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# FLASHOVER ON RF WINDOW OF HWR SRF CAVITY

Xinmeng Liu, Yuan He , Guirong Huang,Zheng Gao,

Institute of Modern Physics, Chinese Academy of Sciences 730000, Lanzhou, China

*Abstract*

Superconducting RF (SRF) technology Breakdown on the RF ceramic windows always happen in different kinds of accelerator. It is one of the main limitations in current day superconducting cavities and couplers. The PT signal trip caused by discharge on the surface of RF ceramic window lead LLRF control system trip which affect the stable operation of the superconducting linac. Simulation of field emission electron trajectory in superconducting cavity and experimental measurements of the frequency of the pickup signal trip have been performed. A lot of aged window with characteristics of flashover were studied by means of material characterization. The flashover on the surface of RF ceramic window caused by electrons and field emission provide the origin of initial electrons. A modified design of the pickup antenna have solved the PT pickup trip problem.

## INTRODUCTION

The Chinese initiative Accelerator Driven Sub-critical System (CiADS) project is based on a 10 mA, 1.5 GeV CW proton linear accelerator for nuclear waste transmutation. The main components of the Linac are superconducting radio frequency accelerating cavities. 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 cryomodule of this 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 trans-mission 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.

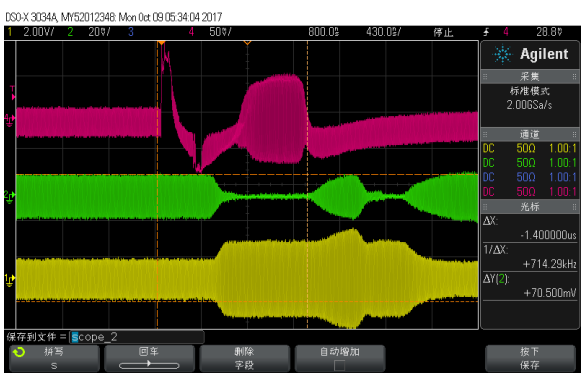


Figure 1: The signal with pickup-drop on oscilloscope.

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 frequently deviant signal result to the irregular responses of LLRF control system and limit the stable operation of the SRF linac. The pick-up signal shows that there is discharge happened on the surface of RF ceramic window [1].

## 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.

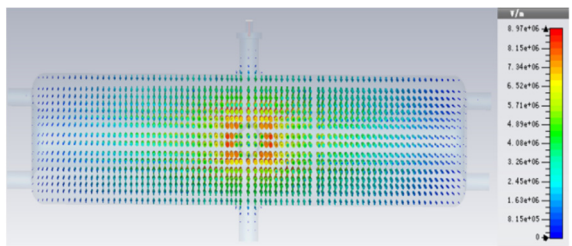

Figure 2: The electric field in HWR010 SRF cavities.

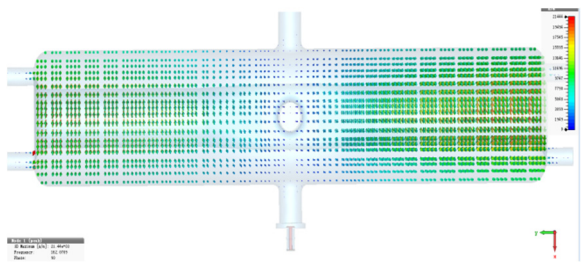

Figure 3: The magnetic field in HWR010 SRF cavities.

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. The particles movements straight 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). The energy of the bombarding electrons is too strong to producing secondary electrons on the surface of ceramic. Therefore the flashover occurs by field emission electrons constantly accumulated on the surface of ceramic window.

liuinmeng@impcas.ac.cn

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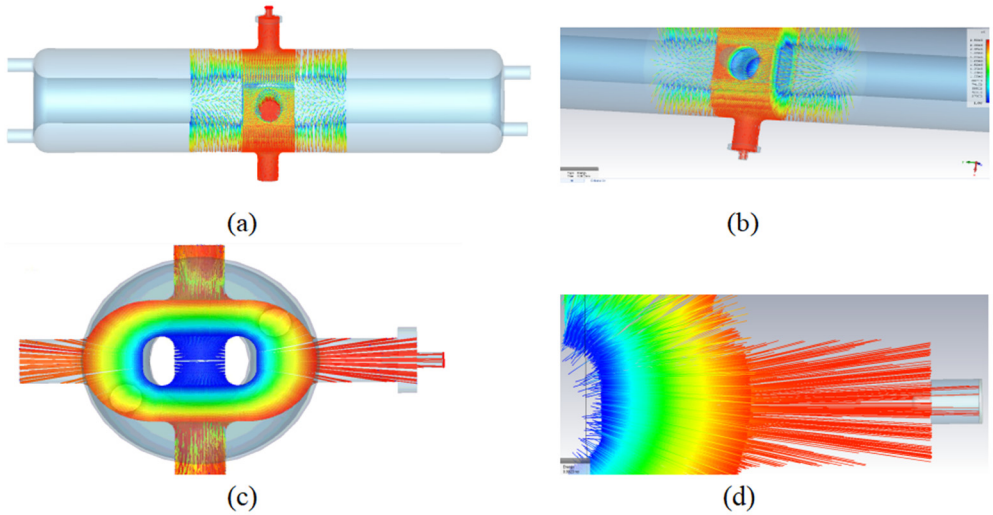


Figure 4: The FE particles trajectory simulation of HWR.

## EXPERIMENT IN MEASUREMENT

In order to further understand the physics between the phenomena, the frequency of pick-up-drop signal at different Epk were monitored. The interval of each pickup-drop decreases as the increase in accelerating gradient. Figure 5 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 [2]. Therefore, the frequency of pickup-drop is proportional to field emission. The accumulated field emission electrons on the window may be the reason of flashover.

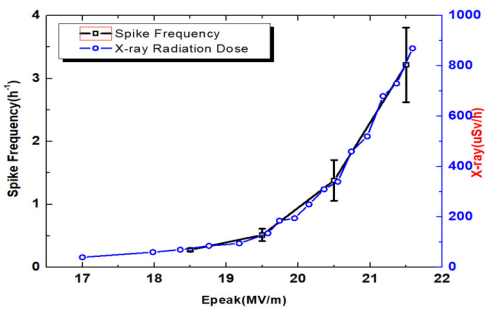


Figure 5: The frequency of pickup-drop and radiation dose are proportional to gradient.

## THE FLASHOVER TRACE OF THE SAMPLES

The surface of ceramic windows in PT couplers of the first three HWR010 SRF cavities (CM1-1,CM1-2,CM1-3) in module 1 have been presented completely (Fig. 6). The left one with some dark area. There are three obvious and clear discharge channels on the surface of the middle one. A more obvious and wider discharge channel on the surface of the right one. The trace on the surface of the window proved that there is flashover happened.

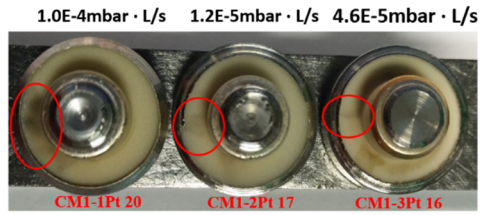


Figure 6: The surface of ceramic windows.

## THE XPS MEASUREMENT

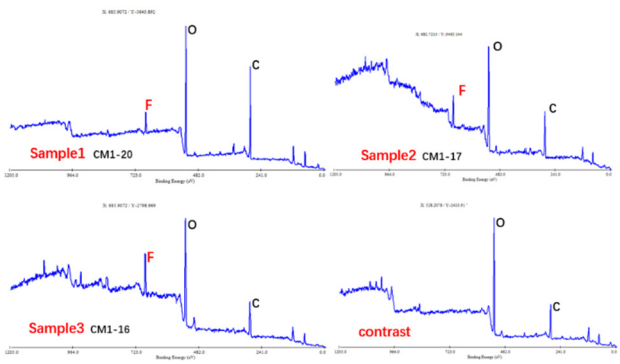


Figure 7: The results of elemental component test by XPS.

The windows as samples are placed on the X-ray photo electron spectroscopy (XPS) measurement platform for inspection (Fig. 7). The elemental component of the surface of the window can be performed. The ceramic window in PT coupler taken from the SRF cavity without the occurrence of field emission was tested as the contrastive sample. The samples with flashover trace has fluorine on the surface and without fluorine on the contrastive one. The fluorine comes from HF on the surface of the SRF cavity and was transported by field emission electrons [3].

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The field emission should be the original reason of flashover.

## 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 Qe 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 (Fig. 8).

Figure 8: 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 (Fig. 9).

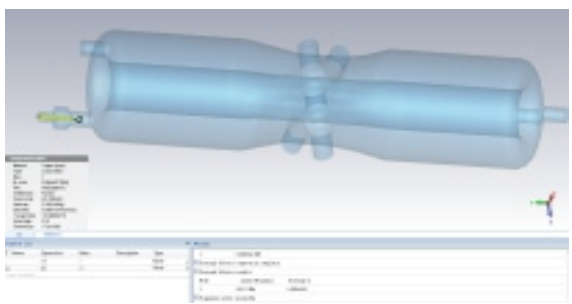

Figure 9: A modified design of magnetic coupled antenna.

## 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 should be the source of origin. To solve this problem, two modified designs of transmitted power had be presented, and they will be validate in our following experiments.

## ACKNOWLEDGMENT

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## REFERENCES

[1] R. L. Geng *et al.*, "Field emission in SRF accelerators: instrumented measurements for its understanding and mitigation", in *Proc. IBIC'17*, Grand Rapids, USA, 2017, pp.470-477. doi:10.18429/JACoW-IBIC2017-TH1AB1

[2] H. Padamsee, J. Knobloch, T. Hays, *RF Superconductivity for Accelerators*, New York, NY, USA: John Wiley & Sons, 1998, pp. 3–4.

[3] H. Padamsee and J. Knobloch, "The nature of field emission from microparticles and the ensuing voltage breakdown", in *AIP Conf. Proc.*, vol. 474, pp. 212-248, 1999. doi: 10.1063/1.59014