BEAM COUPLING IMPEDANCE CHARACTERIZATION OF THIRD HARMONIC CAVITY FOR ALS UPGRADE*

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Abstract

The ALS upgrade to a diffraction-limited light source (ALS-U) depends on the ability to lengthen the stored bunches to limit the emittance growth and increase the beam life time. In order to achieve lengthening in excess of four-fold necessary to this end, we are investigating the use of the same passive 1.5 GHz normal-conducting RF cavities currently used on the ALS. While the upgraded ring RF parameters and fill pattern make it easier as long as the beam-induced phase transient is concerned, the large lengthening factor and the strongly non-linear lattice require particular attention to the cavities contribution to the machine overall impedance budget. In this paper we present our estimates of the narrow-band impedance obtained by numerical simulation and bench measurements of the cavities' resonant modes.

INTRODUCTION

The ALS upgrade to a diffraction-limited light source (ALS-U) [1] depends on the ability to lengthen the stored bunches to limit the emittance growth and increase the beam life time. In order to achieve lengthening in excess of four-fold necessary to this end, we are investigating the use of the same passive 1.5 GHz normal-conducting RF cavities currently used on the ALS. While the upgraded ring RF parameters and fill pattern make it easier as long as the beam-induced phase transient is concerned [2], the large lengthening factor and the strongly non-linear lattice require particular attention to the cavities contribution to the machine overall impedance budget. In this paper we present our estimates of the narrow-band impedance obtained by numerical simulation and bench measurements of the cavities' resonant modes.

The short range wake of the cavity has been discussed in [3]. In this paper, we will focus on the narrow band impedance below the beam pipe cutoff frequency.

To characterize the beam coupling impedance of the cavity, we have simulated its wakefield and beam coupling impedance with CST [4] to identify the resonant modes with significant contribution to the beam impedance. Low power RF bench measurement has been carried out on three cavities identical to the ones currently installed in the ALS. Combing the CST simulation and the bench measurement results, we have estimated the beam coupling impedances of the undamped TM110 modes in the cavity.

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NUMERICAL RF SIMULATION

To identify the higher order modes with considerable impedances, we have carried out the wakefield simulation with CST Particle Studio. The cavity model is built from the mechanical drawings with piston tuner and two HOM dampers, as shown in Figures 1 and 2. In the wakefield simulation, the beam is placed 5 mm away in the x direction from the cavity center. The longitudinal and transverse wakefields are integrated along the cavity center. Since the beam pipe cutoff frequencies are 3.5 GHz for TE01 mode and 4.6 GHz for TM11 mode, we have limited the analysis to frequencies under 5 GHz, as shown in Figures 3 and 4.

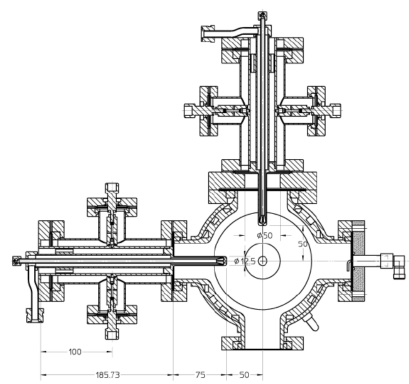

Figure 1: Mechanical drawing of 3rd harmonic cavity.

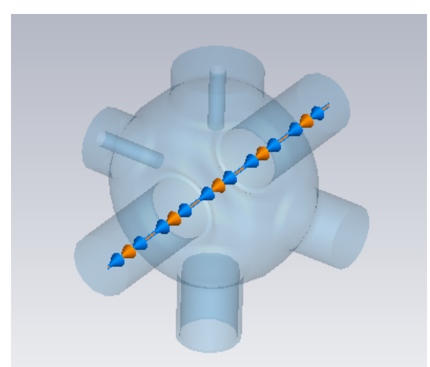

Figure 2: CST simulated model (wakefield solver).

From the wakefield simulation results, we can see that:

1. Without the HOM damper, the major contributors to the beam coupling impedances are longitudinal modes TM011 at 2.3 GHz and transverse modes TM110 at 2.3 GHz, TM120 at 2.9 GHz and TM121 at 3.4 GHz.
2. The fundemantal mode TM010 at 1.5 GHz is little affected by HOM dampers.
3. The HOM dampers effectively suppresses the longitudinal mode TM011, and transverse modes TE111,

TM120 and TM121, with significant drop of their Q values.

4. Transverse modes TM110 and TM111 at 3.3 GHz are not strongly damped.

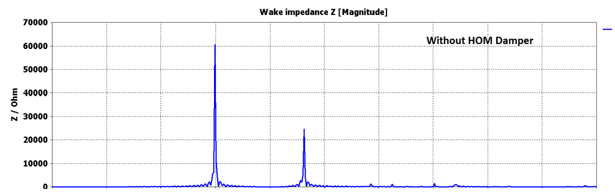

Figure 3: Longitudinal wake impedance with and without HOM dampers.

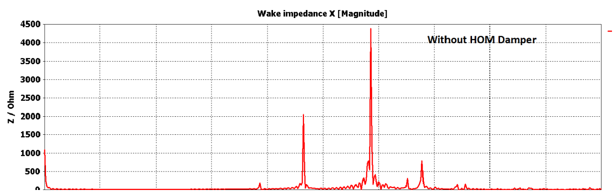

Figure 4: Transverse wake impedance with and without HOM dampers.

LOW POWER RF MEASUREMENT

The low power RF measurements have been carried out on the currently not installed three cavities. The measurement setup is shown in Figure 5. Two antenna probes are inserted into the beam pipe and weakly coupled to the field inside the cavity. S parameters are measured by a network analyzer.

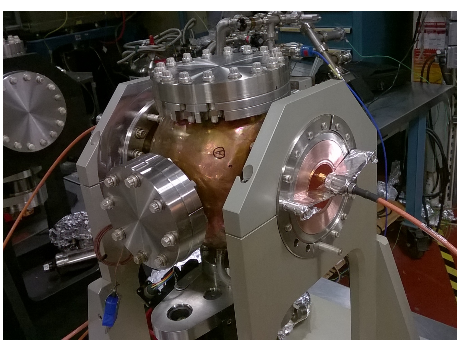

Figure 5: Low Power RF Measurement Setup.

For each cavity, we have measured the S21s with different tuner positions, with and without the dampers. The cascade plots of S21 up to 4.2 GHz are shown in Figure 6.

Although there are a lot of resonant modes on the S21 spectrum, we are only interested in the modes with significant impedances, as identified in Figure 3 and 4. Also, the orientation of the excited dipole modes depends on the placement of the probes. When both probes are placed in vertical location, vertically polarized dipole modes are strongly excited while the horizontal modes are weak. Vice versa. By changing the probes' azimuthal position, it is possible to selectively measure the horizontally and vertically polarized dipole modes and identify monopole modes. In most of our measurements, both probes are placed at 12 o'clock location, mainly exciting the vertical modes.

The fundamental mode TM010 at 1.5 GHz is not affected by the dampers. Figure 7 shows the resonant frequency and Q value barely change with or without HOM dampers. For higher order modes, TE111 and TM011 modes are effectively damped, while TM110 modes still have high Q value, which is consistent with CST simulation.

BEAM COUPLING IMPEDANCES OF UNDAMPED TM110 MODE

The major undamped modes in the cavity are the TM110 modes, which contribute to the transverse beam coupling impedance. The S21 measurements are shown in Figure 8. Around 2.3 GHz, there are three modes, V-TM110, H-TM110 and TM011 modes. Longitudinal mode TM011 is effectively damped. Two transverse modes V-TM110 and H-TM110, even with Q value dropped from about 10000 to 4000, still shows significant resonance.

The piston tuner position effects the resonant frequency and Q factor of two TM110 modes, especially the V-TM110 since the tuner moves in the vertical direction, as shown in Figure 9.

From Omega3P [5] simulation, the transverse shunt impedances of V-TM110 and H-TM110 modes are 18.77 Ω/cm and 19.12 Ω/cm respectively. Thus assuming the tuning won't affect the transverse shunt impedance, we can calculate how the beam coupling impedance changes as we tune the cavity, as shown in Figure 10.

CONCLUSION

In this paper we have reported the simulation and bench measurement of ALS 3rd harmonic cavity, which will also be used for future ALS Upgrade. We have identified the higher order modes with significant beam coupling impedance below the beam pipe cutoff frequencies and verified the damping effect of the pistol HOM dampers. For the undamped TM110 modes, we have estimated their impedances by combining the simulation and low level RF measurement results.

ACKNOWLEDGMENT

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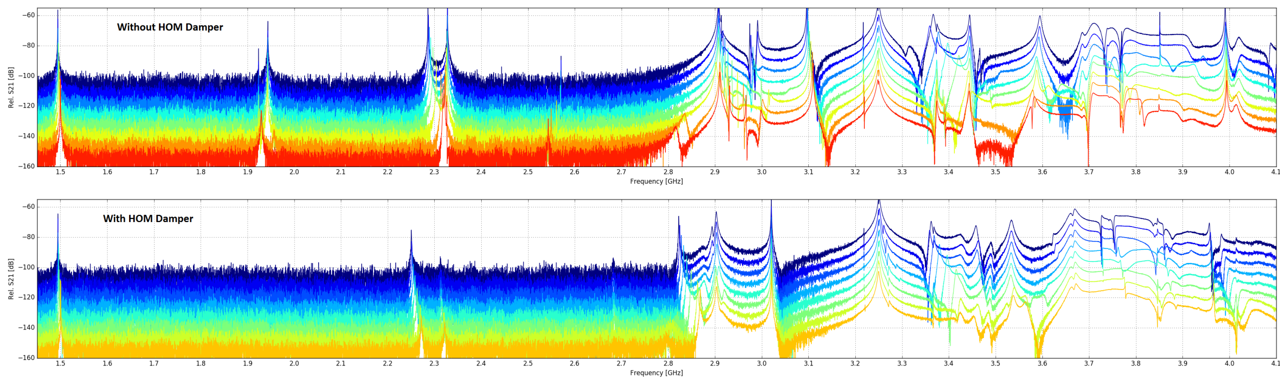

Figure 6: S21 measurements with different tuner positions, with and without HOM dampers.

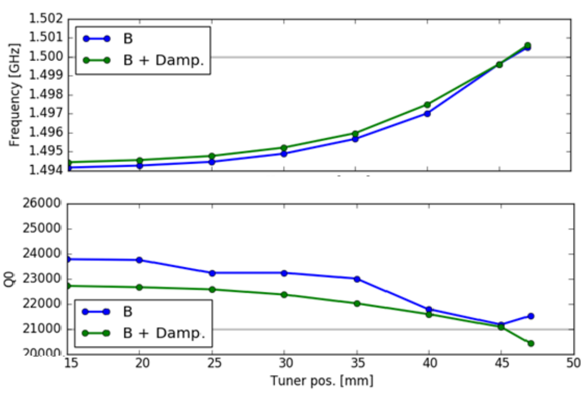

Figure 7: Low Power RF Measurement Setup.

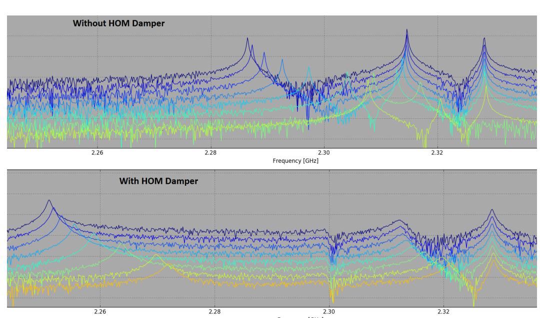

Figure 8: S21 measurements with different tuner positions near 2.3 GHz, with and without HOM dampers.

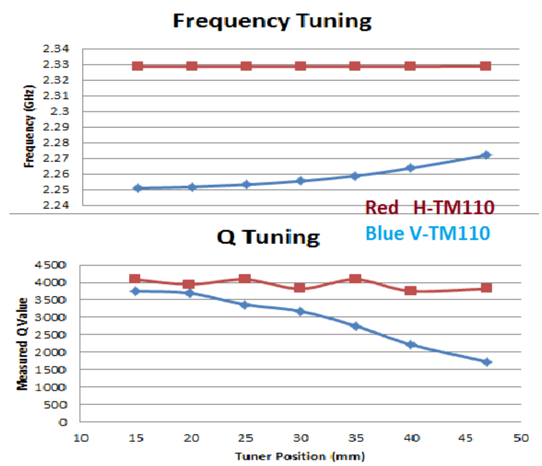

Figure 9: The tuning of TM110 modes.

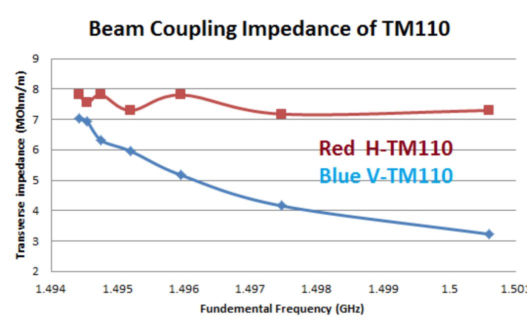

Figure 10: Beam coupling impedance of TM110 modes.