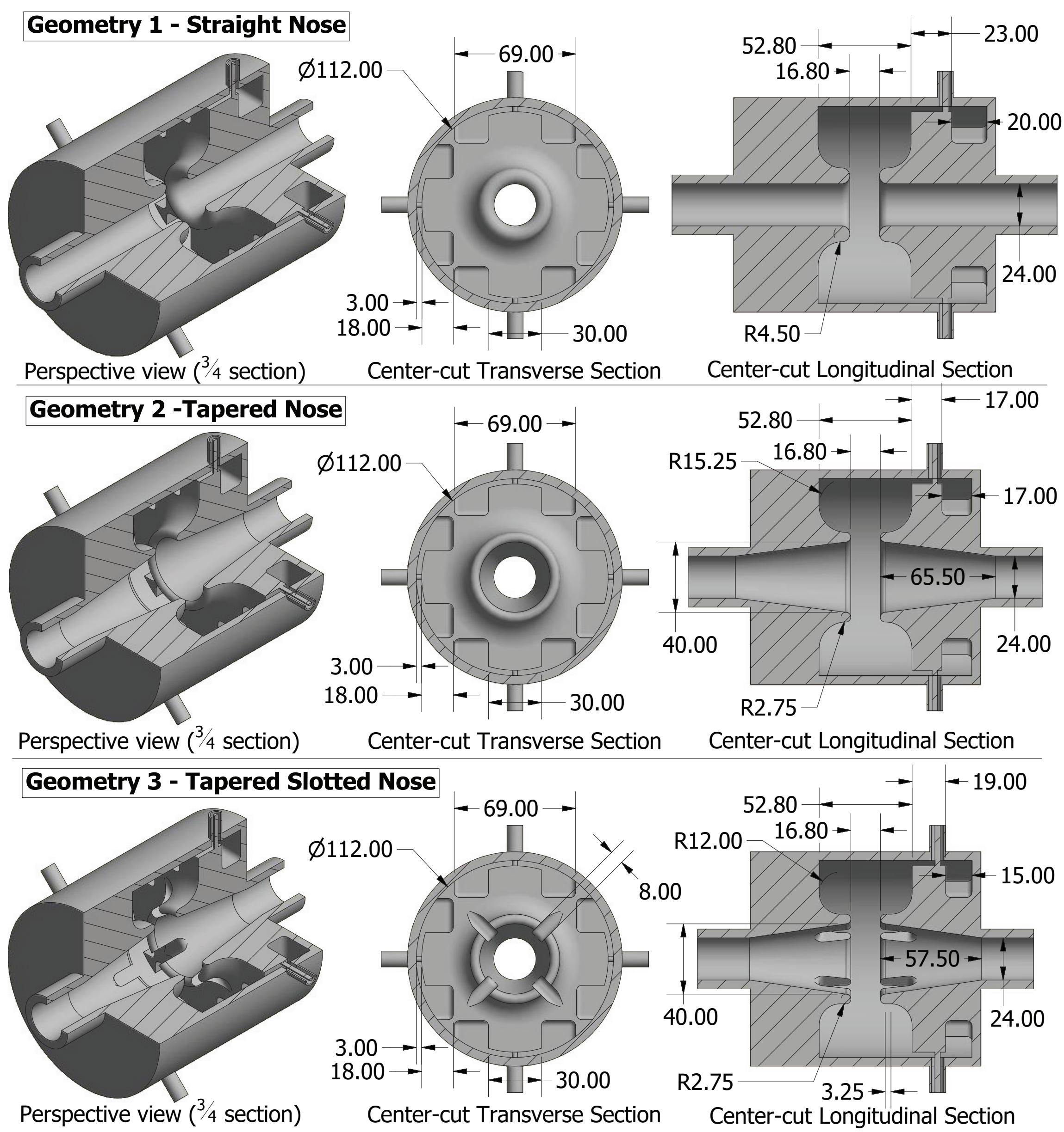

Figure 1: Geometry sketches representing the three design evolution stages: Straight Nose (1), Tapered Nose (2) and Tapered Slotted Nose (3) kickers. Units in millimeters.

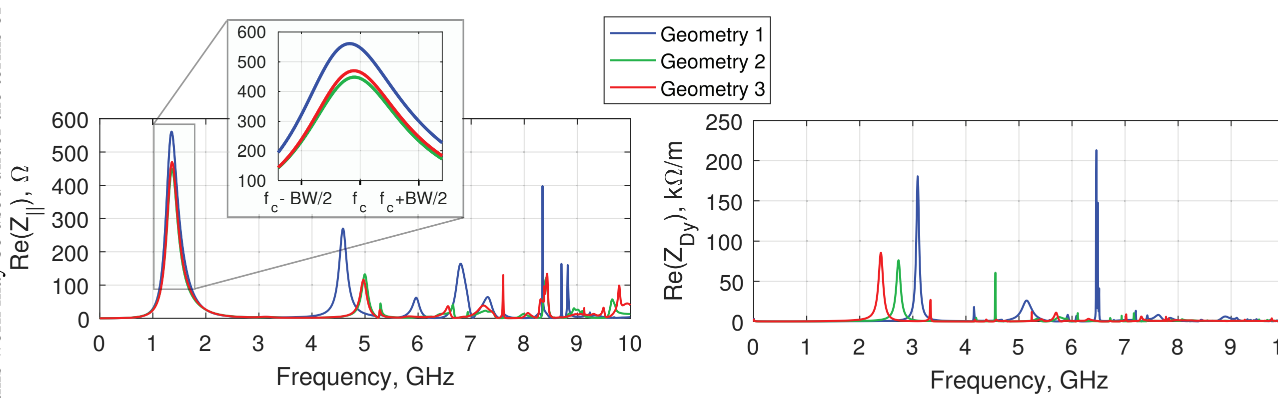

Figure 2: Real part of longitudinal (left) and dipole transverse (right) impedance comparison. The highlighted fundamental mode are within f_c and BW specifications for all 3 geometries.

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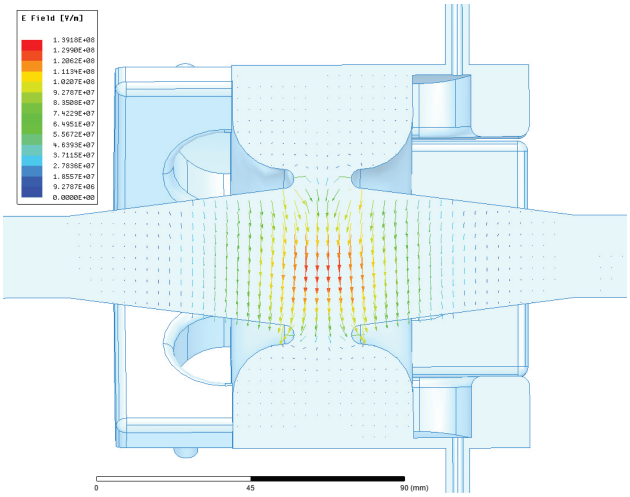

Figure 3: TE_{111} mode electric field distribution pattern, trapped inside the tapered nose cone cavity shape.

parameters were required since the slots presence affected the cavity f_c, change in taper length was performed due to HOM damping reasons.

MECHANICAL DESIGN

The Tapered Slotted Nose longitudinal kicker was machined and assembled. For insertion the feedthrough pin into the waveguide ridge, the press-fit adapter design proposed at DIAMOND [11] was used. Figure 4 details it in both assembled and bare ridge perspectives.

Figure 4: Press-fit adapter detail for electrical contact between the waveguide ridge and the feedthough pin.

The front-view perspective in Fig. 5 highlights the chosen waveguide RF-shielding approach through a single coil spring for each aligned face. Wakefield simulations have shown negligible contribution and the electrical contact was tested and approved by assembling the waveguides using an isolating gasket in the cavity flange.

S-PARAMETER MEASUREMENT

After assembly and bake-out, the longitudinal kicker was evaluated by a vector network analyzer through S1,1 parameter measurement as a non-invasive method for checking

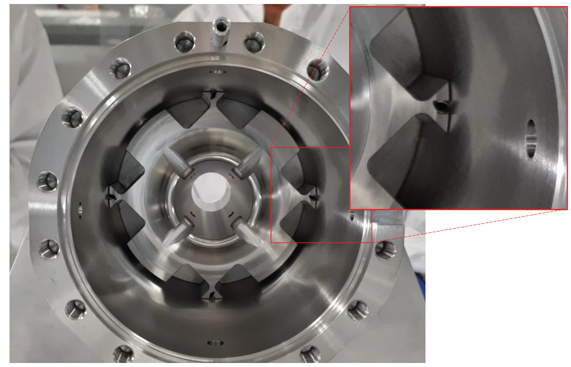

Figure 5: Front-view perspective with detailed coil spring RF-shield.

any cavity center frequency deviation from to the simulation result. The calibrated reference plane was set at the input port of a 4-way splitter and each of its output port connected to a upstream feedthrough of the kicker. Each of the 4 downstream feedthroughs was terminated with a matched load. Figure 6 depicts the satisfactory result, where the ripple in measurement can be attributed to the measurement setup after the reference plane.

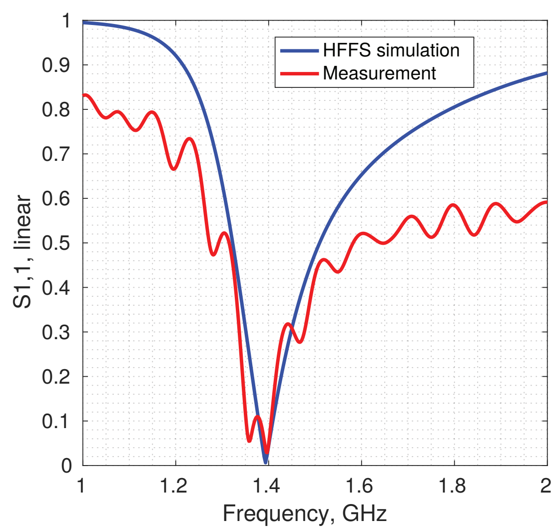

Figure 6: Measured *vs* simulated S1,1 parameter.

CONCLUSION

The compact design of the Slotted Nose longitudinal kicker facilitates machining, assembling and installation, still keeping good electromagnetic performance. The HOM-damped design achieved a satisfactory 900 Ω shunt impedance and will assembled on Sirius storage ring within the next few months.

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