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THE NEW 118 MHZ CAVITY FOR RF DEVELOPMENT ACTIVITIES OF THE RF FOR ACCELERATOR LABORATORY AT SLRI

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Abstract

The RF for accelerator laboratory is established at SLRI to perform RF related development activities of the current light source and the future synchrotron light facility in Thailand. One of activities is to build an in-house RF cavity. It will be used for testing of RF amplifier unit and the developed LLRF system. The cavity is a nose-cone pillbox cavity operating at 118 MHz and aiming at 100 kV gap voltage. Details of designing in particular the inner surface profile, the RF properties, the higher order modes properties, the RF power coupler, and the tuning mechanism will be presented with the manufacturing timeline.

INTRODUCTION

Synchrontron Light Research Institute (SLRI) is preparing documents for an approval process of the new light source project. The RF for accelerator laboratory is established to strengthening knowledge and skills of RF staffs preparing for the new light source and also serving the existing light source. The RF related developments such as the RF structure design, the solid-state RF amplifier test bench, and the FPGA based LLRF development will be conducted under this laboratory. Laboratory requires RF cavity for testing of a solid-state RF amplifier unit and the FPGA based LLRF system. The new cavity is designed to the 118 MHz resonant frequency of the existing storage ring. Cavity fabrication is planned to be an in-house fabrication for understanding each step of fabrication process.

RF CAVITY DESIGN

The new 118 MHz RF cavity was designed base on the nose-cone pillbox type cavity in order to ease the fabrication. This is not similar to the cavity in the storage ring, which is the capacitive-type cavity. The storage ring cavity is the modified version of the MAX-IV RF cavity [1, 2]. Superfish [3] code was used to get a cavity profile, which later be verified using CST microwave studio [4] 3D-simulation. The insertion flange-to-flange length of the cavity is set to 50 cm. The accelerating gap can be varied from 3 cm to 5 cm to find a good design. The large gap was not considered because the goal of cavity voltage is 100 kV. This should require approximately 5 kW RF power, which reflects the goal shunt impedance of greater than 2 MΩ.

2D Profile Design

Superfish code was used for a quick searching of a suitable cavity geometry. The reasonable design regarding specification described above was obtained as the cavity geometry shown in Fig. 1. It has 90 cm diameter, 42 cm cavity length, 11 cm beam port diameter, and 3 cm accelerating gap. The shunt impedance and the unloaded quality factor is 5 MΩ and 27,000, respectively. So, the 2 kW RF power is required to produce an accelerating voltage of 100 kV. The maximum cavity voltage is 200 kV with the peak amplitude of electric field at the nose-cone area of 7.1 MV/m. It requires 8 kW RF power.

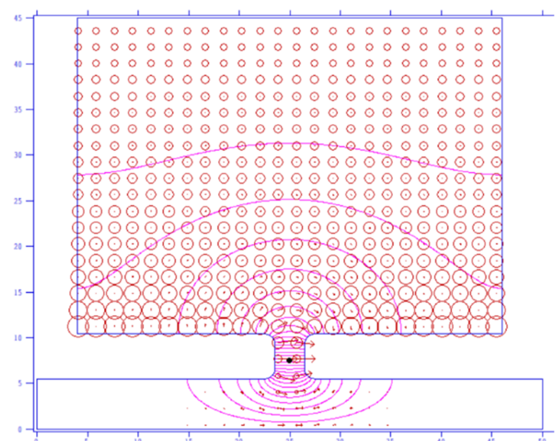

Figure 1: Geometry of the 118 MHz cavity with arrows and circles represent electric and magnetic fields, respectively. The electric field contours lines are also displayed.

3D Profile Design

The advantage of 3D simulation is that the vacuum ports, frequency tuner, and input and pickup couplers can be added in the simulations. These components break the axial symmetry of the pillbox cavity, so it is beyond the 2D code capabilities. High investment in computing resources is needed for the 3D simulations as it requires a powerful computing resources. It is also a time consuming process in the 3D simulations.

Table 1: RF Properties of the118 MHz Cavity

Parameters	Superfish	CST MWS
Frequency (MHz)	118.06	118.14
Unloaded quality factor	27,000	27,000
R/Q (Ω) definition of $V^2/\omega U$	185	183
Shunt impedance (MΩ)	5.0	4.9
Maximum cavity voltage (V)	200	
Dissipated power (kW)	8	

The 2D cavity profile obtained from superfish was verified by a 3D simulations using CST microwave studio (CST MWS) software. The 3D simulations gave similar results to the 2D simulations as a comparison RF properties

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listed in Table 1. The unloaded quality factor of the fabricated cavity will be lower than the simulation value due to ports on the cavity body and the quality of the inner surface treatment. It can be 7%-20% lower. Later, when tuners and coupler are introduced in simulations the quality factor decreases to 26,000, which is 4% lower than the ideal cavity. The shunt impedance also decreases to 4.7 MΩ.

FREQUENCY TUNER

The tuner was combined in 3D cavity simulations to find a tuner range of the cavity. The tuner is a plunger style made from copper with a diameter of 14 cm. It will be equipped with a standard DN160CF flange. Tuner was placed at the middle of the cavity in radial rotation symmetry plane. The simulation results shown that with the tuner moves inward the frequency is increased. But when the tuner move outward the frequency does not linearly decrease as can be seen from the first design with one and two tuners curves in Fig. 2, where the inward direction is in the negative position. The zero position means the tuner is at the cavity inner surface level. For the first design, when the tuner at the zero and positive position the resonant frequency does not decrease to 118 MHz.

The cavity was redesigned to have a lower resonant frequency than 118 MHz in order to make a ±0.5 MHz tuner range. With a slightly change of cavity dimensions, extending the cavity length to 42.2 cm, the second design can maintain the same RF properties as the first design. The resonant frequency is 117.7 MHz. The tuner was introduced in simulations with one tuner and two tuners cases. The tuner range of ±0.3 MHz was obtained from one tuner. The second tuner was added in order to get 1 MHz tuner range (+0.7 MHz to -0.3 MHz) as curves displayed in Fig. 2. Both tuners have to move inward 5 cm for the 118 MHz resonant frequency.

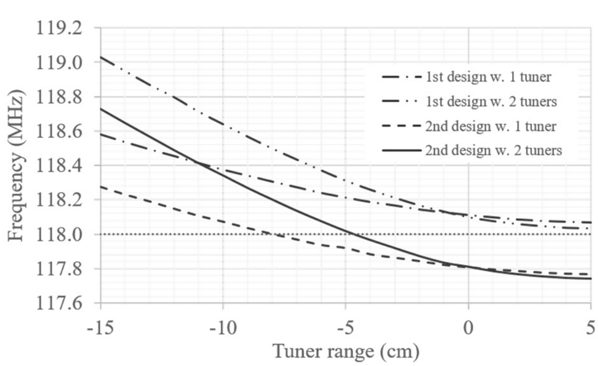

Figure 2: Tuner range of the 118 MHz. Minus sign indicates inward direction.

RF POWER COUPLER

There are two RF input power couplers available in the lab. So, these couplers will be used to coupling RF power to the new cavity. The input power coupler is the loop-type, so it couples RF power via the magnetic field. Model of the input coupler is shown in Fig. 3. The input power coupler was introduced in the cavity simulations together with two tuners. The simulation aimed to find a proper position of the input coupler and the rotation angle of the coupling loop. With the original coupling loop height of 2.5 cm, the maximum achievable RF power coupling factor (β) is 0.25. This coupling factor is lower than the requirement of β > 4. The study was carried out to find a suitable height of the coupling loop. The results shown that the height of 9 cm can satisfy β > 4 condition as plot shown in Fig. 4.

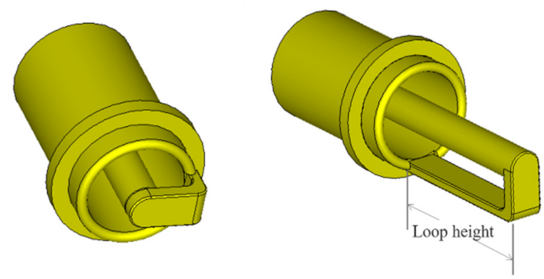

Figure 3: Model of the RF input coupler with the original loop height (left) and with the modified loop height (right).

The modified coupler, with 9 cm loop height, was rotated in simulations to study a behaviour of the coupling factor. With a full circle rotation, the coupling factor has complete two repeat pattern loops as illustrated in Fig. 5. This reflects a coupling behaviour of the coupler's magnetic field to the TM010 cavity's magnetic field. So, a quarter rotation of coupler is sufficient to get a full coupling factor range and the maximum is greater than 4.0.

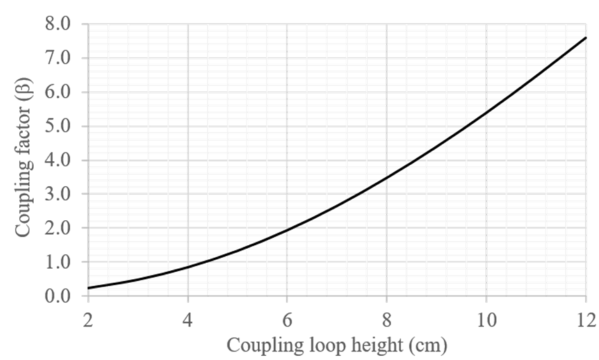

Figure 4: RF coupling factor with various coupling loop height.

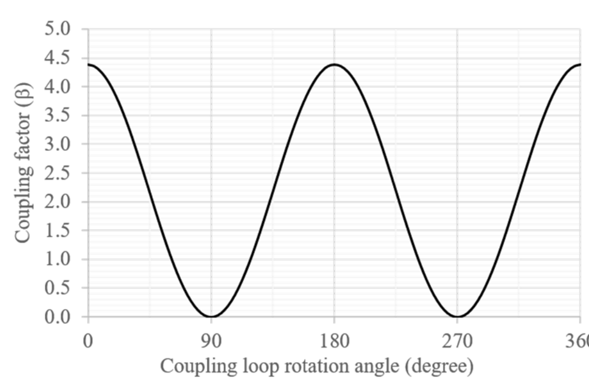

Figure 5: RF coupling factor with various coupling loop rotation angle.

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HIGHER ORDER MODE PROPERTIES

The higher order mode (HOM) of the cavity were simulated up to 900 MHz. The resonant frequencies and theirs shunt impedance were calculated. The longitudinal and transverse shunt impedances of the HOM were listed in Table 2 and plotted in Fig. 6. The 5 MΩ shunt impedance of the fundamental mode (118 MHz) is omitted in Fig. 6 in order to show the small values of the longitudinal HOMs shunt impedance. The nearest longitudinal HOM, which has an electric field in longitudinal direction, are found at the frequency of 356 MHz and 439 MHz. The 439 MHz mode has a highest shunt impedance of < 0.2 MΩ.

The transverse shunt impedance has the maximum of lower than 10 MΩ/m at the 603 MHz mode as shown in Table 2. Only dipole modes were studied because they have more effects to the beam than other transverse HOMs. The nearest transverse HOMs are found at the frequency of 398 MHz and 447 MHz. The 398 MHz mode has small shunt impedance, which can be neglected, compare to the 447 MHz mode. All of the high transverse shunt impedance HOMs need a carefully damped via the HOM couplers. The HOM coupler design will be a future activities of the lab.

Table 2: Properties of the HOMs

Mode frequency (MHz)	R_{sh} (MΩ)	R_T (MΩ/m)
117.7	4.97	-
356.5	0.00	-
397.6	-	0.01
439.1	0.17	-
447.3	-	2.88
478.5	-	0.00
553.0	0.00	-
557.7	-	2.66
569.4	-	0.00
582.3	0.00	-
583.7	-	0.00
603.2	-	9.73
636.3	-	0.02
662.9	-	8.34
666.3	-	0.00
679.4	-	0.08
726.2	0.12	-
756.9	-	3.59
767.0	-	5.38
767.4	-	0.00
767.5	-	0.03
776.2	-	0.38
805.1	-	0.51

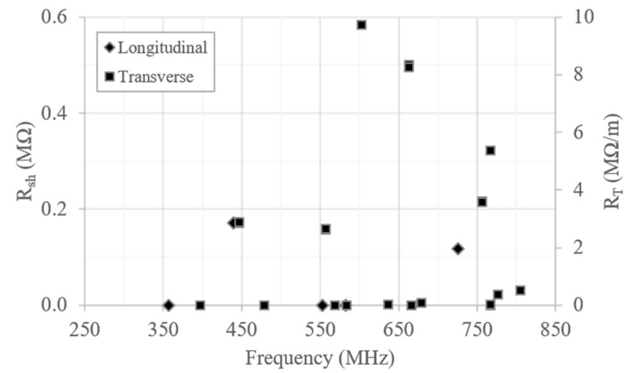

Figure 6: The longitudinal and transverse shunt impedance of the HOMs.

FABRICATION WORK

The new RF cavity is planned to fabricate in-house of the institute. The mechanical shop of the SLRI has a high precision machine, which can fabricate cavity's parts. The problem is in the welding and brazing process of the cavity parts as the mechanical shop people does not have experience of cavity assembly and there isn't a large brazing oven at the institute. So, the cavity parts can be fabricated at SLRI mechanical shop, but the cavity assembly will be done elsewhere. The potential collaboration with the RF lab of SSRF in Shanghai for cavity assembly is in discussion process.

CONCLUSION

The design of the new 118 MHz RF cavity for using in the RF for accelerator laboratory at SLRI is complete. The cavity is the nose-cone pillbox cavity type. It has shunt impedance of 5 MΩ with 27,000 unloaded quality factor. The maximum accelerating voltage is 200 kV at the 8 kW RF power. The tuner, equipped with DN160CF flange, is a plunger style with a diameter of 14 cm. Two tuners were required to obtain 1 MHz tuner range. The RF power input coupler will be a modified version of the available couplers in the lab. The coupling loop height will be extended to 9 cm to get β > 4. The HOMs of the cavity were also studied. The longitudinal HOMs does not have severe effects to the beam as their shunt impedances are less than 0.2 MΩ. The transverse HOMs have higher effects with the shunt impedance of ~10 MΩ/m at the 603 MHz mode. The fabrication of cavity parts will be done at the mechanical shop of SLRI, but the cavity assembly will be done elsewhere. This because the facility is not capable of brazing the large diameter parts. The cavity fabrication and the HOM coupler design are the future activities of the lab.

REFERENCES

[1] N. Juntong and S. Krainara, in *Proc. IPAC'14*, Dresden Germany, Jun. 2014, "The New 118 MHz Normal Conducting RF Cavity for SIAM Photon Source at SLRI", paper THPRI055, pp. 3896-3898, doi:10.18429/JACoW-IPAC2014-THPRI055

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[2] N. Juntong *et al.*, "Commissioning of the SLRI Storage Ring Second RF System", in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, paper THPIK102, pp. 4328-4330, doi:10.18429/JACoW-IPAC2017-THPIK102

[3] K. Halbach and R. F. Holsinger, *Part. Accel.*, vol. 7, pp. 213-222, 1976.

[4] CST Computer Simulation Technology GmbH.