CHARACTERISATION OF MICROPHONICS IN HOBICAT *

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Abstract

The HoBiCaT test-facility at BESSY, which is designed for cryogenic testing of superconducting TESLA units has been equipped with a 9-cell TESLA-type cavity. Mechanical vibrations in the cryostat result in microphonic detuning of the cavity resonance. These microphonics have been characterized, and their sources analyzed, including the impact of operating conditions such as LHe pressure, cavity field and heater power. Furthermore, the mechanical transfer functions needed for the eventual compensation of the microphonics have been recorded.

INTRODUCTION

For CW operation of a superconducting, TESLA-type cavity microphonics represent the largest disturbance of the resonant frequency. In particular at a small bandwidth $\Delta f = \omega / Q_L$, according to the equation

$$\mathrm{P} \propto 1 + \frac{(\delta f)^2}{(\Delta f)^2} \tag{1}$$

the microphonics δf lead to a significant increase of the generator power P, which is required to maintain a constant cavity field. Therefore it is highly desirable to minimize the microphonics. Measurements characterizing the microphonics and their impact on the cavity operation are presented below. The perspectives on possible countermeasures are described elsewhere [1].

MICROPHONICS MEASUREMENTS

Microphonics have been recorded in two different ways. In a first method, the RF-feedback signal, see Figure 1, is recorded over time. This is preferably done in open loop configuration, because obtaining a calibration factor is more straightforward here, than in closed loop configuration. A second method utilizes the sensor-actuator design of the piezo tuner to record the induced piezoelectric voltage over time. In this design, two high-voltage piezos are attached to the tuner, thus piezoelectric forces can be exercised on the cavity and measured simultaneously. The latter is only an indirect method, as the mechanical influence from cavity and tank on the frequency response does not necessarily lead to a linear relationship between cavity- and piezo position. The results presented here were solely obtained from the RF-feedback signal.

* Work funded by the European Commission in the Sixth Framework Program, contract No. 011935 EUROFEL.

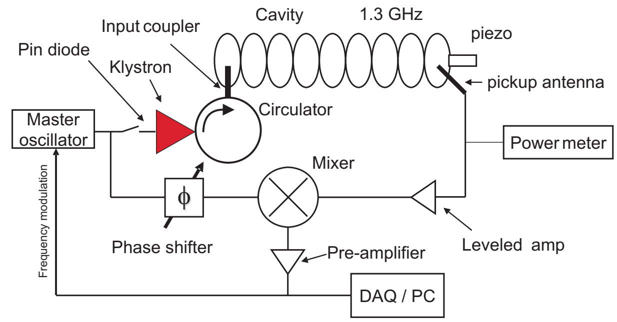

Figure 1: Phase-lock-loop used for cavity RF-measurements.

Calibration of RF-feedback signal

In order to interpret the voltage value from the RF-feedback in terms of a detuning frequency, a calibration factor has been determined. This was done by mechanically detuning the cavity with the piezo stack, which exhibited a detuning behavior of $\Delta \mathrm{f}/\Delta \mathrm{V}$ = 1.131 Hz/V. By varying the piezo voltage the cavity resonance was scanned open loop at a fixed master oscillator frequency over several bandwidths. The RF-feedback value varied by 0.84 V. Hence, all voltages could be easily interpreted as frequencies. This procedure is only possible because a leveled amplification is applied to the cavity pickup-signal. This ensures that the mixer output signal is solely dependent on the phase difference between master oscillator and cavity. Note that the frequency stability of the Rohde & Schwartz master oscillator at 1.3 GHz is better than 0.1 Hz.

Measurements at cryogenic temperatures

Microphonics have been measured at cryogenic temperatures. In Figure 2 the Fourier transform of a 30 second long measurement of the RF-feedback signal sampled at 5 kHz is depicted. An immediately identifiable feature is the constant signal of a turbo vacuum pump (18000 rpm) at 300 Hz. Furthermore, prominent features occur at 41 Hz, 90 Hz, and 170 Hz and are resonances of the cavity-tank-tuner system. The feature at 30 Hz is a so far unidentified source not related to any of the mechanical cavity resonances. It was further investigated whether the measured microphonics would change with the quality factor, or the bandwidth, respectively. For that purpose, the quality factor was varied over a wide range (a) by changing the coupler position and (b) by using a three stub tuner.
In Figure 3 the integrated microphonics frequency spectra taken at different values of $\mathrm{Q_L}$ are plotted. It can be seen that in general the RMS value of the microphonics in-

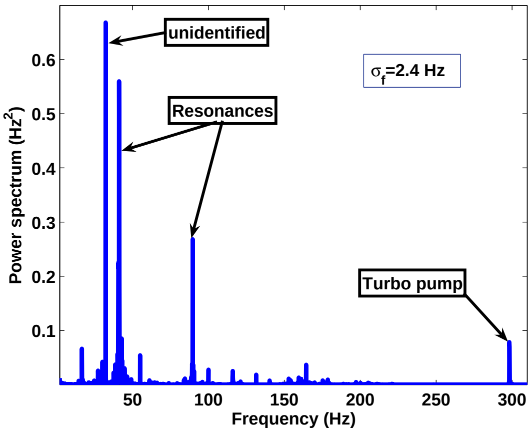

Figure 2: Microphonics in cavity measured open loop at 1.8 K.

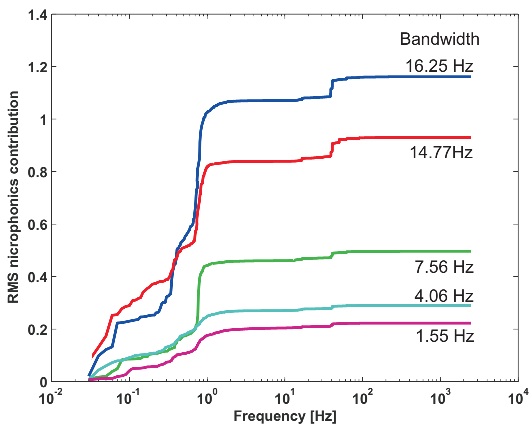

Figure 3: Integrated microphonics frequency spectra at different cavity bandwidths. The main contributions to the overall RMS value of the microphonics come from low microphonics frequencies (< 1 Hz). Microphonics increase with higher cavity bandwiths.

creases with the bandwidth, or in other words the cavity becomes less susceptible towards microphonics with increasing Q_L. It can also be seen that the largest contributions to the RMS-microphonics are at low frequencies.

Influence of cryogenics on the microphonics

The heavy machinery in our cryogenic system consists of a Sogevac SV200 Leybold pump and two pairs of Leybold SV1200 and RA7001 SO pumps. They operate at 24 Hz, 11.66 Hz, and 50 Hz, respectively. Note that these mechanical vibrations can not be found in the microphonics spectra which was also confirmed by slightly varying the pumping frequencies. This observation suggests that the decoupling of the pumps from the HoBiCaT facility is sufficient.

The main contribution to the microphonics was found to be

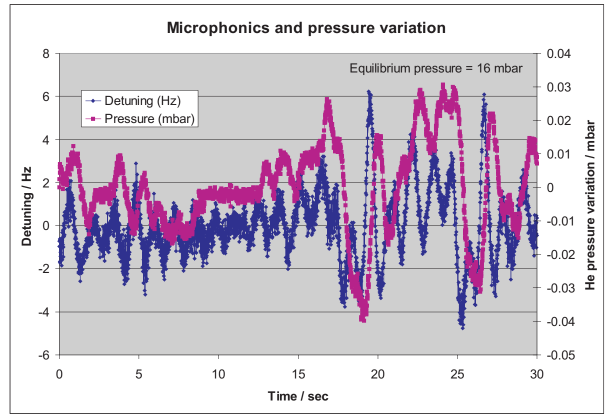

Figure 4: Microphonics and He-pressure difference.

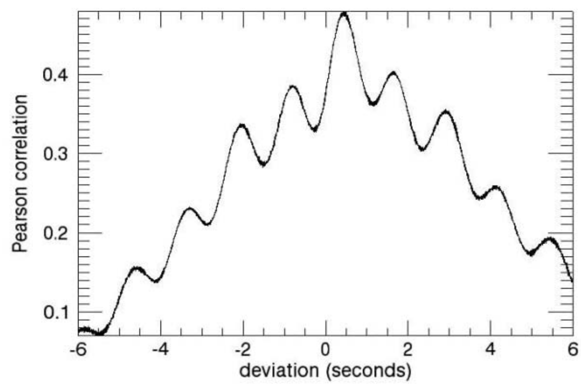

Figure 5: Pearson correlation between Helium bath pressure and microphonic detuning The 0.4 seconds offset is due to the preset sampling time of the pressure sensor. The occurrence of side maxima suggests, that there is some periodicity within the microphonics.

from within the cooling medium itself. A change in Helium pressure (measured with a Rosemount sensor) was measured to lead to a detuning of the resonant frequency of 55 Hz/mbar. Figure 4 shows the microphonics recorded over a period of 30 seconds in correlation with the He-bath pressure. In Figure 5 the Pearson correlation between the two signals is plotted. The maximum correlation occurs at an offset of 400 ms, which is due to the sampling time of the pressure sensor. This observation suggests, that a significant portion of the microphonics can be compensated with a feed forward system, provided fast and accurate pressure sensors are used. The microphonics created by the Helium heater, which is part of the cryogenic system and supports the Joule-Thomsen expansion of the cooling medium, were also investigated. In Figure 6 microphonics have been recorded as a direct fft from the RF feedback signal at different values of the heater power. It can be seen that different heater powers create significantly different microphonics spectra, suggesting that the heater itself is a source of microphonics.

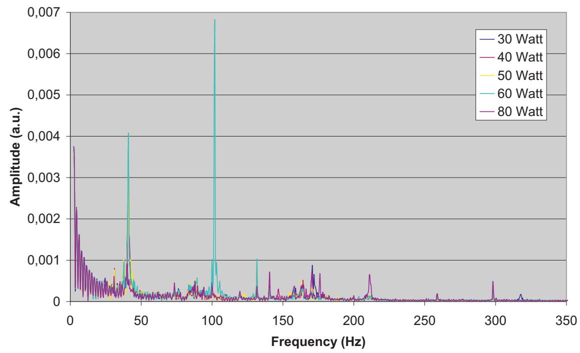

Figure 6: Influence of the heater power on the microphonics spectra

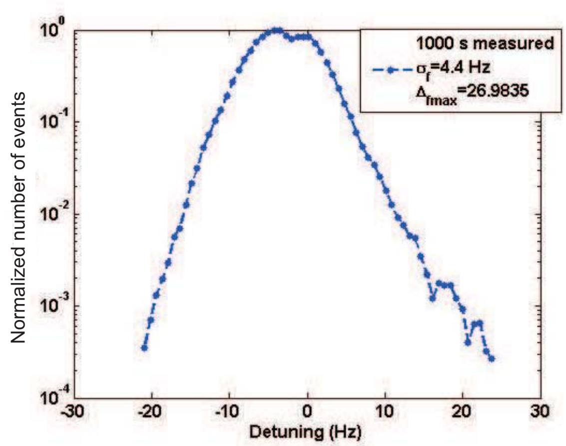

Figure 7: Long-time microphonics measurement.

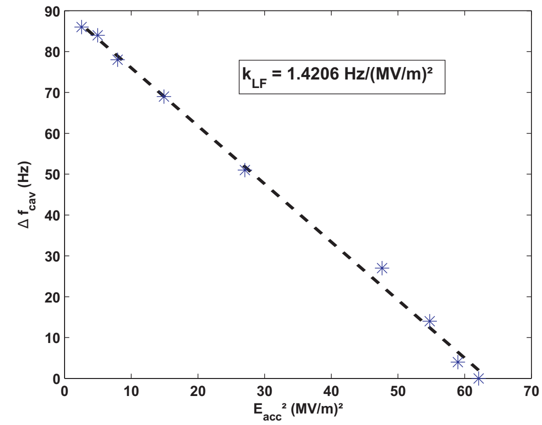

Figure 8: Lorentz Force Detuning vs. field gradient

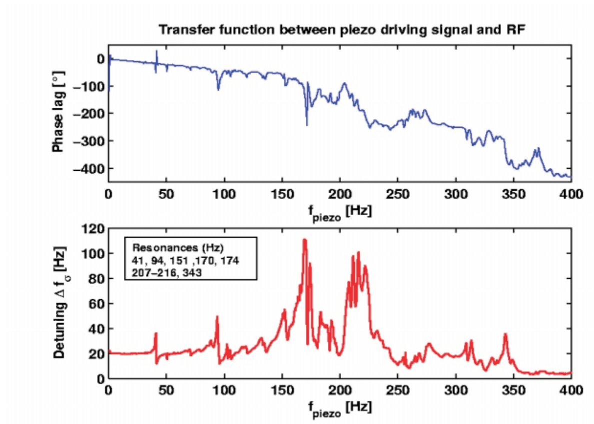

Figure 9: Transfer function of the cavity-tank-tuner system recorded over a frequency range of 0-400 Hz.

Long-time measurements of microphonics

As the RF-system has to be laid out to deal with the maximum possible microphonics detuning, several long-time microphonics measurements have been performed. From these measurements the probability for a certain detuning within a given time period could be determined. The measurement presented in Figure 7 is a histogram of measured detuning values. It was taken over 1000 seconds and gives a maximum detuning frequency of 26.8 Hz and a rms detuning of 4.4 Hz. A 24 hours+ measurement is planned, but has so far been postponed due to long time stability issues of the klystron.

Lorentz force detuning

The static response of our setup to Lorentz force detuning has also been measured. We have obtained a value of $\mathrm{k_{LF}} = 1.42\ \mathrm{Hz/(MV/m)^2}$, see Figure 8, which is within the range of values of 1–2 $\mathrm{Hz/(MV/m)^2}$ gained at DESY [2].

Transfer function

The reaction of the cavity resonance frequency on microphonic vibrations is determined by the mechanical eigenmodes of the tank-tuner-cavity system. Such Q-modes are measured via the transfer function. Here, the piezos are used to create sinusoidal vibration at distinct frequencies over a certain frequency range. The RF-feedback signal is recorded over time, yielding amplitude and phase information of the mechanical response, see Figure 9. Such modes arouse from transverse and longitudinal vibrations with respect to the cavity axis. Note, that only longitudinal symmetric stretch modes can be excited with the present piezo setup and thus only such modes can eventually be compensated. Numerical simulations by Luong et al. [3] suggest that these modes make up for the largest contribution to the detuning of the cavity.

Influence of passive cavity stabilizers

Titanium fixtures that can be attached between the cavity's stiffening rings and the helium tank have been developed by FZ Rossendorf and manufactured at AC-

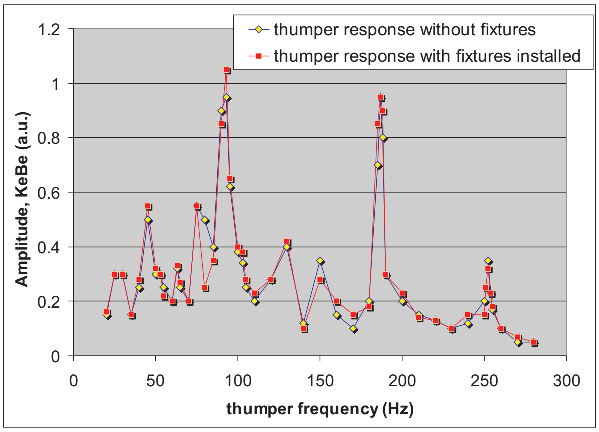

Figure 10: Integrated frequency response signal of cavity mounted in a He-tank (a) with and (b) without fixtures attached.

CEL. While they were originally intended for earthquake-protection, we have investigated to what extent they can dampen mechanical vibrations or shift resonances towards higher frequencies, and thus reduce the impact of microphonics. Room-temperature measurements were done at ACCEL with such a cavity. For the experiment, an acoustic thumper, operating between 30 Hz and 300 Hz, was attached to one end of the cavity (perpendicular to the cavity axis). The response was measured with KeBe inductive velocity meters attached at different positions of the tank. It was found that the fixtures contributed only marginally to a decrease of the microphonics response signal. As can be seen from Figure 10 the response function with and without fixtures is practically identical. The only significant deviation occurs at 80 Hz, but no significant microphonics were measured in HoBiCaT at this frequency.

OUTLOOK

The next step after characterization of microphonics is to take countermeasures to compensate them. Such a compensation does not have to be complete as even small improvements lower the required RF-power significantly. The correlation between He-pressure and low frequency microphonics suggests, that a feed-forward algorithm might be feasible. Such work is underway and will be presented soon. Also we are investigating adaptive feed forward compensation of higher frequency microphonics.

REFERENCES

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[2] H. Gassot, “Mechanical Stability Of The RF Superconducting Cavities”, Proceedings of EPAC 2002, Paris, 2002.

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