EXPERIMENT OF PLASMA DISCHARGE ON HWR CAVITY FOR IN-SITU SURFACE CLEANING STUDY*

A.D. Wu#, L.Chen, Y. He, T.C. Jiang, C.L. Li, Y.M. Li, F. Pan, Z.X. Shi, Y.K. Song, T. Tan,
L. Yang, W.M. Yue, S.H. Zhang, H.W. Zhao, Institute of Modern Physics,
Chinese Academy of Sciences, Lanzhou,Gansu 730000, China

Abstract

Hydrocarbons, which migrate from the vacuum bumps system, will absorb on the cavity surface after periods of operation. The contaminants can reduce the surface electron work function. It will enhance the field emission effect and restrict the cavity accelerating gradient. The room temperature in-situ plasma surface processing to clean the hydrocarbon contaminants can act as a convenient and efficient technology for the accelerator performance recovery on line. For better control of the discharge inside the cavity, the experiment works on a HWR cavity to research the ignited discharge between the swarm parameters (gas flow, pressure, forward power).

INTRODUCTION

The Superconducting Linac Injector II for Chinese Accelerator Driven System (C-ADS) was consisted of twelve Have Wave Resonators (HWR) which in two Cryostats. The Injector II operates at 162.5 MHz, and the 10 mA proton beam will be accelerated to 10 MeV on the CW mode. The parameters of HWR cavity for this section are shown in the Table 1[1].

Table 1: Parameters of HWR for the Injector II.

Parameters	Value	Unit
Frequency	162.5	MHz
βopt	0.10	-
Vacc	0.78	MV
Epeak	25	MV/m
Bpeak	50	mT
R/Q0	148	Ω
G	28.5	Ω

FIELD EMISSION

The field emission is one of the limiting for superconducting cavities to reach higher acceleration gradient. Beyond the certain gradient point, the electrons tunneling out from the cavity surface will increase exponential with the gradient value. From the *Fowler-Nordheim Theory*, the field emitted current density was described as Eq. (1) [2].

$$j = a\frac{(\beta E)^2}{\varphi}\exp\left(\frac{-b\varphi^{3/2}}{\beta E}+\frac{c}{\varphi^{1/2}}\right) \qquad (1)$$

where, j is the density of the emission current, φ is the surface electron work function, E is the surface electric field, β is the field enhancement factor, and the parameters a=1.54E6, b=6.53E3 and c=10.4 are constants.

The field emission electrons can be weight from its *X-ray* radiation produced by the bremsstrahlung. The field emission effect was measured on the Chinese ADS Injector II facility as shown in the Fig. 1.

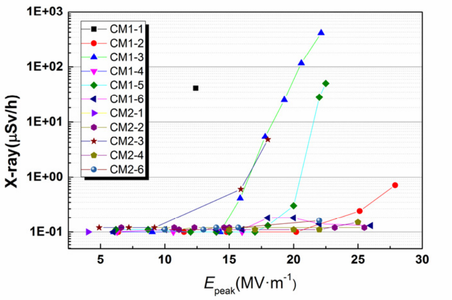

Figure 1: The *X-ray* radiation on C-ADS Injector II.

The target of the *E*peak for operation is 25MV/m, but numbers of the cavities were under restriction of field emission, for the ranging 15 to 20 MV/m. The electromagnetic energy absorbed by field emission electron and dissipated on the cavities wall will increase the cryogenic load.

The electromagnetic energy absorbed by field emission electron and dissipated on the cavities wall will increase the cryogenic load. The in-situ plasma on the superconducting cavities was efficient technology for the performance recover on the elliptical cavities at SNS [3]. Thus the plasma glow discharge experiment was set up at IMP to research the in-situ cleaning for the HWR cavity.

COUPLER COSIDERATION

To accord with the operation on line, a fundamental power coupler (FPC) was chosen to transmit the RF power to the HWR cavity for plasma discharge research. The maximum power of the solid amplifier is 200 Watts, the length of the antenna need to make enough RF power input into the cavity. And to protect the ceramic window, the plasma discharge on the coupler needs to avoid. The length of the antenna to the cavity was simulated with Microwave Studio, the model was displayed as Fig. 2.

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# Email address: antonwoo@impcas.ac.cn

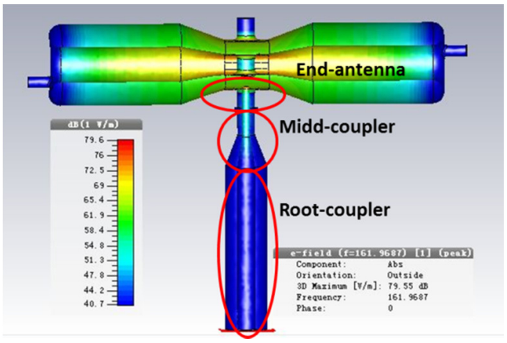

Figure 2: The simulation model of HWR with coupler.

The coupler was divided into three parts, the end-antenna, midd-coupler and the root-coupler. These peak electric fields were normalized to the peak electric field of cavity. The power put into the cavity (P_c) and the power forward (P_f) can be evaluated with $P_c/P_f = (4\beta)/(1+\beta)^2$, where the β is known as the coupling factor defined from the Q_0/Q_{ext}, $Q_0 = 2800$ at room temperature and the Q_{ext} is the external load for the coupler port. The simulation result was shown in the Fig. 3.

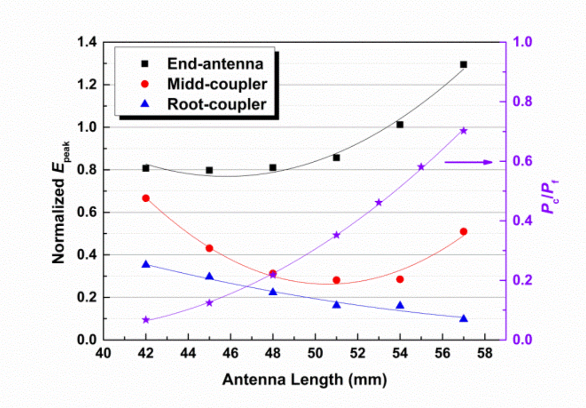

Figure 3: The dependence of normalized E_{peak} and the ratio of P_c/P_f with antenna length.

Finally, a 55 mm antenna was chosen for the FPC. The fundamental frequency of the HWR with this antenna is 162.145MHz, and the reflection coefficient $S_{11} = 0.574$ measured by the vector network analyzer.

IGNITION OF INERT GAS

Two types of inert gas, the Argon and Neon, were taken into consideration. The Argon with higher atom number is more easily ionization than Neon. The set points of electric fields for the plasma ignition were evaluated by measuring the forward power to the cavity. On the ignition point, the peak electric fields were figured out from the Eq(2):

$$E_{peak} = k \cdot \sqrt{(1-S_{11}^2) \cdot P_f \cdot R/Q_0 \cdot Q_0} \qquad (2)$$

where, the k is constant for E_{peak}/V_{acc} = 32 m^{-1} and other parameters were introduced above. The results are shown in the Fig. 4. It depicts that the Neon needs higher electric field to glow discharge than Argon for the same pressure.

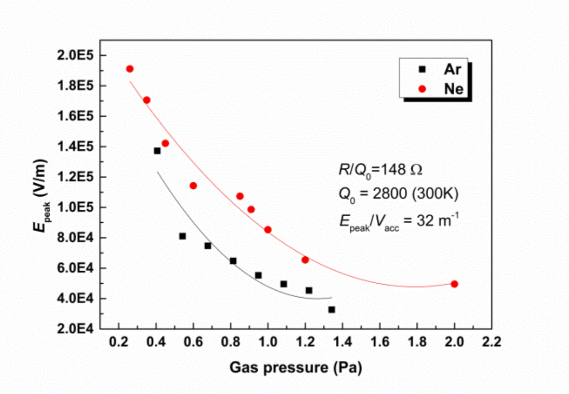

Figure 4: Dependence of E_{peak} on the cavity for ignition with the gas pressure.

DISTRIBUTION OF GLOW DISCHARGE

The uniform distribution of the discharge was chased to make the plasma interact with cavity surface as more as possible. The broad discharge areas will helps to release the emission effects, especially for the electric stronger fields which are the electrons more likely to emit.

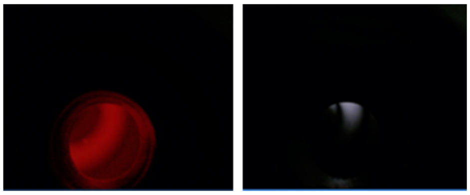

Figure 5: The glow of Neon (left) and Argon (right) discharge, both at the pressure of 0.4 Pa and with 200Watts RF power forward.

The distributions of glow discharge are compared between the Neon and Argon, shown in the Fig. 5. From our experiments, the Neon glow discharge areas are more widen than the Argon. But we need more details data by changing the parameters of gas pressure and forward power.

DISCHARGE IN THE COUPLER

From the ignition curve on the Fig. 4, the Argon gas is more easily discharge at higher pressure regions. For some regions, when the power forward increased to the certain threshold, the discharge can be ignited in the coupler, even though the electric field near the ceramic window was much lower than the cavity surface. An example was given on the Fig. 7.

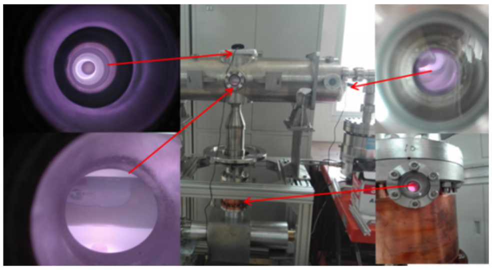

Figure 7: Argon plasma discharge at 0.7Pa with140 Watts power forward.

CONCLUSION

For the inert gas discharge on the HWR cavity, the Neon requires high electric field to ignition and distribution was more uniform than the Argon. The discharge near root coupler becomes a critical issue for our future works.

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