PARAMETER MEASUREMENT OF 2CELL SUPERCONDUCTING CAVITY

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Abstract

The main parameters of a 1.3GHz, 2cell TESLA type superconducting niobium cavity, designed and developed by Peking University, are simulated using MAFIA in institue of applied electronics, CAEP. The curves of E_{acc} to Q_0 and Rs to $1/T$ relations are measured at 2K temperature, after this cavity treated by CP, rinsed by high pressure de-ionized water and vacuum pumped. Results show that E_{acc} and Q_0 of this cavity

INTRODUCTION

The technology of radio frequency superconductivity has been sophisticated for more than 40 years' researches. It has been succeeded in some great science projects, for example: CERN, DESY, CEBAF etc, and RF Superconducting cavity also is the preferred technology in accelerator projects in the 21century, such as high average power free electron laser, the high-current proton accelerator, high energy colliders. These years, the ERL source, based on RF superconductivity, becomes hot spot: the 4th light source[1].

Exploration of rf superconductivity for particle accelerators began at Stanford University in 1965 with the acceleration of electrons in a lead-plated resonator, where the electronics was accelerated to 500 KeV from 80 KeV[2]. The phenomenon of multipacting, in the nomal copper cavity structure, limited the achiverable gradient under 3MV/m in 1960s. the first generation practical RF superconducting cavities overcame the multipacting problem by using ellipse or circular structure, i.e, the CEBAF cavity in Conell, the 2th LEP cavity in CERN, the HERA cavity in DESY, the TRISTAN cavity in KEK, which operating gradient was5MV/m[3][4]. The E_{acc} without load were 7.5MV/m to 15MV/m.The idea of TeV Electron Superconducting Linac Accelerator (TESLA), based on rf superconducting cavity required the Eacc from 20MV/m to 40MV/m in1990s.

Now some relevant steps are taken to further advance gradients which was limited by field emission and thermal breakdown, such as (a) improving the thermal conductivity of niobium by purification or[5] (b) postpurifed highpurity niobium to further raise the thermal conductivity, high pressure rinsing to provide cleaner, and high-pulsed-power processing, to destroy residual emitters and[6] (c) getting higher E_{acc} by optimizing structure to reduce E_{pk}/E_{acc}[7].

2CELL SUPERCONDUTING CAVITY

The 2cell superconducting cavity, offered by Peking university, adopted the 1.3GHz TESLA structure and further optimized by using superfish program for reduce its E_{pk}/E_{acc} and B/E_{acc}. We simulate it by MAFIA program. Figure 1shows the simulated π mode electric field pattern. Figure 2 shows the π mode E_z distribution in the cavity, figure 3 and figure 4 show the E cross-sectional distribution and B cross-sectional distribution respectively. Table 1 shows the calculating eigenvalues. We can learn the peak E_{pk} and B detail distribution from Fig.3 and Fig.4. Figure 5 shows the picture of the 2cell cavity.

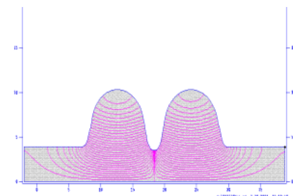

Fig.1: The simulated π mode electric field pattern

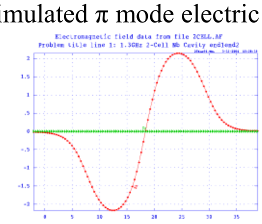

Fig.2: The π mode Ez distribution in the cavity (Courtesy of Lin Zhou)

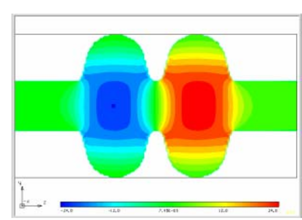

Fig.3: E cross-sectional distribution

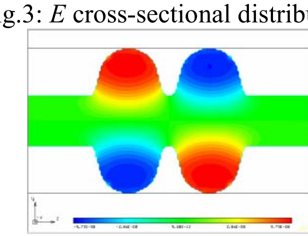

Fig.4: B cross-sectional distribution (Courtesy of Lin Zhou)

Fig.5: the photo of the 2cell cavity

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Table 1 shows the calculating eigenvalues(Courtesy of Lin Zhou)

f	1.292GHz
E_{acc}	1MV/m
U	0.0128J
P_{loss}	11.57mW
R/Q	258Ω
Q_0	9.08E9
E_{pk}/E_{acc}	2.29
B_{pk}/E_{acc}	5.46mT/(MV/m)
$G=R_s*Q$	282Ω

SURFACE PREPARTION

The performance of the cavity will be influenced by the residuum on the inner surface, and grease, dust and fine damage during machining. To achieve the optimum RF performance, such as higher E_{acc}, the surface of the cavity must be post-treatment by mechanically-polished, chemical etched and electropolished and high pressure rinsing.

The 2cell cavity was buffered chemical polished after be surface-treated at Peking University. It is important to using the appropriate acid solution (HF (40%) : HNO_3 (65%) : H_3PO_4 (85%) = 1: 1: 1) and keeping the temperature low than 20ºC during chemical etching of the cavity. Figure 6 shows that The cavity is polished 5minutes (≈4μm/min) and cooled by cooling water outside to keep the temperature stability. At the same time, for the bubble reacted on the surface damped the reaction of niobium and acid mixture. The cavity must be rotated uniformly.

Fig.6: Picture of BCP for the 2cell cavity

Fig 7: High-pressure rinsing of the cavity in Class-100 clean room

After acid etching, the cavity is placed in a closed loop with the ultrapure water system and followed by high-pressure rinsing with the theoretically pure water (>18 MΩ-cm) for 2.5 hours in a Class 10-100 clean room. The newly cleaned surface is dried for 24 hours, then clean assembly with the test stand in the Class 10 clean room. After leak detection, the cavity is evacuated for two weeks and heated at 120ºC for 48 hours. Finally, the vacuum is $1.42*10^{-6}$.

PARAMETERS MEASUREMENT

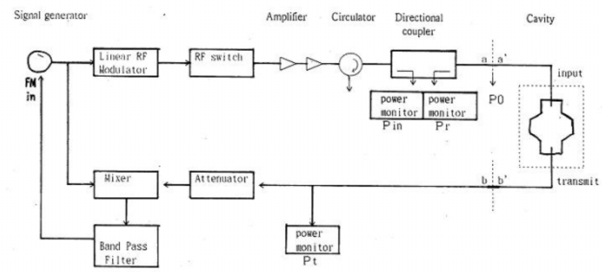

Fig.8: rf schematic of the vertical test system (Courtesy of Mingqi Ge)

To evaluate the 2cell superconducting cavity's performance, we measure the Q_0 and E_{acc} as functions of the cavity's field level. Figure 8 shows the radio frequency schematic of the vertical test system at superconducting test Lab at IHEP, Beijing. The procedure for the test is

a) precooling with he gas;
b) cooling with liquid helium to 4.2K;
c) calibration of the measurement: cable correction;
d) searching for the resonance frequency;
e) measurement of the decay time, the reflected power

Before the 2K superconducting experiment, the cavity vacuumed with seal flanges is mounted on the testing jig. When all rf detectors and sensors for temperature, pressure and position were connected carefully, we marked each test positions and the cavity's out surface, adjusted the bellows of the rf coupler, wrote down the maximum and minimum distance. When the testing jig is lifted into the vertical dewar, we began our experiment.

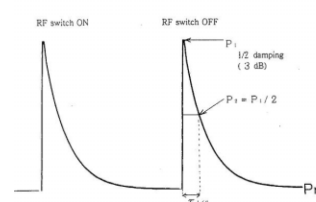

Fig.9: The decay time of the reflected power, from the shape we can decide whether over or under couple.

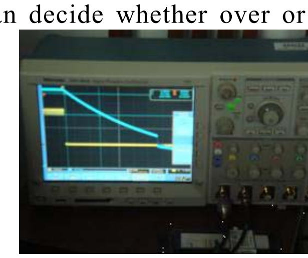

Fig.10: The picture of decay time measurement

We measured the f_π =1292.37MHz, the bandwidth is 5 MHz, after the liquid helium immersed the test cavity. The Q_L is calculated when the reflect power and delay time were measured. Figure 9 shows that when tuned the antenna length of the input coupler to be the coupling β=1, the reflected power of switching on is equal to the power of switching off. We can decide the over or under coupling from the shape of the reflected power. The decay time $\tau_{1/2}$ of the reflected power at switching off is measured.

We keep the saturated vapour pressure to keep the liquid helium temperature by controlling the valve of Vacuum pumped equipment. When the temperature is dropped to 2K, we measure the p_r and p_t at different p_{in}, at the same time record all the datas. For the transimit antenna is not adjustable, the external Q_t factor is constant at that time, we calculated the β, Q_0 and E_{acc} according to the R_s/Q and the following formula:

$$Q_L = \omega\tau_{1/2} / \ln 2$$

$$P_{loss} = P_{in} - P_r - P_t$$

$$\beta_t = \frac{P_t}{P_{in} - P_r - P_t}$$

$$\beta = \frac{1+\sqrt{P_r/P_{in}}}{1-\sqrt{P_r/P_{in}}}$$

$$Q_0 = (1+\beta)(1+\beta_t)Q_L$$

$$E_{acc} = A\sqrt{Q_0 P_{loss}}$$

$$A = \frac{\sqrt{R_s/Q}}{L_{eff}}$$

Where:

ω: rf frequency; τ: delay time; P_{in}: input power at steady condition; P_{loss}: dissipated power of the cavity wall (wall loss); P_r: the reflected power; P_t: the transmitted power; β: coupling constants; β_t: coupling constant of transmit coupler; Q_t: external Q factor of transmit coupler; L_{eff}: effective length of the cavity.

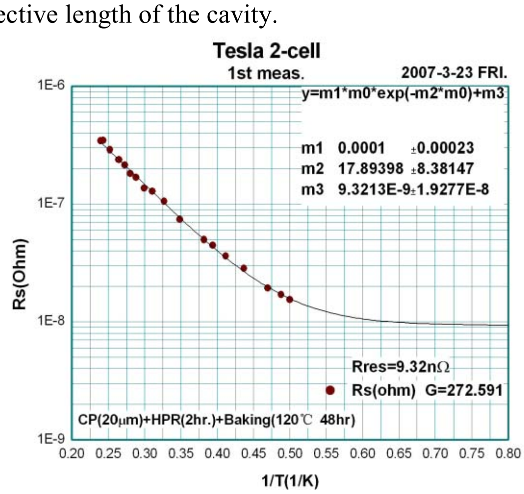

Fig.11 The R_s vs $1/T$ curve

We feed higher power to the cavity until the quench happened at E_{acc}=7.69MV/m. The input power increase a little after repeating several times. Figure 11 shows the curve of residual resistance vs 1/t. At low field , the Q_0 increases when the power increases(see fig.12). Several test ports superposed up and down.

CONCLUSION

In this study, we simulated the 2cell superconducting cavity and learn the relevant distribution of E and B. After carefully surface treatments, we succeeded in the 2k temperature parameter measurements of the superconducting cavity. The E_{acc} is 7.69MV/m, and the Q_0 is $1.2*10^{10}$. We can learn that multipacting occurs in the experiment. It may because of the quality of electron beam welding during processing. The E_{acc} of the cavity maybe rise by using other surface treatment, i.e. electrical polishing and mechanical barrel finishing.

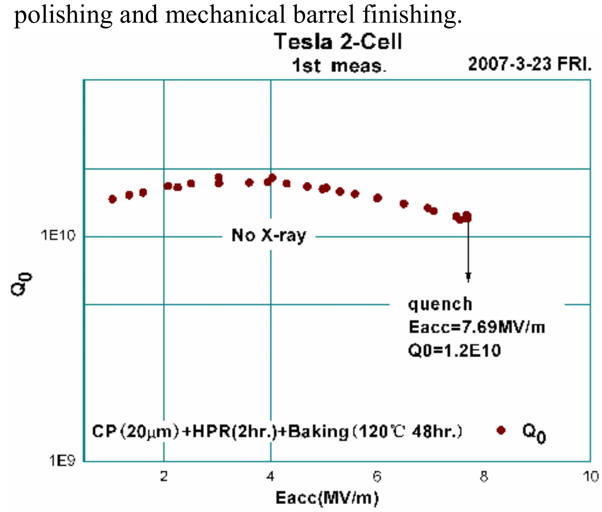

Fig.12: Calculated Q_0 vs different E_{acc}.

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