FIRST RF TESTS IN THE HOBICAT SUPERCONDUCTING TEST FACILITY AT BESSY *

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Abstract

In preparation for the construction of the BESSY-FEL User Facility, BESSY recently completed the installation of the HoBiCaT cryogenic test facility for superconducting RF (SRF) TESLA cavity units [1], including all ancillary devices (helium tank, input coupler, tuner, magnetic shielding). It is designed to house two such units in a configuration similar to that envisaged for the superconducting CW linac of the BESSY FEL. Commissioning of the facility is now complete and the first TTF-III RF coupler and cavity unit has been tested. In particular, the complete production, cleaning and assembly of the cavity unit was carried out by industry. These tests thus serve as a first step at qualifying industrial partners for series production of such systems, which will be essential for the future construction of SRF based light sources.

EXPERIMENTAL WORK

HoBiCaT

The first cavity to be tested at HoBiCaT, see Figure 1 was a TESLA-type 9-cell mounted into a titanium liquid Helium tank. Deviating from the original design this tank has wider Helium supply pipes, in order to accommodate the increased heat load during CW operation as opposed to pulsed operation. The coupler position is observed from within HoBiCaT with an Allnet ALL2200 Ethernet camera. A VKL 7811ST klystron supplies the coupler with up to 10 kW of CW RF-power. A three stub tuner increases the available coupling range by a factor of 10. The facility is equipped with multiple thermocouples, thermoresistors, pressure sensors, etc., which are being constantly recorded during operation with a Labview interface.

Q measurements

An important parameter characterizing the cavity is the quality factor Q_0, which is a measure for the ability of the cavity to store energy at its resonant frequency ω_0. A Labview routine was devised, to measure Q_0 automatically. As can be seen in Figure 2, the quality factor is significantly increasing on cooling the cavity down to lower temperatures. Note that no saturation of Q_0 was observed down to 1.5 K, which hints at a sufficient magnetic shielding of the cavity, better than 5 mG. There are two shields in HoBiCaT, one warm shield at the diameter of the vacuum vessel and one cold TESLA-style cryo-perm shield.

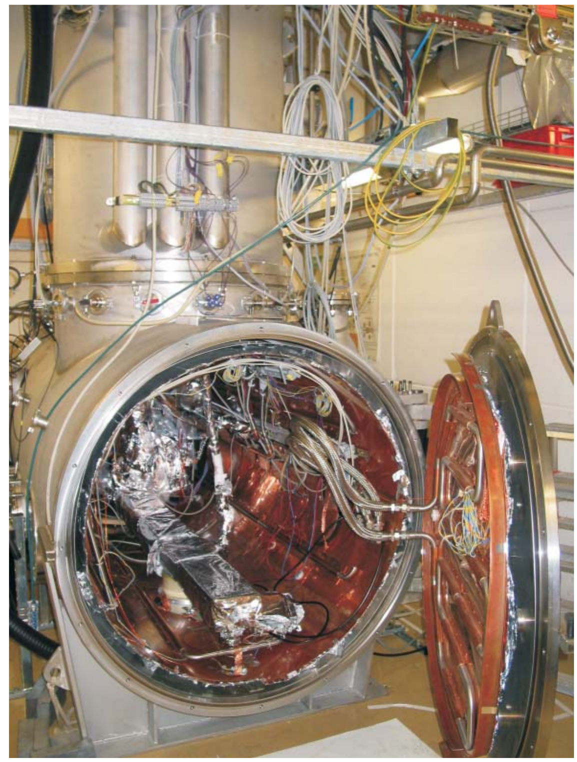

Figure 1: The HoBiCaT facility

Field emission can significantly decrease Q_0 at higher field-gradients. The first Q_0 measurements, Figure 3, yield a value of $1.8 \cdot 10^{10}$. At field gradients greater than 7 MV/m Q_0 starts to decrease exponentially.

Cryogenic issues

The onset of the Q_0 decrease in dependence of the field gradient is accompanied by an increased thermal load on the exit flange of the cavity. As can be seen from Figure 4, its temperature is constantly rising during high-power operation. The Helium flow is increasing accordingly. After turning off the RF, the temperature drops only very slowly, despite manually increased Helium flow rates. This hints at an insufficient cooling of the exit flange. Clearly the cooling of the beam-tube is limited and there is the danger of quenches (e.g. of the HOM pickup tip) in this situation.
Our assumed explanation for the heating is that field-emission electrons have been created within the cavity. Those electrons follow the electric field gradient and are accelerated towards the exit flange where they are being

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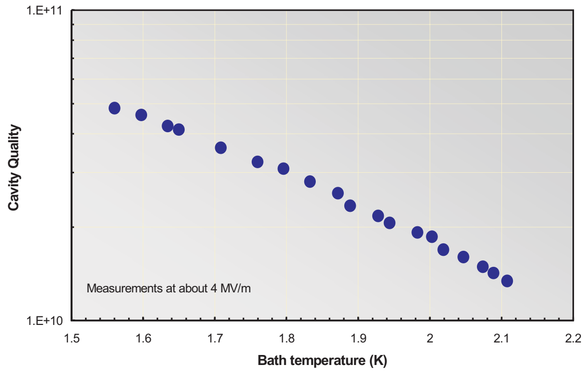

Figure 2: Quality factor Q_0 vs. temperature. Cooling down yields a higher quality factor or lower bandwidth of the electromagnetic field inside the cavity.

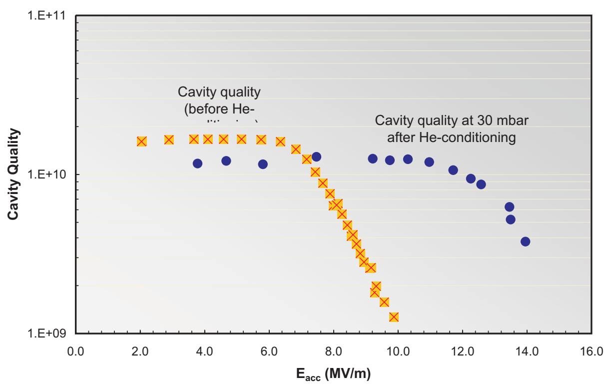

Figure 3: Measurement of the quality factor (yellow squares) yielded a zero-gradient value for Q_0 of $1.8 \cdot 10^{10}$, and a field-emission onset of Q_0 of 7 MV/m. By Helium conditioning (blue circles) the onset field-gradient could be raised to 12 MV/m, while the zero-gradient value of Q_0 dropped to $1.1 \cdot 10^{10}$.

absorbed, creating heat. As this process involves a cascade reaction one would expect elevated radiation levels of Bremsstrahlung and neutrons, which was also observed in our measurements.

He conditioning

In order to increase the critical field-gradient, cavity and He-tank were shipped back to ACCEL for an additional HPR (**H**igh **P**ressure water **R**insing) treatment. Unfortunately this did not improve the achievable field significantly. It was therefore decided to process the emitter with He conditioning. In this process, as described in [2], the cavity is filled with Helium at 10^{-4} mbar, while the RF-power transmitted into the cavity, is slowly increased until the onset of discharge. By operating just below the discharge point, the field emission is slowly diminishing. In this manner the field emission onset was raised to ≈12 MV/m, see Figure 3.

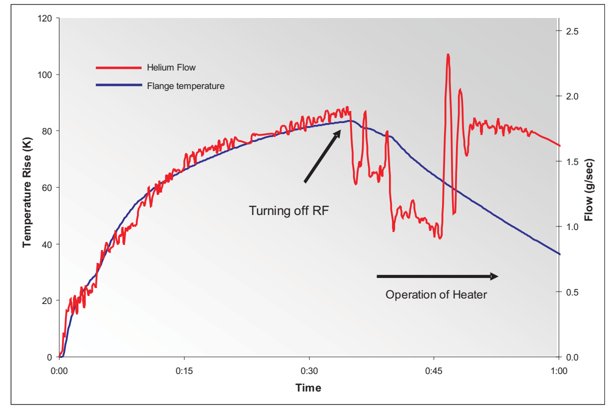

Figure 4: Thermal load on the cavity exit flange. Electron absorbtion leads to an asymptotic temperature increase over time. The long time constant of the temperature drop upon shutting off RF-power hints at an insufficient cooling of the exit flange. The spikey shape of the Helium flow curve is due to active user manipulation.

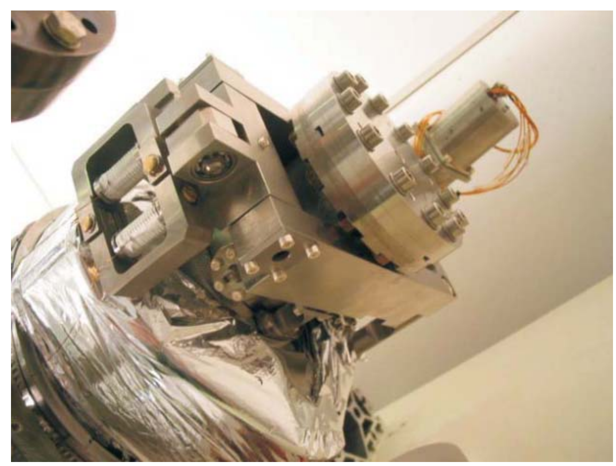

Figure 5: The piezo tuner integrated into the cavity-tank-tuner system.

Tuner

The cavity has been equipped with a Saclay I type tuner consisting of a stepper motor and a piezo-holder frame supporting two parallel piezo-elements, see Figure 5. We have used PSt 1000/16/40 high-voltage piezo elements by Piezomechanik, operating at 0-1000 volts. Due to the higher blocking force of 12-15 kN we could work at a higher pre-stress as compared to low voltage piezos. Although the sparking voltage for Helium of 156 volts is exceeded with HV-piezos, we have determined the risks for a HV-shortcut according to Paschen's law negligible in our setup.
The tuner is more thoroughly described in [3]. Its main function will be to compensate the microphonics which have been characterized for HoBiCaT in [4].

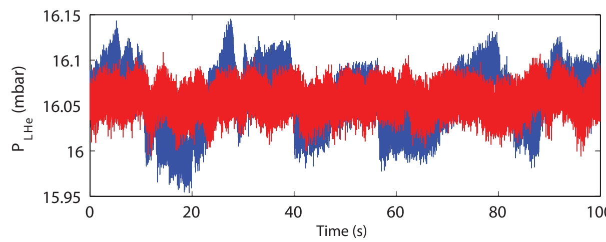

Figure 6: Comparison of different cooling modes of the Linde cryo-system. The reduced He-pressure fluctuations in mode "Fernsteuer I" (red, smaller amplitudes) lead to reduced microphonics.

Helium pressure stability

He-pressure stability has been measured and determined to be <0.03 mbar rms. We have verified different cooling modes of the Linde cryosystem with respect to pressure stability. In the standard mode "Fernsteuer II" the control valve is located parallel to the Helium pumps, already in the warm section behind a 30 meters long pipe. This leads to a stable operation, but also to prolonged time constants. In the mode "Fernsteuer I" the control valve is placed in series with the He supply line still in the cold section before the heater. This leads to smaller time constants, but somewhat unstable operating conditions. In Figure 6 both modes are compared regarding their pressure stability. We have obtained rms microphonics values of 1.8 Hz for "Fernsteuer II" and down to 0.5 Hz for "Fernsteuer I".

Testing of the TTF-III coupler

The TTF-III was originally developed for pulsed operation in the TESLA linear-collider. Regarding the intended cw-operation in the BESSY-FEL, the coupler had to be tested with respect to thermal aspects. Figure 7 depicts the layout of the input coupler. It consists of two coaxial parts ("warm" and "cold") and a waveguide-to-coaxial-line transition. The "cold" part attaches to the cavity beam tube and has a common vacuum with the cavity, preserved by a ceramic cylindrical window. The "warm" part is attached once the cavity is inserted in the cryostat. Details on the coupler can be found in [5].

Figure 8 is a typical temperature measurement of the inner conductor as the power is being raised in steps. Note that the thermal time-constant of the inner conductor is very long (about 50 min). Also included in the figure is the temperature of the warm ceramic, which never came near the recommended maximum values of 80° during any of the tests. We have obtained values for the power induced temperature rise $\Delta T/\Delta P$ of about 29 K/kW for loaded power termination of the RF-system. Our results suggest that the existing TTF-III coupler can very likely be operated safely up to 10 kW TW and 5 kW SW.

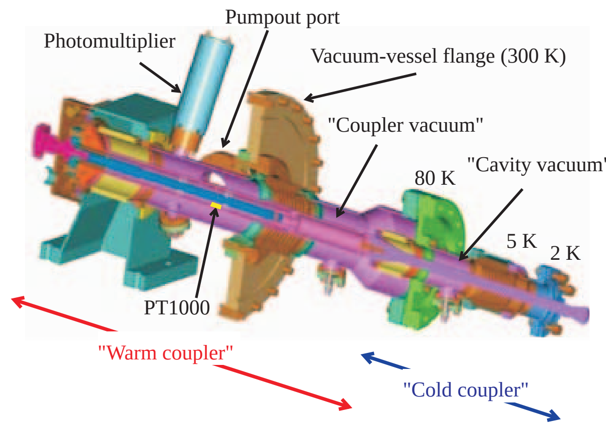

Figure 7: The TTF-III coupler

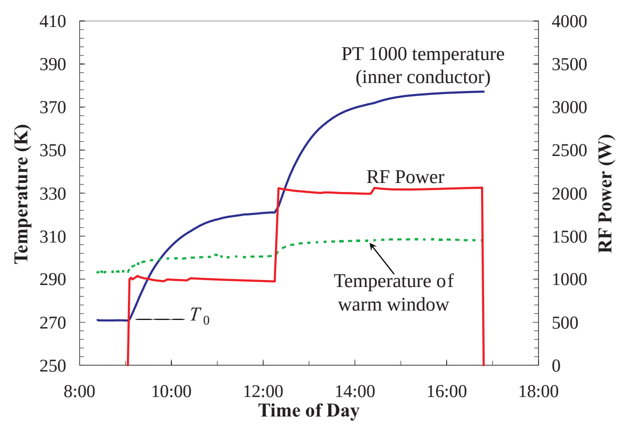

Figure 8: Example of PT1000's temperature versus time. Measurements were made with HoBiCaT cold and the waveguide shorted.

SUMMARY AND OUTLOOK

The HoBiCaT facility has been successfully taken into operation. We have performed Q_0 measurements, microphonics measurements [4], characterisation of the cryogenic system, tuner characterization [3], TTF-III coupler characterization and He-conditioning to improve the quality factor. The next steps will be active fee-forward microphonics compensation and incorporation of a new tuning system.

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