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High power conditioning of the input coupler for BEPCⅡ superconducting cavity*

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Abstract High power conditioning of the input coupler for BEPCII superconducting cavity has been performed. After room temperature conditioning, the RF power of 150 kW with continuous wave at standing wave mode passed through the coupler without any problem. Meanwhile, a series of methods have also been studied to improve the performance of the coupler during the beam operation. Up to now, the input coupler can feed a RF power up to 100 kW stably with high current of 250 mA at 2.5 GeV.

Key words high power input coupler, high power conditioning, superconducting cavity

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1 Introduction

BEPCⅡ is an upgrade project of BEPC, the Beijing Electron Positron Collider. It is constructed for both high energy physics and synchrotron radiation research. BEPCⅡ as an electron-positron collider has a designed luminosity of 10^{33} cm^{-2}·s^{-1} at 1.89 GeV, which is 100 times higher than the BEPC. To achieve high luminosity, the beam length is compressed from 50 mm to 15 mm, and the beam current is increased from 70 mA to 910 mA. To meet the above requirements, two 500 MHz superconducting cavities (SCC) are used in the BEPCⅡ RF system instead of four 200 MHz normal conducting cavities for BEPC[1]. Meanwhile, an input coupler for the superconducting cavity is demanded to transfer 150 kW power with continuous wave (CW). The coupler is designed on the basis of the KEKB 508 MHz SCC coupler. Considering the difference of the central frequency, some modifications in structure have been made compared with the KEKB coupler, i.e. the height of the upper doorknob has been increased to 97.35 mm[2] (see Fig. 1).

The purpose of high power conditioning is to clean the surface and desorb the condensed gas. Knowing that the electron bombardment is very effective in surface clean, a D.C bias voltage aimed to produce more electron bombardments was applied. This paper describes the status of the room temperature conditioning and the RF processing during beam operation.

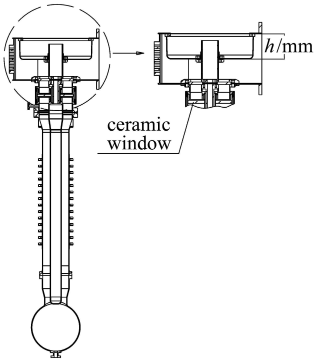

Fig. 1. High power input coupler for BEPCⅡ SCC.

2 Monitoring instruments of the coupler

The ceramic window is equipped with three monitor ports for detecting electron current, vacuum and arc discharge. Several thermocouples are placed on the doorknob and the outer conductor to measure the temperature change. These monitoring instruments

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are very important to prevent a fatal discharge breakdown of the ceramic window and identify the multipacting power levels and positions. The location of the above monitoring instruments is shown in Fig. 2. An interlock system will execute its function to cut the RF power once one of the monitored signals exceeds its interlock level. Table 1 gives their interlock levels.

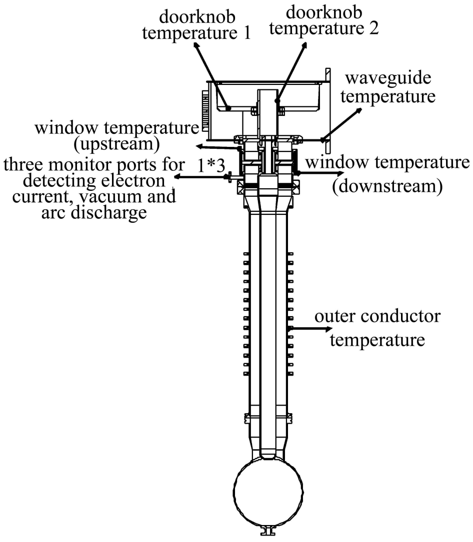

Fig. 2. Distribution of various monitoring sensors.

Table 1. Interlock levels of various monitored signals.

monitored signals	interlock levels
electron current/μA	<5
window vacuum/Pa*	$<3\times10^{-5}$
cavity vacuum/Pa*	$<3\times10^{-5}$
doorknob temperature 1/℃	<80
doorknob temperature 2/℃	<80
waveguide temperature/℃	<60
window temperature (upstream)/℃	<60
window temperature (downstream)/℃	<60
outer conductor temperature/℃	<62

∗Interlock levels of vacuum pressure at the window and cavity were set to 5×10^{-6} Pa without D.C bias voltage. With a D.C bias voltage applied, both of them were reset to 3×10^{-5}Pa due to a large amount of gas desorption.

3 Conditioning at room temperature

3.1 Conditioning without D.C bias voltage

The preliminary testing had been carried out at KEK using a high power test stand. Since the coupler was exposed to air when assembled into the cryomodule, high power conditioning again was necessary. Starting with gradual increment of the RF power, 150 kW with CW and full reflection was reached without any problem. As seen in Fig. 3, the conditioning was very difficult and the time up to 40 kW was 45 hours due to serious vacuum burst or arc discharge. The number of monitoring sensor-initiated triggers is shown in Fig. 4. As found in Fig. 5, the electron current and vacuum burst occurred frequently between 30 kW and 50 kW, which suggests that the above power range is a multipacting effect power band. Both of them also appeared almost simultaneously. This proves that the electron bombardment is effective in gas desorption. Actually, the bombardment helps to clean the surface and reduce the secondary electron emission coefficient (SEC) below unity, so a kind of "soft" barrier multipacting effect[3] (not caused by the coupler structure itself) can be eliminated successfully. Moreover, it can be found that the arc discharge happened at the lower power levels. Since the arc sensor is located near the ceramic window and the discharge mainly resulted from the multipacting effect[4], we suppose that the multipacting effect near the ceramic window happens at lower power levels.

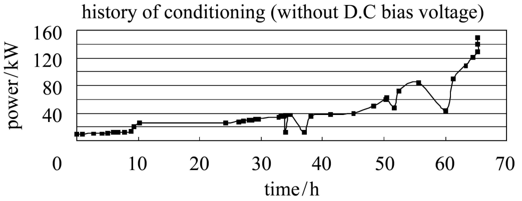

Fig. 3. History of conditioning.

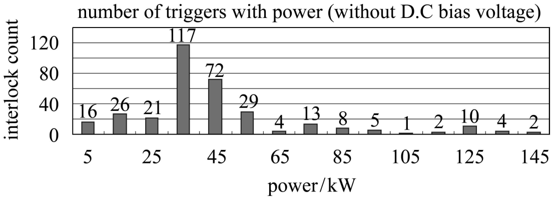

Fig. 4. Number of triggers as a function of power.

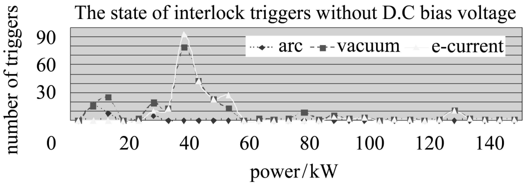

Fig. 5. State of interlock triggers.

3.2 Conditioning with D.C bias voltage

Conditioning without D.C bias voltage is limited to the area of the nodes of the standing waves[4]. A D.C bias voltage applied between the inner conductor and the outer conductor can be used for expanding the conditioning area. It can also excite a new type of one-point, one-order multipacting effect on the inner conductor, which is very stubborn and its power band is the broadest[5]. So conditioning with D.C bias voltage can produce more electron bombardments.

As mentioned above, the electron bombardment was quite effective in gas desorption, a D.C bias voltage was applied after the conditioning with full reflection power of 150 kW. We first increase the bias voltage up to +2000 V, and then decrease it down to −2000 V, both in steps of 100 V. For each voltage level, we increase the RF power up to 150 kW, passing slowly through all the power levels. The arc, electron current and vacuum burst reappeared in several power levels. The change of the vacuum pressure is illustrated in Fig. 6. In the bias voltage between +200 V and +800 V, vacuum burst happened frequently, especially in lower power levels. However, as the voltage reached +1000 V, nearly no vacuum burst appeared. When it came to the minus bias voltage, the electron current and vacuum burst became more serious. Especially for the bias voltage below −1600 V, the electron current was so heavy that the conditioning had to be stopped for a while for the recovery of the vacuum. Finally, the RF power passing through the coupler reached 150 kW at standing wave under ±2000 V without any interlock trigger. From the following horizontal test of the SCC and the beam operation, the room temperature conditioning was proved to be very effective in eliminating the "soft" barrier multipacting effects (not caused by coupler structure itself) before the coupler was used under real conditions.

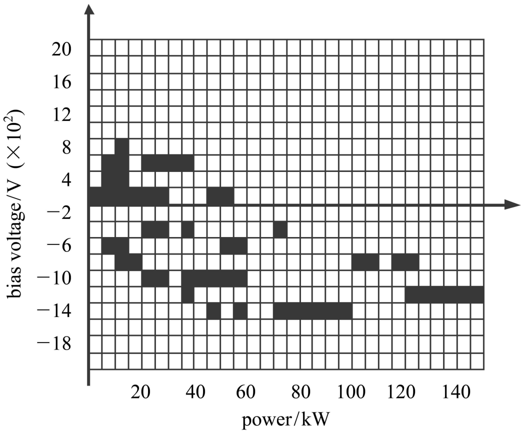

Fig. 6. Change of vacuum pressure during the D.C bias voltage conditioning (the filled blanks indicate the vacuum pressure increasing).

4 RF processing in beam operation

In the beam operation, as the beam increases, the RF field in the coupler changes from the standing wave to partial reflection, even to the traveling wave. The change of the field expands the conditioning area and may bring more positions satisfying the multipacting effect resonance condition. Furthermore, when the beam passes through the cavity, a lot of gas leaks into the coupler and condenses on the surface, which increases the SEC of the coaxial line surface above unity. So multipacting effect reappeared in the coupler, especially for the beam current over 200 mA at 2.5 GeV. A series of methods have been tried to improve the vacuum inside the coupler, such as tuning the reference phase of the frequency-control-loop to move the nodes of the standing wave, applying D.C bias voltage to suppress the multipacting effect and so on. Up to now the SCC has been operated under a beam current of 400 mA at 1.89 GeV in collision mode and 250 mA at 2.5 GeV in synchrotron radiation mode, which means the input coupler can transfer a RF power up to 100 kW stably with high current. This is the highest CW RF power passing through the input coupler of SCC under real beam operation in domestic accelerators.

5 Summary

Through the conditioning at room temperature, most of the so-called "soft" barrier multipacting effects inside the input coupler have been eliminated and the distribution of them has been found. The room temperature conditioning with D.C bias voltage was effective for gas desorption. We also have tried to apply a D.C bias voltage to suppress the multipacting effect during the beam operation, which seemed to be helpful to improve the coupler performance. We will further optimize the high power conditioning process and study how to further ensure the safety of the ceramic window in higher power levels and beam currents, such as optimizing the D.C bias voltage, applying and adding more effective monitoring instruments.

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