COUPLER DESIGN FOR A SAMPLE HOST TE CAVITY*

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Abstract

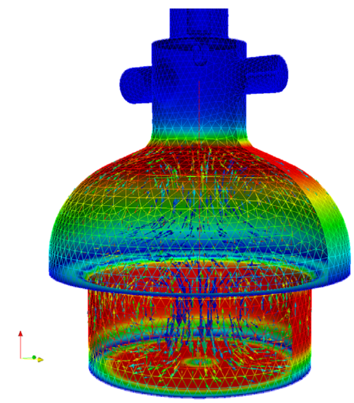
A sample host niobium superconducting cavity operating at both TE_{012} and TE_{013} modes has been developed. The cavity features a flat 3.75 inch diameter demountable bottom plate allowing RF testing of new materials such as Nb_3Sn and MgB_2. Since the surface resistance of the sample plates may vary a lot, an adjustable input coupler has been developed for this cavity. A hook shape coupler tip is designed and optimized to couple to the magnetic field of both transverse electric modes. The coupler optimization, external Q calculations and 3D multipacting simulations using ACE3P will be discussed.

INTRODUCTION

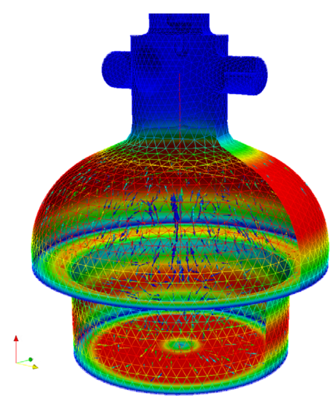
The rf surface resistance of superconducting niobium is typically studied by testing single cell or multi-cell superconducting cavities. Due to the time consuming and complex process of preparing those entire cavities, getting statistically significant data sets on various phenomena impacting surface resistance is challenging. To systematically characterize rf surface resistance of niobium and other new materials such as MgB_2 and Nb_3Sn, a sample plate demountable superconducting niobium cavity was designed and fabricated [1],[2]. The mushroom shape cavity operates at both TE_{012} and TE_{013} modes as shown in Fig.1.

The rf design parameter are shown in Tab.1. The maximum magnetic field which can be achieved at the sample plate is estimated based on niobium breakdown field 2000 Oe. The design enables that the sample plate is exposed to the maximum field in the entire cavity. The main design goal is to maximize the ratio R of maximum sample plate surface magnetic field to maximum host cavity surface magnetic field. Three optimized shape had been obtained and only the shape which enables dual modes operation and operates at monopole transverse electric field TE_{0mn} was chosen to be fabricated. The maximum of the surface magnetic field on the sample plate is at the same location for both modes as seen in Fig.2.

The input coupler port is located at the center top of the mushroom type cavity and the pickup probe and pumping probe are distributed symmetrically at the input coupler port. In the following sections, the rf design of the input coupler, coupler heating considerations and 3-dimensional multipacting simulations using SLAC A3P codes will be described.



(a) Spacial magnetic field distribution of TE_{012} mode,red indicates high magnetic field, the maximum magnetic field on the sample plate is 1.24 times higher than on host cavity wall



(b) Spacial magnetic field distribution of TE_{013} mode, red indicates high magnetic field, the maximum magnetic field on the sample plate is 1.57 times higher than on host cavity wall

Figure 1: Magnetic field distribution of TE mushroom cavity.

Table 1: The design parameters of the TE mushroom cavity (H_{max} on sample assumes 2000 Oe maximum field on host cavity wall)

	TE_{012}	TE_{013}
f(GHz)	4.78	6.16
H_{max} @ sample (Oe)	2480	3480
Sample diameter (cm)	10.0	10.0

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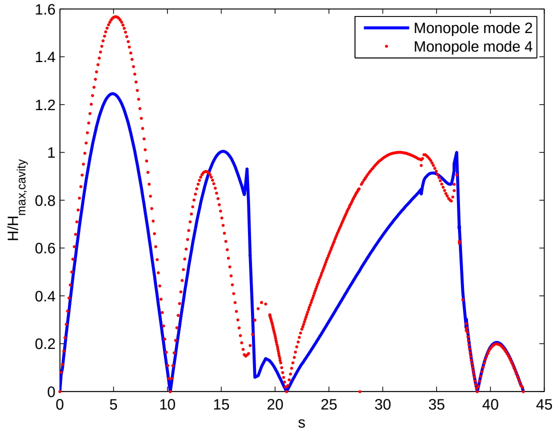

Figure 2: Normalized surface magnetic field along the sample plate and walls of the host cavity. Sample plate: s=0 to 10 cm. Host cavity: s=10 to 43 cm. mode 2: TE_{012}, mode 4: TE_{013}

INPUT COUPLER DESIGN FOR TE MUSHROOM CAVITY

The input coupler to the TE_{012} and TE_{013} modes of the TE mushroom cavity needs to effectively couple both TE_{012} and TE_{013} modes. As we can see from a typical ”Saclay” style input couplers of Fig.3, the coupler tip plane is always parallel to magnetic field line planes of the TE_{0mn} monopole modes no matter what direction of the tip is positioned if loop/hook is at cavity axis. Therefore we use an off-center hook tip coupler which can be seen from Fig.4 to increase magnetic field coupling. The strength of coupling depends both on tip penetration depth and the angle / the direction of hook. The input coupling coefficient Q_{ext} was calculated by both Omega3P and MWS and agreed well. Since rf surface resistance of new superconducting material may vary a lot, the coupler is designed to enable a large range of coupling from 10^7 to 10^{10}. The Q_{ext} dependence on hook tip penetration depth is shown in Fig.5.

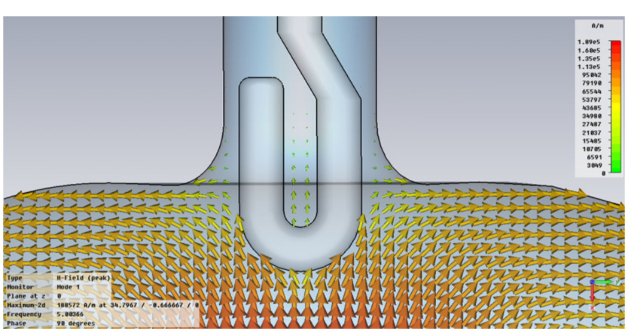

Figure 3: Magnetic field distribution near a ”Saclay” style loop coupler tip calculated by MWS

As the input coupler tip penetrates into the cavity, the superconducting host cavity quality factor Q_0 may be degraded. Fig.6 shows that if a typical host cavity baseline Q_0 is around 10^9, coupler heating effect is not significant.

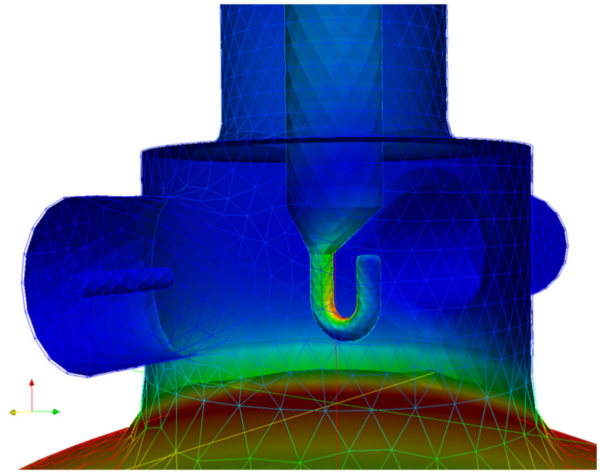

Figure 4: Magnetic field distribution near an off-center hook coupler tip calculated by Omega3P.

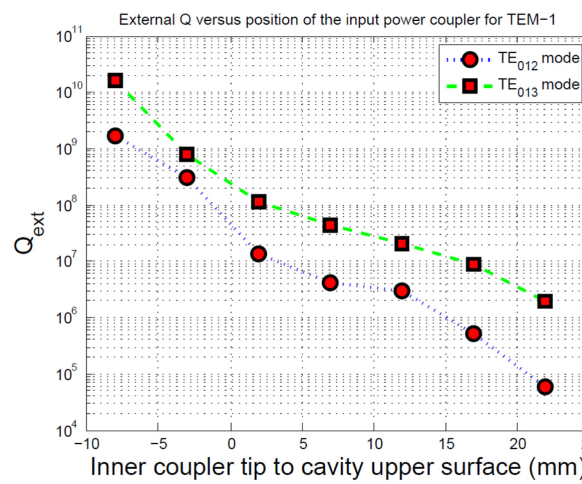

Figure 5: Q_{ext} dependence on coupler penetration depth into cavity.

3D MULTIPACTING SIMULATION IN PRESENCE OF COUPLER

Ideally TE_{0mn} monopole modes do not have surface electric field on the host cavity. Therefore there should be no multipacting. However due to the presence of the non axis-symmetric off-center hook coupler, a fully 3-dimensional multipacting simulation was performed to check the possible existence of multipacting barriers. Numerical simulation using SLAC’s parallel computing EM codes ACE3P was used [3]. The cavity with full length input coupler port and side ports were calculated using Omega3P with the high order tetrahedra mesh elements. The magnetic field distribution of TE_{012} mode inside entire host cavity is shown in Fig.7.

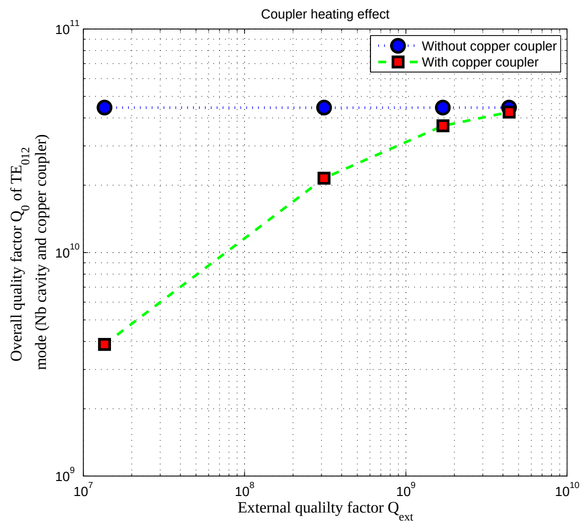

Figure 6: Host cavity Q_0 degradation due to coupler penetration.

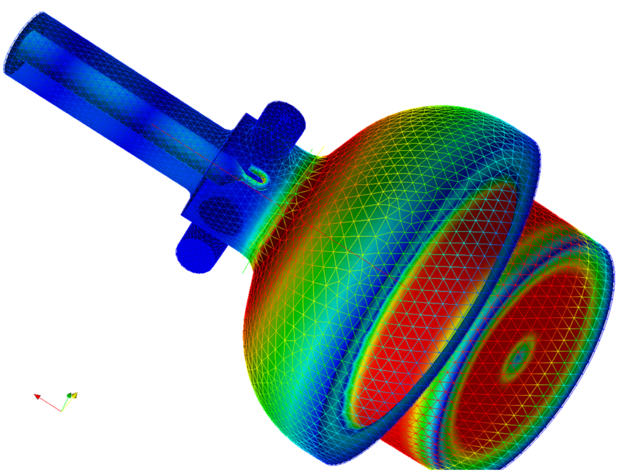

Figure 7: TE_{012} magnetic field distribution of TE mushroom cavity with full length input coupler port calculated by Omega3P.

Track3P was used based on the precise surface field extracted from Omega3P [4]. Electrons were launched from specific surfaces at different phases over a full rf period. The initial launched electrons follow the electromagnetic fields in the structure and eventually hit the boundary, where secondary electrons are emitted particles. The simulated particles just bounces back and the trajectories continue to be determined by EM field. The tracing of electrons will continue for a specified number of rf cycles, after which resonant trajectories (possible multi-impact events) were identified. Fig.8 shows electron impact energy as the function of peak magnetic field for the TE mushroom cavity simulated near the input coupler region. Although we haven't identified any possible multipacting barriers, two events were used to illustrate the identification process of the possible multipacting barriers. Event 1 has 50 impacts during 50 simulated rf cycles as shown in Fig.9. from SEY data of niobium, this event will not cause the electron number to increase because the impact energy is too low. Event 2 has 11 impacts during 50 simulated rf cycles as shown in Fig.10. The impacting energy is in the range of high SEY region, but the trajectory is not stable. Therefore a steady multipacting event can not be established.

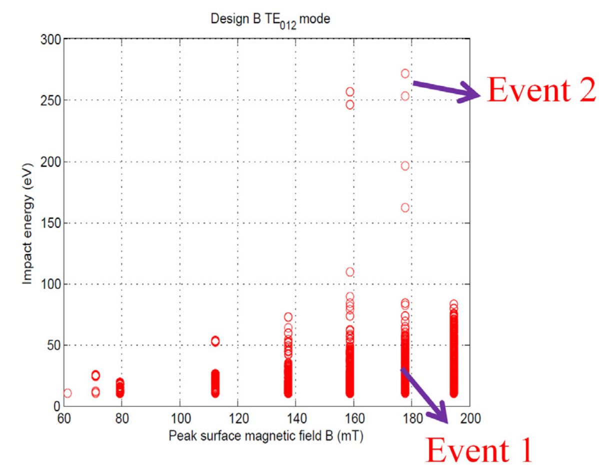

Figure 8: Impact energy dependence with cavity peak surface magnetic field near the input coupler region.

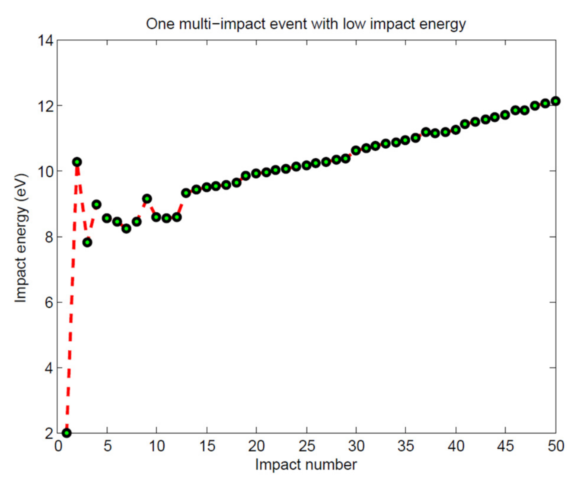

Figure 9: Impact energy dependence with impact number for event 1.

Similar studies have shown that asymmetric coupling ports on the side of the beam tube can cause sufficient distortion of the TE_{011} mode to lead to multipacting [5]. Our studies also confirm that by symmetrizing the side ports, monopole TE modes will not have multipacting barrier existing in the flat bottom plate.

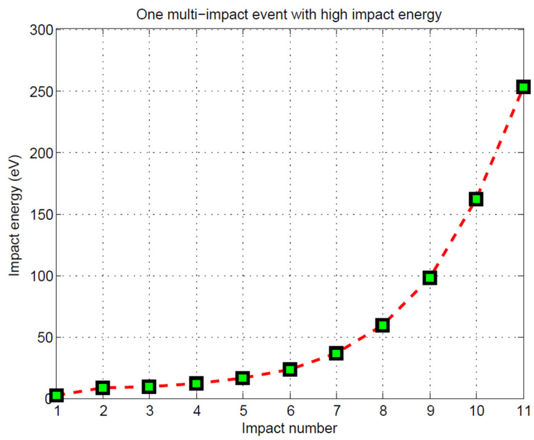

Figure 10: Impact energy dependence with impact number for event 2.

CONCLUSIONS

An off-center hook tip variable coupler for TE_{012} and TE_{013} modes is designed and 3-d multipacting simulations have been performed. Good coupling to both monopole TE modes has been achieved and no multipacting barriers have been observed in the simulations. Currently the coupler is under fabrication and will be ready for use soon.

REFERENCES

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