Quartz Resonator for MEMS Oscillator

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A dedicated three dimensional quartz crystal micro-resonator in a length-extension mode (LEM) has been developed for fundamental physics experiments[1] (Fig. 1a), showing very promising frequency stability properties[2]. Obtained by collective chemical etching, the most recently evaluated 25 µg mass resonators present a quality factor Q of about 3 million for a frequency F=3.9 MHz thus reaching a Q.F product above 10^{13}, near the state of the art of macro shear mode quartz resonators used in Ultra Stable Oscillators (USO). This concept is now being studied in a planar 2D configuration compatible with collective etching processes as well but can be more easily integrated.

The new concept is a planar cut of the cylindrical three dimensional resonator (Fig. 1b). Like the previous 3D resonator, the 2D concept is designed to reduce the energy losses out of the resonator, condition sine qua non to achieve a high quality factor. Provided the geometry of the pillar and the two adjacent beams meet some precise constraints[3], the insulation of the mounting areas of the structure can be insured. Complex mechanisms coupling flexion and opposite phase length-extension modes of the beams are involved.

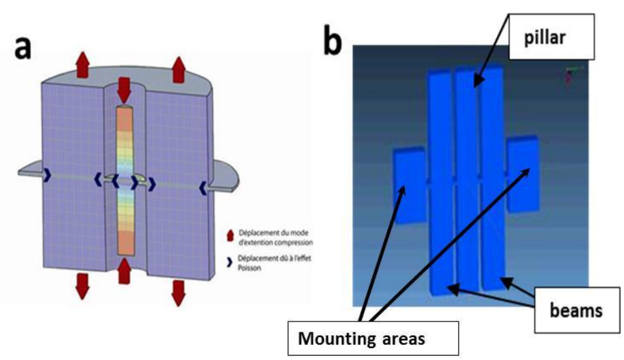

Fig. 1a: the three dimensional resonator; 1b: the two dimensional resonator.

This work will present the global optimization of the 2D resonator, including the energy losses minimization, the identification of specific quartz cuts reducing the frequency temperature dependence while allowing an efficient piezoelectric coupling for low motional resistance.
First realization will also be presented, based on an original technology using hybrid quartz on silicon wafers[4] and Deep Reactive Ion Etching of quartz.

This new quartz resonator should find interesting applications in the field of high stability crystal MEMS oscillators.

[1] A. G. Kuhn & Al., "Free-space Cavity Optomechanics in a Cryogenic Environment", Applied Physics Letters 104, 044102, 2014.
[2] O. Le Traon et Al. "A Micro-Resonator for Fundamental Physics Experiments and its Possible Interest for Time and Frequency Applications", EFTF, 2011.
[3] O. Le Traon et Al., "Structure plane de résonateur mécanique découplé par des vibrations de flexion et d'extension-compression", patent demand deposited on feb. 14th 2013 n°FR 13 00322.
[4] S. Grousset et Al., "Quartz-based Vibrating MEMS Fabricated Using a Wafer-bonded Sealed Cavity Process", IFCS, 2014.