Experiment on the first prototypes of pipe cooled 500 MHz cavities from explosion bonded niobium copper

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Summary

Superconducting pipe cooled cavities made from composite material offer several advantages compared to conventional bath cooled cavities /1 - 3/. Since pipe cooled cavities do not experience pressure variations in the He-system the stability of the resonance frequency is improoved. This is the more important the higher the loaded Q of the cavity is.

The He-volume in the cryogenic system is drastically reduced as compared to bath cooling. This is especially favourable for large scale applications like in HERA out of safety considerations. Pipe cooling leads to a simplificatin of the cryogenic equipment.

After first experiments on a pipe cooled 1 GHz single cell silver electro-plated cavity which prooved the feasibility of that cooling design, a joint development program between DESY and Interatom on 500 MHz pipe cooled cavities was started.

Basic considerations

Niobium cavities can also be cooled by an arrangement of cooling pipes attached to the outer surface of the cavity instead of immersing the whole cavity in a bath of liquid helium. To keep the number of pipes small an additional layer of high thermal conductivity metal is needed to produce transverse heat flux especially for cavities with large surfaces (350 MHz, 500 MHz). As shown by computer simulation /4 - 5/ only a few cooling pipes per cavity are necessary. The number of pipes depends on the thickness and thermal conductivity of the metal layer. Taking OFHC-copper with a thermal conductivity of 350 W/m/K at 4.2° K and a thickness of 2.5 - 3.0 mm, 4-6 pipes per cell are necessary for a 500 MHz cavity to keep the decrease in quality factor below 10 % at a field level of 5 MV/m.

For the first 500 MHz single cell prototype Nb-sheet material of 2.5 mm thickness and RRR > 100 and OFHC-copper sheet material of 3.0 mm was used.

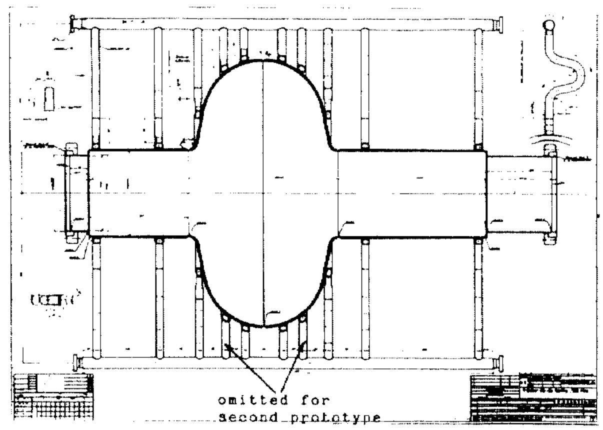


Fig. 1: Basic layout of a single cell cavity with 6 cooling pipes attached to the cell. The second prototype cavity was built with only 4 pipes on the cell, the marked pipes where omitted.

Fabrication of copper plated Nb-cavities with cooling pipes

The first step in the production sequence is to explosively clad the niobium and the copper to a compound sheet. The explosion process can either be done under vacuum in dedicated chambers, in air or using an inert gas between the plates during the explosion process.
Both methodes - vacuum and air - have been used to produce explosion bonded Nb-Cu-sheets. The shear strength of the bonding zone was measured to be about 170 N/mm² which is higher than the shear strength of the copper material itself (150 - 160 N/mm²).

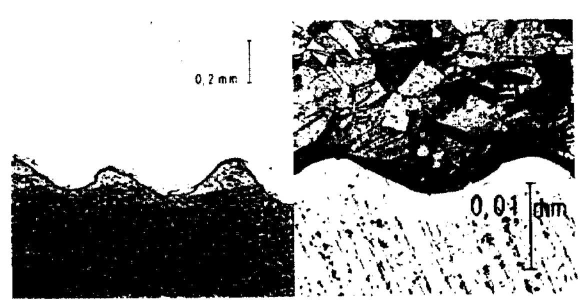


Fig. 2: Bonding-Zone of specimen of copper (upper part) and Niobium left specimen explosion bonded in air. Right specimen explosion bonded under vacuum.

The explosion bonding did not affect the qualtiy of the niobium and the copper material. RRR-values and thermal conductivities have been measured and remained unchanged.

After an ultrasonic test of the compound sheets the half cells of the cavity were formed by a spinning process. The cut-off-tubes were rolled. Ultrasonic testing was applied before and after a cooling cycle in liquid nitrogen. No difference in bonding quality was observed before and after spinning and after the cooling cycle.

For eb-welding of the cavity the copper is machined off the niobium leaving a 4 mm gap for the Nb-seam.

Attachment of the copper pipes can either be done by UHV-brazing the pipes to the copper layer or by electron beam welding. The brazing process needs a sufficient vacuum ($p < 10^{-5}$) not to lower the thermal conductivity of the niobium by contamination. The eb-welding on the other hand needs a good adjustment of the tubes to the cavity with low tolerances to end up with a good quality seam. Both methods have been prooved to be reliable.

The last step is the completion of the piping system by connecting the pipes of the cell and the cavity cut-off-tubes with the LHe-distribution and gas collection pipe.

Before shipment to DESY for rf-test the standard preparation steps for a superconducting cavity consisting of

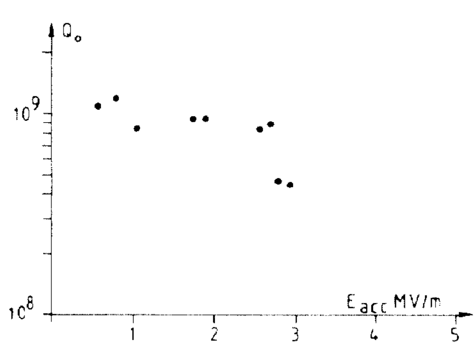
- tumbling
- chemical polishing
- rinsing with ultrapure water
- mounting under dustfree conditions

were performed.

<u>Test results</u>

- Cavity # 1

The first prototype was built according to figure 1. It was measured in March 1987 in a horizontal cryostat at DESY and reached an accelerating field of 3.3 MV/m with a qualtiy factor of $1.1 \; 10^9$ at 4.2 K (low field).

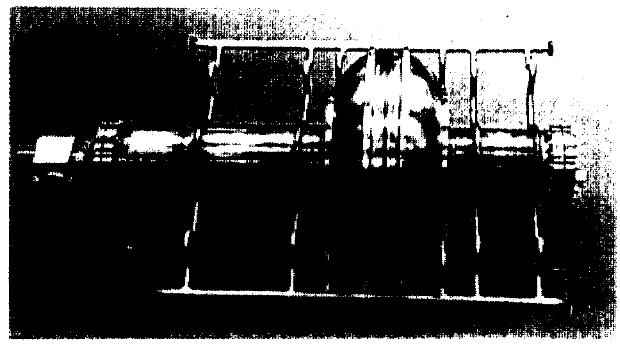


The field was limited by a quench. The quench-location was detected after opening of the cavity near the iris in a region which showed increased temperatures during the test measured with a fixed resistor network.

Regions with disbonded copper were detected near the iris after dismounting. Those observations led to an improved fabrication technique.

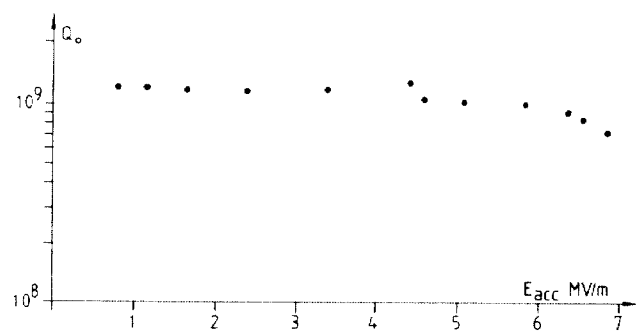
- Cavity # 2

The second prototype was built with only 4 cooling pipes attached to the cell (cmp figure 1).



After standard preparation it was shipped to DESY under vacuum where it was tested in a horizontal cryostat in June 1988.

The preliminary test results given below were taken immediately before this conference and measurements are still going on.



The figure above shows the initial measurement where a field of 7 MV/m was reached within the first minute without He- or rf-processing. No electron loading was observed during increase of field. The field was limited by a quench. A radiation level of 2.5 rem/h was observed the cryostat at quench field level.

The Q_o ($T \geq 4.2$ K) measured at the beginning of the cold test was $1.2 \; 10^9$ and degraded slowly during the test well below 10^9. In a warm-up cycle the cavity-vacuum reduced from 10^{-7} mbar to 10^{-3} mbar which is assumed to be due to absorbed gases on the cavity surface resulting from a leak in the pumping system the cavity is connected to. It is planned to find and remove the leak and to continue measurements with a second cold test.

The pipe-cooling-system showed the capabiltiy of cooling 40 Watt of rf power without problems and thus the feasibility of this cooling concept.

Quench location, measurments on temperatures across the cavity, He-processing will be the next steps in the experiment with that cavity.

Acknowledgements

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