Thermal Fluctuations in Cryogenic Quartz Resonators

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Acoustic resonances at frequencies around 500 MHz and Q-factors exceeding one billion were reported in [1]. This was observed with the so-called BVA quartz resonators employing the non-contacting electrode technology [2]. Such resonators are the time-keeping elements of the most frequency-stable quartz oscillators [3].
By cooling the 400 MHz BVA resonator to 15 mK, which is well within the range of modern cryogen-free dilution systems (for example, http://www.bluefors.com), one can putatively observe the quantum behavior of macroscopic objects, as well as perform various high-precision tests of fundamental physics.

We report the first observations of thermal fluctuations in the BVA resonators at cryogenic (4 K) and ultra-cryogenic (20 mK) temperatures. The measurements were conducted with commercial DC SQUID readout system at frequencies up to 20 MHz.

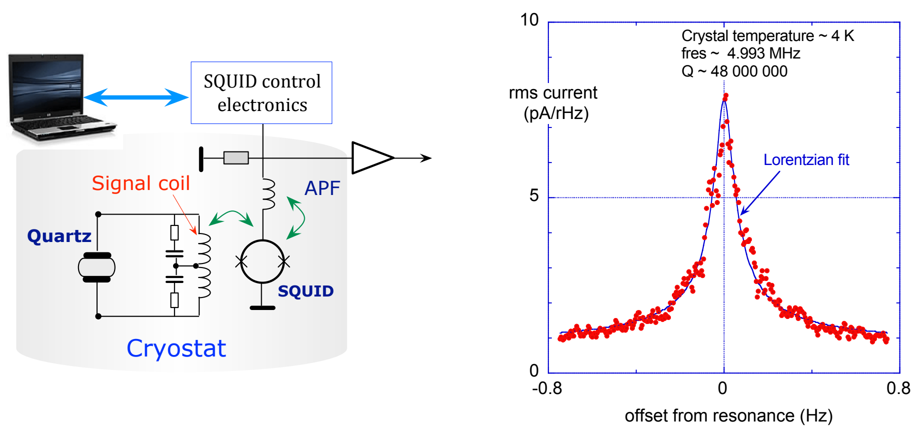

Fig. 1. Experimental setup and spectrum of current fluctuations through the SQUID signal coil at 4 K

Our investigation showed that:
- Spectra of thermal fluctuations are Lorentzian;
- Statistics of thermal fluctuations is Gaussian;
- At T~ 4K, mode temperatures of all acoustic resonances detected is close to physical temperature of the crystal;
- The Q-factors extracted from the thermal noise spectral fits are consistent with those measured with impedance analyser.

The following aspects of our study will be discussed in details at the conference:
- Calibration and noise floor measurement of the DC SQUID readout;
- Conversion of FFT voltage noise spectra into mode temperature;
- Comparison of thermal noise spectra at cryogenic and ultra-cryogenic temperatures.

[1] M. Goryachev, D. Creedon, S. Galliou, and M. Tobar, "Observation of Rayleigh Phonon Scattering through Excitation of Extremely High Overtones in Low-Loss Cryogenic Acoustic Cavities for Hybrid Quantum Systems Physical Review Letters, 111, 085502 (2013).
[2] R. J. Besson, Proc. of 31st Annual Symposium on Frequency Control (1977), pp. 147–152.
[3] P. Salzenstein, A. Kuna, L. Sojdr, F. Sthal, N. Cholley, and F. Lefebvre, "Significant step in ultra-high frequency stability quartz crystal oscillators", Electronic Letters, v. 46, issue 21, 686 (2010).