THE WINDOW REPLACEMENT AND Q RECOVERY OF BEPCII STORAGE RING SCC

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Abstract

Two 500 MHz superconducting cavities (SCC) are adopted in the storage ring RF system for the upgrade of the Beijing Electron Positron Collider (BEPCII): west for the positron ring (BPR); east for the electron ring (BER). The excessive heating of the coupler window for the west SCC was observed in Nov. 2013, and not cured thoroughly. After two years operation, the window cracked suddenly. The in-situ replacement of the window was subsequently implemented. However, the quality factor (Q) of the cavity decayed a lot after the window replacement. An innovative trial, 90 degrees Celsius Nitrogen gas baking of the outer surface of the cavity, was carried out in situ and the cavity Q recovered in a short time. The success provides a possible measure to cure the Q decay of SCC. This paper will present the process of the window replacement and the cavity Q recovery in detail.

INTRODUCTION

The upgrade project of the Beijing Electron Positron Collider (BEPCII) has been in operation since the end of 2006. Two 500 MHz superconducting cavities (SCCs) are adopted in the RF system of the storage ring for BEPCII: west for the positron ring (BPR); east for the electron ring (BER). Each SCC is fed through one power coupler; and each coupler has to deliver a maximum RF power of 135 kW in continuous wave (CW) mode.

The coupler is derived from the power coupler of KEKB 508MHz SCC [1], which features a coaxial disk window with choke structures. However, after 7 years online operation, the excessive heating of the coupler window of the west SCC was observed in Nov.2013, and not cured thoroughly [2]. After two years operation, the window cracked suddenly. The in-situ replacement of the window was implemented subsequently. A new window developed at IHEP was assembled onto the cavity, then received RF conditioning at both room temperature and low temperature respectively. The conditioning reached to a maximum RF power of CW 80 kW in 40 hours. However, the quality factor (Q) of the cavity was found almost two-thirds lower; and the radiation dose was almost one order higher.

An innovative trial, 90 degrees Celsius Nitrogen gas (N2) baking of the outer surface of the cavity, was carried out in situ and the cavity Q recovered in a short time. The success provides a possible measure to cure the Q decay of SCC. This paper will describe the process of the window replacement and the cavity Q recovery in detail.

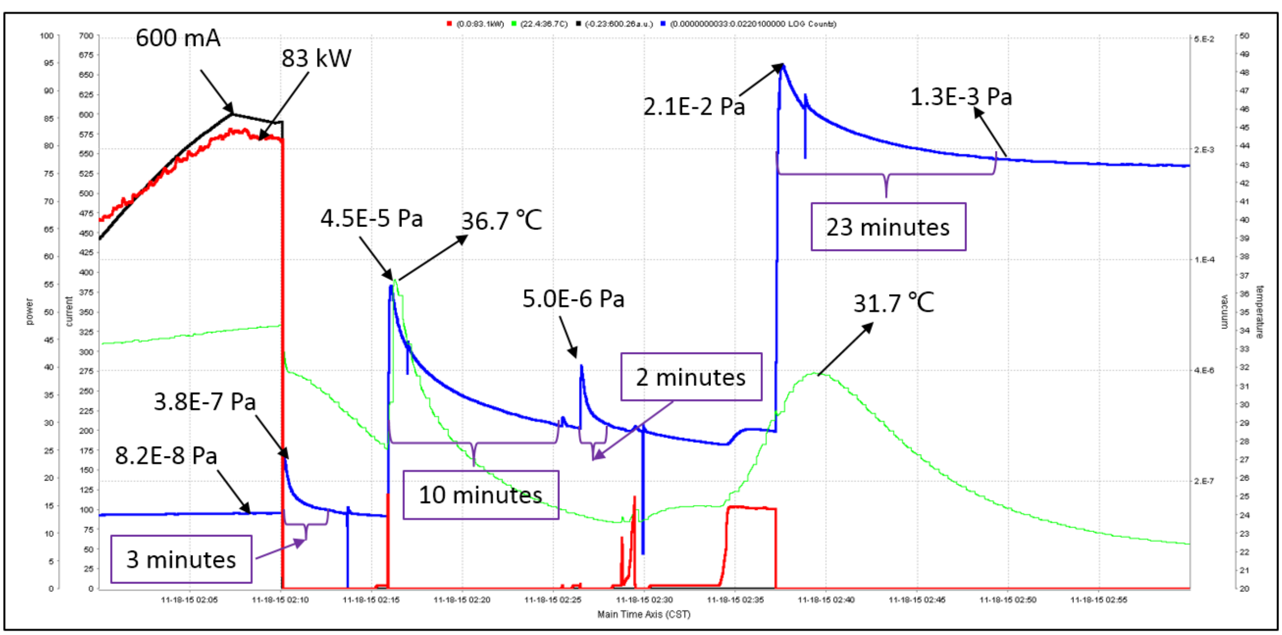

Figure 1: The vacuum pressure and temperature of the cracked window just before the vacuum leak happened. Red: forward RF power (kW); Blue: vacuum pressure of the window (Pa); Green: temperature of the window (℃); Black: Positron current (mA).

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WINDOW CRACK

The power coupler for BEPCII storage ring SCC consists of a doorknob, a Tristan type single warm window and a 50 Ohm coaxial line [3]. After two years overheating operation, the window cracked suddenly on Nov.18, 2015. The vacuum pressure and temperature of the damaged window just before the accident happened are shown in Fig.1. As can be seen that the window operated at 80kW, with accelerating voltage 1.5 MV and positron current 600 mA; suddenly the positron beam lost and the window vacuum pressure changed from 8.2E-8Pa to 3.8E-7 Pa. After vacuum recovery, the operator tried to recover the RF power; however, the window vacuum interlock triggered and the vacuum pressure worsened from 7.6e-8Pa to 4.5E-5 Pa at the power level of 18 kW. One abnormal phenomenon was that the vacuum pressure recovered very slowly; another one was that the window temperature increased obviously, from 28 ℃ to 36 ℃ as the RF power increased to 17 kW. Finally, the vacuum pressure worsened to 2.1E-2Pa as the RF power reached to 15 kW once again.

Since the window vacuum pressure stayed at 1.3E-3Pa, we doubted that fatal damage of the window happened and did the vacuum leak checking step by step. First, the helium gas was injected from the hole on the outer conductor of the airside of the window; and both window and cavity vacuum pressures before and after Helium gas injection was compared. It was found that only the reading of the window vacuum pressure became smaller in value, which indicates that the window may leak. Then, the cavity was warmed up; and the leak checking of the window was processed by helium mass-spectrometer detecting system. The leak rate was 3.0 E-4 mbar.l/s, which proved the window vacuum cracked.

REPLACEMENT OF THE CRACKED WINDOW

In order to save time and manpower, the replacement of the cracked window was processed in a local clean booth in tunnel instead of the standard clean room in laboratory. The sketch map of the replacement is shown in Fig.2. A special designed local clean booth with slide way for window pulling out and plugging in, a removable class 100 clean room and an operating platform were built.

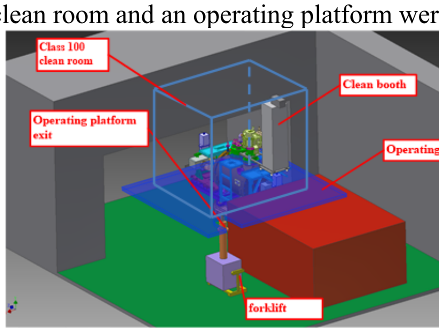

Figure 2: The sketch map of the window replacement.

All the handlings of the window replacement were clean processed to meet the ultra-high vacuum requirements. Fig. 3 lists the entire process. The particles were measured continuously to keep the value down to zero during the key handlings.

- Inflating high purity N2 into the cavity
  - Gas flow 0.5 L/min;
  - Time: 6 hours

↓

- Old window pull out
  - Old window put out from cavity → cavity port covered → old window put into storage container
  - Gas flow 1.5 L/min, keep cavity plus atmosphere;
  - Assure particle value close to zero during handling;
  - Time: 0.5 hours

↓

- New window plug in
  - New window put out from storage container → the cover of the cavity port removed → new window plug in the cavity
  - Gas flow 1.5 L/min, keep cavity plus atmosphere; ;
  - Assure particle value close to zero during handling;
  - Time: 0.5 hours

↓

- Evacuation, leak checking and baking
  - 1.2E-9 mbar.l/s
  - Baking: 145 ℃; 63 hours

Figure 3: The entire process of the window replacement.

The cracked window was later inspected visually as shown in Fig.4. It can be seen that: 1) there is a fish scale ring close to the inner choke; 2) there are three snow figures on the outer conductor of the window vacuum side;3) the surface of the snow figures feels rough; 4) the color of the ceramic turns dark on the whole. All the above characteristics indicate that serious discharging activity happened around the window area. Then we checked the window arc interlock and found that it was disabled. Further study concludes that the fiber was damaged by radiation, which considered the chief culprits of the window crack accident.

Figure 4: The vacuum side of the cracked window.

CONDITIONING OF THE NEW WINDOW

After the replacement, baking of the new window was implemented, with temperature up to 145 ℃ and baking time of 63 hours. A very careful checking of interlocks was processed before the conditioning. Then RF

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conditioning at room temperature (RT) and low temperature was done sequentially. For the RT conditioning, CW and pulse were used alternately, and it took only 26.5 hours with power up to CW 80 kW The main outgasing and discharging happened at the power level of 20~30kW and 50~60kW, as shown in Fig.5. Then the cavity was cooled down to 4.2 K; and the conditioning with and without DC bias voltage, detuned and tuned of cavity was processed in low temperature.

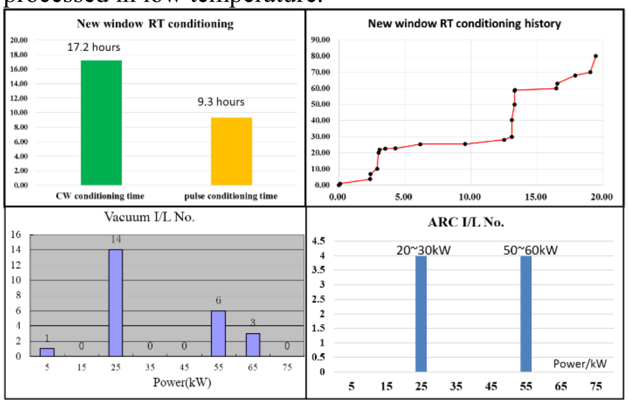
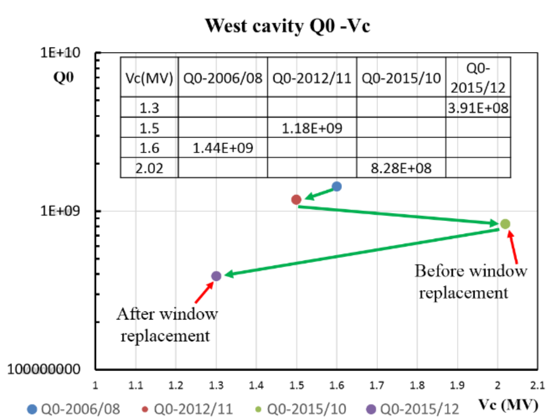


Figure 5: The room temperature conditioning status of the new window.

Q RECOVERY OF THE CAVITY BY HOT NITROGEN GAS BAKING

Unfortunately, the quality factor (Q) of the cavity was found almost two-thirds lower; while the radiation dose was one order higher as shown in Fig.6, which indicated that the cavity was contaminated in the window crack accident.

After sufficient discussion, an innovative trial, hot N2 gas baking of the cavity, was carried out in situ. The hot N2 gas was injected into the helium vessel from the liquid helium inlet pipe and filled the blue space shown in Fig.7, to warm the cavity outer surface and to speed up the outgassing. Considering the coupler and the cavity were sealed by Indium, the temperature of the N2 was controlled below 100 ℃. The baking lasted nearly one week.



Vc(MV)	Q0-2006/08	Q0-2012/11	Q0-2015/10	Q0-2015/12
1.3				3.91E+08
1.5		1.18E+09		
1.6	1.44E+09			
2.02			8.28E+08	

Figure 6: The Q of the west cavity decayed after the window replacement.

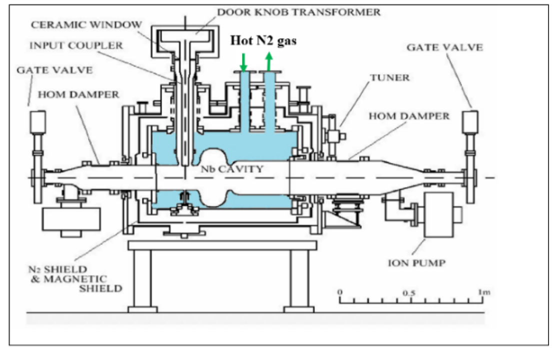


Figure 7: The schematic of the hot Nitrogen gas baking of the cavity for Q recovery: N2 fills the blue space.

The outgassing of west cavity was obvious; and the window vacuum improved from 1.1E-6 Pa to 3.6E-7 Pa at the end of baking. After baking, the cavity conditioning and beam commissioning started. The acceleration voltage (Vc) of the west cavity was increased step by step, while the radiation decreased greatly: from 172 mSv/h at 1.4 MV (before baking) to 5.7 mSv/h at 1.57 MV (after baking). The most exciting effect was that the Q of the west cavity recovered obviously, from 3.91E8 at 1.3 MV to 9.52E8 at 1.5 MV.

CONCLUSION

The power coupler window of the west SCC for BEPCII storage ring encountered cracked during the online operation. Then the replacement of the damaged window was implemented in tunnel. However, the Q of the cavity decayed a lot after the replacement. Then hot N2 gas baking of the outer surface of the cavity, was carried out in situ. After the baking, the Q of the cavity recovered finally. The total process lasted about 2 months and the experience is very valuable for RF people.

By the further study of the window crack reason, one important lesson we learned is that the fiber used for discharging interlock may be damaged by heavy radiation and should be updated at regular intervals.

Now both the new window and the west cavity work well in the beam operation. In April 2016, BEPCII luminosity reached its design parameters of $1\times10^{33}cm^{-2}s^{-1}$ at energy of 1.89 GeV, with RF power of 126 kW and Vc of 1.67 MV.

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REFERENCES

[1] Y.Kijima, S.Mitsunobu, T.Furuya et al. Input Coupler of Superconducting Cavities for KEK-B, EPAC2000.

[2] Tongming Huang et al. Some experiences with BEPCII SRF system operation, Chinese Physics C Vol. 40, No. 6 (2016) 067001-6.

[3] T. M. Huang, W. M. Pan et al, Nuclear Instruments and Methods in Physics Research A, 623: 895-902 (2010).