Flicker Noise in Quartz Crystal Resonator at 353 K as a Function of Q Factor at 4 K

F. Sthal[a*], A. Pokharel[a], J. Imbaud[a], M. Devel[a], F. X. Esnault[b], G. Cibiel[b]

a. FEMTO-ST Institute, Univ. Bourgogne Franche-Comté, ENSMM 26 Rue de l'Epitaphe, 25030 Besançon, France

b. Centre National d'Etudes Spatiales, 18 Avenue Edouard Belin, 31400 Toulouse, France

* fsthal@ens2m.fr

The unclear physical origin of flicker noise in ultra-stable quartz oscillators limits some practical metrological applications. The origin of this 1/f observed noise is still an unanswered question [1]. Though a quantum theory for this 1/f noise in electronic devices and acoustic resonators has been developed over decades by P. Handel & al. [2], it remains very controversial and does not allow assessing easily the lowest value of 1/f noise that could be obtained for a quasi-perfect material in a perfect setup. We have therefore carried a new series of low temperature measurements in order to try to better assert the influence of material defects as 1/f noise sources and provide some inputs to tentative quantum theories. Characterization of the Q-factor of all of the modes of a given quartz oscillator could give some information about the crystal quality [3], since the Q-factor is representative of damping in the vibrating volume and of the effective mass of the resonant cavity. Furthermore, the harmonic modes and the anharmonic modes due to the plano-convex-shape give different vibrating zones inside the heart of the resonator.

In this contribution, we study experimentally the possible correlations between Q-factor measurements at low temperature (4 K) and the level of flicker noise at nominal operating temperature (353 K) in 5 MHz Stress-Compensated-cut quartz resonators (SC-cut, which is today considered as the best kind to be used in quartz oscillators in terms of stability). Results for 10 SC-cut resonators with a 5 MHz resonant frequency and different noise levels (some excellent) are presented and commented, for several overtones and anharmonic modes. Fig. 1 shows the Q-factor of the different modes of the resonators at the same 3rd overtone, measured at 4 K and/or 353 K, as a function of their short term stability.

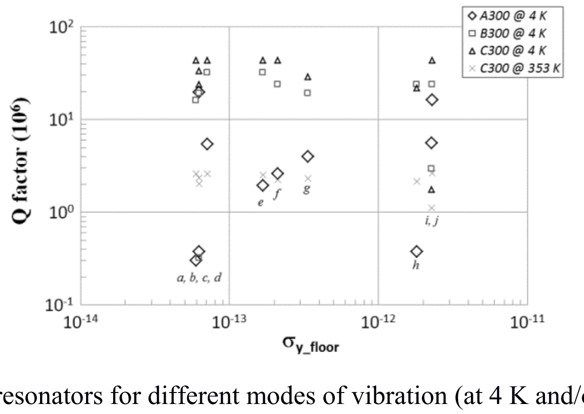

Figure 1 : Q-factor of the resonators for different modes of vibration (at 4 K and/or 353 K) as a function of the short-term stability level (σ_{y_floor}) at 353 K.

We will also report Q-factors for several overtones and anharmonic modes, measured at 4 K, as a function of the short-term stability of the resonator measured on their metrological vibrating mode at 353 K and conclude on the absence of correlations, for which we need theoretical interpretations.

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[3] S. Galliou, M. Goryachev, Ph. Abbé, X. Vacheret, M. Tobar, R. Bourquin, Quality Factor Measurements of Various Types of Quartz Crystal Resonators Operating near 4K, IEEE Trans. on UFFC 63, 975, (2016).