PERFORMANCE OF TESLA CAVITIES AFTER FABRICATION AND PREPARATION IN INDUSTRY

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Abstract

In order to demonstrate cw operation of TESLA cavities in a linear accelerator driven FEL application, two TESLA cavities were manufactured for BESSY. After production, both cavities were prepared for vertical test at ACCEL's premises using state of the art chemical polishing and high pressure water rinsing techniques. The cavities were tested in DESY's vertical RF test installation. Accelerating gradients close to 25 MV/m were reached. One cavity was completed with helium vessel modified for cw operation, prepared with chemical polishing and high pressure water rinsing and assembled with the required high power coupler at ACCEL. The fully dressed cavity was then shipped under vacuum to BESSY and is currently under test in the horizontal cryostat HoBiCaT.

PREPARATION OF CAVITIES FOR VERTICAL TEST

The two TESLA cavities were produced within 6 months after provision of niobium. Directly after final welding, the field flatness was measured being >60 %. The cavities received removal of 30 µm of material from the outer and 120 µm from the inner surface by buffered chemical polishing (BCP 1:1:2) and were shipped to DESY for 800 °C heat treatment.

The chemical treatment of the cavities is done in a closed loop chemistry plant. During the etching process, the acid is cooled constantly to temperatures below 15 °C. After etching, the cavity is rinsed continuously with deionized water until the resistivity of the water reaches values above 17 MΩcm. The cavity is installed in our high pressure rinsing installation located inside a clean room.

In order to allow high pressure rinsing of TESLA cavities, a new high pressure water rinsing system was installed in a class 100 cleanroom. Figure 1 shows one of the cavities during high pressure rinsing. The preparation of the cavity was done with the goal to do it as much as possible identical to the recipe developed at DESY within the TESLA collaboration. In detail, the following steps were performed after the cavities returned from the heat-treatment at DESY:

- Leak-check and dimensional control
- Tuning to field flatness (> 95%)
- Degreasing
- 20 µm removal from the inner surface by closed loop BCP (1:1:2)
- High pressure (100 bar) water rinsing for 3 hours
- Drying by pumping
- Venting with ultra pure filtered nitrogen
- Assembly of all flanges except the lower beam pipe flange
- High pressure water rinsing for 3 additional hours
- Drying by pumping
- Venting with ultra pure filtered nitrogen
- Assembly of vertical test antenna
- Pump down and leak-check
- Transport under vacuum to DESY for cold RF test

The transport to DESY for the vertical test was done with the cavity hanging in vertical direction to not harm the delicate test antenna. After arrival at DESY, the cavity was mounted into the vertical test insert, leak checked and put into the vertical cryostat. Figure 2 shows the cavity after installation into the test insert.

Figure 1: TESLA cavity during high pressure water rinsing at ACCEL. The high pressure water rinsing system is installed in a class 100 clean room.

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Figure 2: TESLA cavity assembled to the vertical test stand at DESY

VERTICAL TEST RESULTS

The two TESLA cavities produced for BESSY were named BE1 and BE2. Cavity BE2 was tested first and tested two times. Cavity BE1 was only tested once. For the first test of cavity BE2, the cavity was not shipped under vacuum, but shipped vented with nitrogen. During the pump-down at DESY, accidentally a valve was opened too fast and the cavity was not evacuated in the laminar flow region, but much faster (within 5 minutes). This was the reason, we decided for later tests to ship the cavity under vacuum. Also cavities prepared at DESY leave the clean room under vacuum and are installed in the test insert being evacuated.

The first RF test of cavity BE2 is shown in Figure 3. The low field Q of the cavity was $2{\cdot}10^{10}$ and within the expectations but field emission was present starting from fields around E_{acc} = 10 MV/m. Finally at 16.8 MV/m, the cavity Q dropped to about $1{\cdot}10^{9}$ and the cavity was limited by field emission.

After a new preparation of the cavity and a transport under vacuum, the performance of the cavity was greatly enhanced. An accelerating gradient of 23.5 MV/m was achieved with the quality factor of the cavity being $6{\cdot}10^{9}$ (see Figure 4). Up to a field of 21 MV/m the Q of the cavity was above $1{\cdot}10^{10}$. The cavity still had some field emission, indicated by observation of moderate amount of x-rays.

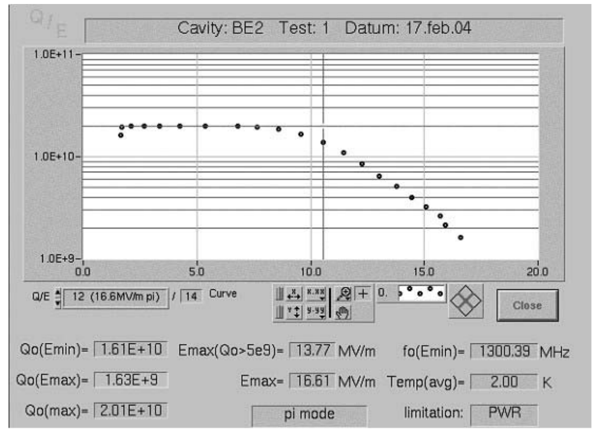

Figure 3: First test of cavity BE2. Field emission limited the cavity to about 16.8 MV/m.

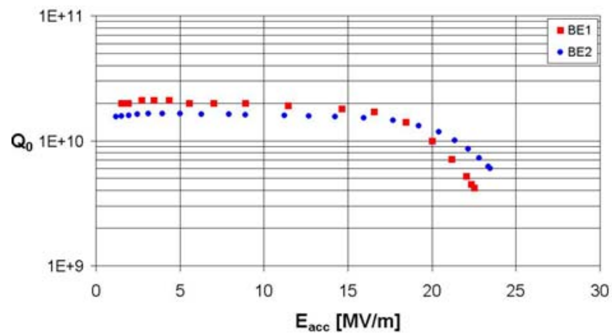

Figure 4: Test results of cavity BE1 and BE2. Fields above 20 MV/m with Q higher than $1{\cdot}10^{10}$ were reached. At the highest fields some field emission was observed. Both cavities were checked for Q-disease and proven to be Q-disease free.

The next step was to check the cavity against Q-disease. The cavity was warmed up to room temperature and cooled down again. During cool down, the cavity was kept for 70 hours in the temperature zone between 80 K and 125 K. The performance of the cavity was identical to that measured before the slow cool down, proving that the cavity does not show Q-disease.

The result of the measurement on cavity BE1 is also shown in figure 4. The cavity reached 23 MV/m with the Q slightly above $4{\cdot}10^{9}$ already after the first preparation. The cavity Q stayed above $1{\cdot}10^{10}$ up to a field level of E_{acc} = 20 MV/m. Also this cavity was checked against Q-disease. No difference in cavity performance was measured before and after the slow coold own and parking the cavity in the temperature zone between 80 K and 125 K.

In order to compare the results of cavities prepared at our facilities and cavities prepared at DESY, we have plotted in Figure 5 the results of the BESSY cavities together with results published in the TESLA TDR. The performance of the BESSY cavities are slightly lower and show in contradiction to the DESY cavities some field emission. However, the difference between the cavities are not high and the BESSY cavity results encouraging.

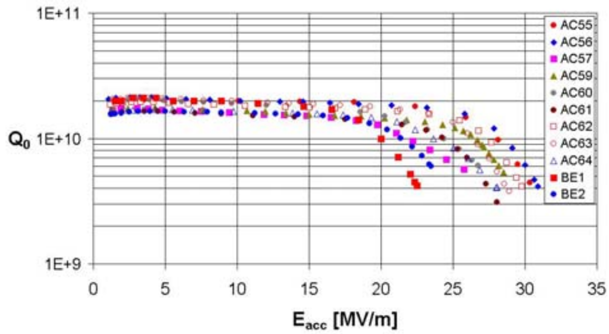

Figure 5: Comparison of cavities prepared at ACCEL for BESSY and cavities prepared by DESY (published in the TESLA TDR). BESSY cavities received 800 °C heat treatment, DESY cavities received 800 °C and some additional 1400 °C heat treatment.

PREPARATION FOR HORIZONTAL TEST

After successful vertical test, cavity BE2 was furnished with the helium vessel. In detail we performed the following preparation steps:

- Electron beam welding of titanium bellow section on one side and titanium ring on the other side to the conical NbTi discs of the cavity
- Tuning to field flatness and correct frequency
- TIG welding of helium vessel; this work was done at DESY.
- Check of the filed flatness after helium vessel welding being slightly below 95 %.
- Adjustment of HOM antennas and HOM couplers to achieve an external Q of the fundamental mode of > $5{\cdot}10^{11}$
- 20 μm removal from the inner surface by closed loop BCP (1:1:2)
- High pressure (100 bar) water rinsing for 3 hours
- Drying by pumping
- Venting with ultra pure filtered nitrogen
- Assembly of pick-up, HOM antennas and one beam pipe blind flange
- High pressure water rinsing for 3 additional hours
- Drying by pumping
- Venting with ultra pure filtered nitrogen
- Assembly of cold part of high power coupler and all metal valve to other beam pipe flange
- Pump down and leak-check
- Transport under vacuum to BESSY for cold horizontal RF test in HoBiCaT

Figure 6 shows one of the two TTF III style couplers produced for BESSY. After production and prior the assembly to the cavity, the couplers were conditioned on a test stand at DESY. After approx. 50 h of conditioning the power couplers reached the design values. The fully dressed cavity ready for cold horizontal RF test is shown in Figure 7. Unfortunately the horizontal RF test at BESSY is somewhat delayed and test results can not yet be presented.

Figure 6: TTF III style power coupler produced for BESSY.

Figure 7: TESLA cavity for BESSY furnished with helium vessel, HOM couplers and input coupler. The cavity is prepared for cold horizontal RF Test in the HoBiCaT cryostat. The second cavity installed into the transport frame is shown in the left.

CONCLUSION

Application of preparation technologies developed at DESY for the TESLA cavities in industry lead to comparable performance. Field levels and Q values needed for FEL-linac applications in the range of 15-20 MV/m are safely reached.