

# AN EFFECT OF FIELD EMISSION ON LOW BETA SUPERCONDUCTING CAVITIES\*

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## Abstract

Superconducting RF (SRF) technology is widely applied in particle accelerators to shorten the accelerator length and lower the construction price due to its high acceleration gradients with low rf losses. Field emission is the chief limitation associated with the surface electric field which will finally determine the cavity performance during the operation. The pickup-drop signal caused by field emission seriously affect the stable operation of the superconducting linac in the Chinese initiative Accelerator-Driven Sub-critical System (CiADS) demon facility. Simulations of the field emission effect and experimental measurements of the pickup-drop signal have been performed on the half wavelength resonator (HWR) cavity. And a modified design of the pickup antenna will be discussed to solve the pickup-drop problem.

## INTRODUCTION

The Chinese initiative Accelerator Driven Sub-critical System (CiADS) project is based on a 10 mA, 1.5 GeV CW proton linac for nuclear waste transmutation. CiADS project needs a high stability linac to demonstrate the technology of 10 mA CW beam of superconducting front-end linac for ADS technology. The first cryo-module of this demon SRF linac includes six 162.5 MHz HWR010 cavities working at 4K with optimum beta equal to 0.1.

In one of coupling ports of the cavity, a power transmission antenna rooted in a RF ceramic window to pick up the RF field power. We measured the pickup-drop signal of HWR010 PT and showed in Fig. 1. The frequently deviant signal result to the irregular responses of LLRF control system and limit the stable operation of the SRF linac.

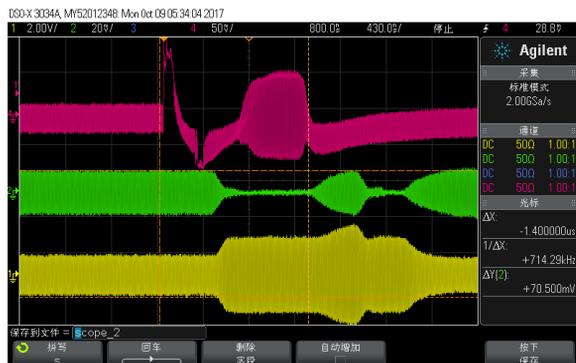


Figure 1: The signal with pickup-drop on oscilloscope.

\* This work was supported by National Natural Science Foundation for Young Scientists of China (Grant NO. 11505255)

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In Fig. 1, the pink signal is pick up power (Pt) from cavity, the green one is forward RF power (Pf) and the yellow one is reflected RF power (Pr). The pick up signal shows that there is discharge happened on the surface of RF ceramic window, which is called flashover[1]. What's behind it is should be the effect of continuous field emission electron beam hit on the surface of ceramic window[2].

## SIMULATION OF FE PARTICAL

This simulation was performed in CST Microwave Studio. The simulation results of electromagnetic field of the cavity is showed in Fig. 2 and Fig. 3.

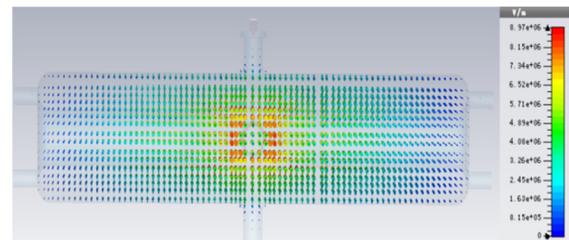


Figure 2: The electric field in HWR010 SRF cavities.

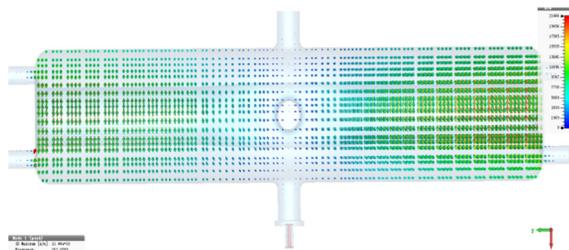


Figure 3: The magnetic field in HWR010 SRF cavities.

The electric field is strongest in the middle of the cavity and is weakest at the ends. The magnetic field is weakest in the middle and strongest at the ends. FE particles were attached to the cavity surface with the high electric field area.

The particles movement in electromagnetic field shows in Fig. 4. From Fig. 4, The particles movements straightly along the electric field line for the movements were dominated by the electric field, and the weak magnetic field has little effect on their direction of motions. These particles will finally hit on the PT antenna and ceramic window, as shown in Fig. 4 (d). Electrons constantly accumulated on the surface of ceramic window due to the electric property of ceramics, flashover happened when the accumulation to the limit.

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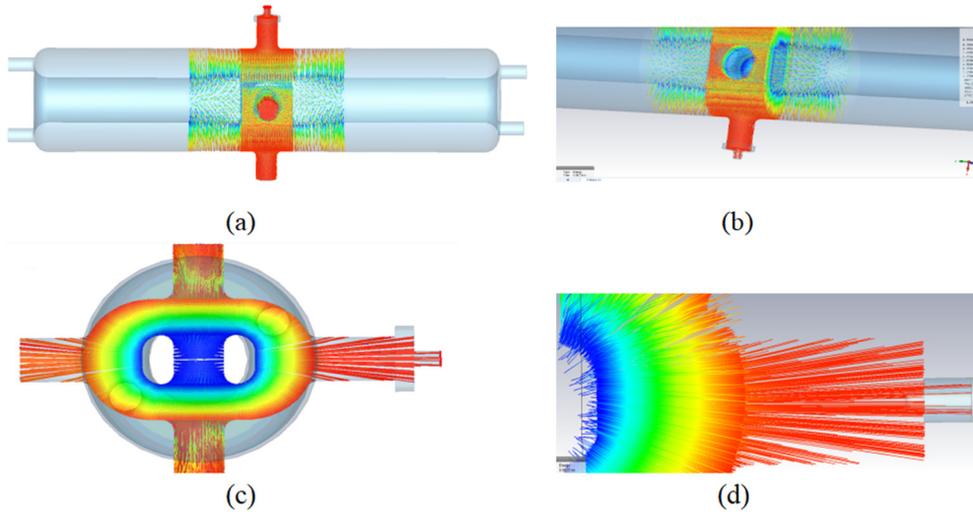


Figure 4: The FE particles trajectory simulation of HWR.

### EXPERIMENT IN SRF ACCELERATOR

As mentioned above, one of the reasons affect the operation stability of our linac is the pick-up-drop signal of the HWR010 cavities. In order to further understand the physics between the phenomena, therefore, we set up a 162.5M digital LLRF control system to monitor the pick-up-drop signal by the apparatus as shown in Fig. 5. Figure 6 shows the frequency of the pickup-drop signal at different accelerating gradient, the interval of each pickup-drop decreases as the increase in accelerating gradient. Figure 6 also displays the radiation dose caused by bremsstrahlung effect increases exponentially with the accelerating gradient, which indicates that the field emission effect inside the cavity is much stronger at high accelerating gradient, and it agrees with the F-N theory [3]. Therefore, the frequency of pickup-drop is proportional to field emission.



Figure 5: Monitoring system.

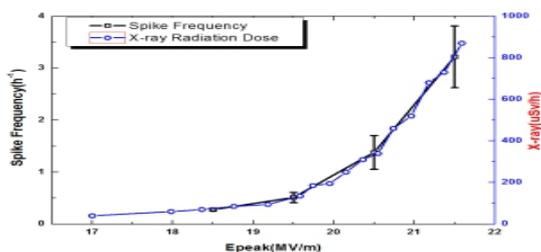


Figure 6: The frequency of pickup-drop and radiation dose are proportional to gradient.

### SOLUTIONS

In light of above analyses, in order to solve the problem, it is essential to avoid the FE electron impact the ceramic window of pick-up coupler. Two types of pick-up coupler were designed with the  $Q_e$  of about  $5E11$ . One is an electrical coupler, whose antenna was designed with a cap on its top to absorb the FE electrons and guide them away through cable, at the same time the cap of the antenna covers the ceramic window at the bottom to avoid the impact of FE electrons (see Fig. 7).



Figure 7: A modified design of electrically coupled antenna.

The other type of the pick-up coupler will be set at the end of the cavity with strong magnetic field and weak electric field. The electric field in this region is too weak to support FE effect act. As the magnetic field is strong in this region, the pickup antenna is designed a magnetic coupled loop made by niobium (see Fig. 8).

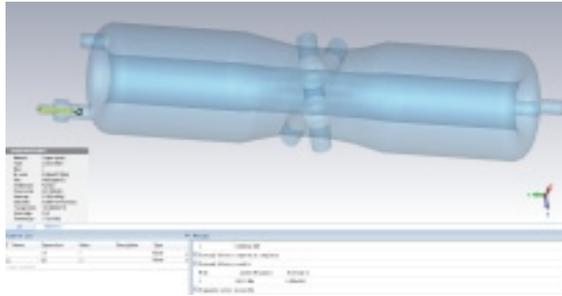


Figure 8: A modified design of magnetic coupled antenna.

## CONCLUSION

The frequently pickup-drop on PT signal is one of the reasons to interfere the LLRF control system and the stable operation of the SRF Linac. From all the results, it can be concluded that the pickup-drop signal are caused by the flashover on ceramic window and field emission (FE) should be the source of origin. To solve this pro-

blem, two modified designs of transmitted power had been presented, and they will be validated in our following experiments.

## ACKNOWLEDGMENT

This work was supported by the SRF group and the LLRF group of Linear Accelerator Center at IMP.

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