Horizontal Test for BEPCII 500MHz Spare Cavity

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Abstract: The horizontal test for BEPCII 500MHz spare cavity has been completed in IHEP. The max voltage of the cavity is 2.17MV, $Q_0$ is $5.78 \times 10^8$. This paper mainly reports coupler aging parameters before the horizontal test, as well as the parameters during cool-down the change of frequency, loaded $Q$, vacuum and the deformation of the cavity with temperature. And the test results were analyzed.

Key words: horizontal test, spare cavity, 500MHz cavity

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1. Introduction

A 500MHz superconducting cavity was fabricated at IHEP in 2011. After completion of assembly, a horizontal test is carried out for the spare cavity in IHEP. The spare superconducting cavity is the first 500MHz spare superconducting cavity of BEPCII. All key parts of the cavity were made in China. The performances of the spare cavity exceeded the design values. The max voltage of the cavity is up to 2.17MV.

2. Structure of spare cavity

The BEPCII spare superconducting cavity consists of niobium cavity, cryostat, high power input coupler, tuner and high-order mode absorber. The spare superconducting cavity structure is shown in figure 1. Superconducting cavity assembly was done by the Institute of high energy physics researchers independently.\textsuperscript{[1]}

![Figure 1: The structure of cavity](image)

3. Test stages

Room temperature

After completing the assembly of the cavity, the cavity was transported to the horizontal test room, where the high...
power horizontal test was done. The horizontal test is an overall test of the cavity without a beam. The process of the test is as follows:

Check all the interlocks to confirm that all the signal equipment works well. The interlocks are shown in table 1.

| Interlocks       | Fast lock | Normal lock |
|------------------|-----------|-------------|
| Coupler Vacuum   | Cooling Water |            |
| Cavity Vacuum    | Air Flow  |             |
| Arc              | Gas Flow  |             |
| Quench           | He Level  |             |
| P+               | He Pressure |           |
| Temperature      |           |             |

Table 1: Interlocks

Tuner test: At the room temperature, the tuner performance is tested. It is the most important test at the room temperature. The tuner of the spare cavity is composed of a main motor and a piezoelectric oscillator. The main motor has a large stroke, while the operation is slow. On the other hand, the piezoelectric oscillator has a small stroke and a fast operation. If there are something wrong with the tuner, it is found at this stage. For the tuner of BEPCII spare cavity, it was found that the movement was smooth.\(^1\)

Coupler test and aging: Operation of the tuner was performed in order to detune the cavity, then aging of the coupler was performed. The results of the coupler aging is shown in figure 2(a). This figure shows the aging of coupler from October 1st to 3rd. The max input power exceeded 106KW, which is also the total reflected. The coupler was preheated before aging to avoid cracking of the coupler window. Both pulsed and continuous waves were applied repeatedly as this method can save aging time and improve safety performance. The first aging condition of the cavity vacuum is \(2.2 \times 10^{-6}\) pa, and the coupler vacuum is \(4.74 \times 10^{-6}\) pa; The second aging condition of the cavity vacuum is \(8.2 \times 10^{-7}\) pa, and the coupler vacuum is \(1.64 \times 10^{-6}\) pa; The third aging condition of the cavity vacuum is \(7.1 \times 10^{-7}\) pa, and the coupler vacuum is \(1.18 \times 10^{-6}\) pa.

During test, the number of interlocks caused by Arc, coupler vacuum, cavity vacuum is shown in figure 2(b). From figure 2(b) we know when aging the coupler at low input power, interlock protection almost caused by cavity vacuum. In high input power, interlock protection were almost caused
by coupler vacuum. Arc mostly happened between 19kw and 43kw, and between 75kw and 87kw.\[2\]

**During cool-down**

During cool-down, the frequency and the loaded Q value of the spare cavity were monitored with a network analyzer every few hours. Figure 3(a) shows the result of the frequency and loaded Q change during cool-down.

Figure 3(a) shows during cool-down the frequency of spare cavity increases. The loaded Q of the cavity also increases. After the cavity temperature reached 80K, the loaded Q increased quickly. At 4.4K the loaded Q of the spare cavity is $1.3 \times 10^5$, and the frequency is 499.507MHz.

![Temperature Curve](image)

Figure 3: (a) The frequency and loaded Q; (b) The change of vacuum during cool-down; (c) The time profile of cavity temperature during cool-down; (d) shrinkage of spare cavity

Figure 3(b) shows that the vacuum of the cavity, coupler, SBP, LBP are all very well. There was no evidence of vacuum leakage during cool-down. From figure 3(c) shows the time profile of the cavity temperature during cool-down. In the first 20 hours the cool-down rate was about 0.91K/hour, which was intentionally very slow to avoid vacuum leakage. In the next 40 hours, the cool-down rate was about 6.8K/hour.\[1\]

In order to analyze the shrinkage situation of the spare cavity, two displacement meters were respectively
installed on the SPB and LBP ends, before cool-down. As shown in figure 3(d), we can see that during the cavity temperature decrease from 300K to 215K, SBP end shrinkage was about 0.752mm. After that, the displacement did not change anymore. The LBP ends displacement changed, during the entire cool-down process, was about 1.438 mm, larger than SBP ends shrinkage.

4.4k

After the cavity temperature decreased to 4.4K, operation of the tuner demonstrated the resonant frequency of the cavity 499.8MHz. During the tuning process through network analyzer observed the change of cavity frequency with load as shown in figure 4. From figure 4 can see that the cavity frequency has a linear relation with load, and the cavity of the elastic coefficient is 1KHz/kg.

4.4k

4.4k

4.4k

4.4k

4.4k

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4.4k

4.4k

4.4k

4.4k

4.4k

4.4k
over 1.5MV, while in vertical test the $Q_0$ declined slowly when the cavity voltage was over 2MV.

Before testing, radiation instruments has been installed at SPB, LBP ends and side of cryostat. Figure 5(b) shows that the radiation is very low when spare cavity voltage is between 0 and 1MV. When the cavity voltage increased over 1MV, the radiation level increased quickly. The radiation level is higher in Axial than in Transverse, with values of 197msv and 76msv respectively.

Table 2: BEPCII Spare Cavity main parameters

| Vcc (Max)          | 2.17MV |
|--------------------|--------|
| $Q_0$              | $7.67 \times 10^8$ (2.0MV) |
| Work frequency     | 499.8MHz |
| Frequency (@4.4K, free Load) | 499.507MHz |
| QL                 | $1.33 \times 10^5$ |
| Static heat leakage| 41W    |
| Coupler Power (Total reflection) | 100KW |
| Mechanical frequency| 46Hz  |

As shown in table 3, spare cavity performance is superior to the East cavity, but lower than west cavity.

Table 3: BEPCII Spare Cavity main parameters

| Voltage (MV) | $Q_0$         |
|--------------|---------------|
| Spare cavity | $2.05$ $7.67 \times 10^8$ |
| East cavity  | 2.0 $5.45 \times 10^8$ |
| West cavity  | 2.05 $9.5 \times 10^8$ |

4. Conclusion

1. BEPCII 500MHZ $Q_0$ value is $5.78E+8$ at 2.17MV, exceeding the design requirement that cavity $Q_0$ value not be less than the requirements of $5.0E+8$ at 1.5MV.

2. The spare cavity $Q_0$ in the horizontal test was lower than that in the vertical test. When cavity voltage was over 1.5MV, $Q_0$ decreased greatly, and the radiation level rose substantially. These results suggest that pollution may have entered the superconducting cavity compromising the inner surface of the cavity during the cavity assembly process. The cavity performance would be further improved with aging time[4].

3. BEPCII spare superconducting cavity’s frequency is 499.507MHz at 4.4K free load condition. When load is 295kg, the frequency of the spare cavity is 499.8014MHz, without compensating springs. Superconducting cavity processing, polishing, and assembly would impact the cavity frequency, but at all stages we could control the frequency in a Proper value. This shows that in the manufacturing process of the superconducting cavity, we have had bigger breakthrough.

5. Acknowledgement

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