Supplementary

Quartz Tuning Fork Resonance Tracking and application in Quartz Enhanced Photoacoustics Spectroscopy

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Supplementary information

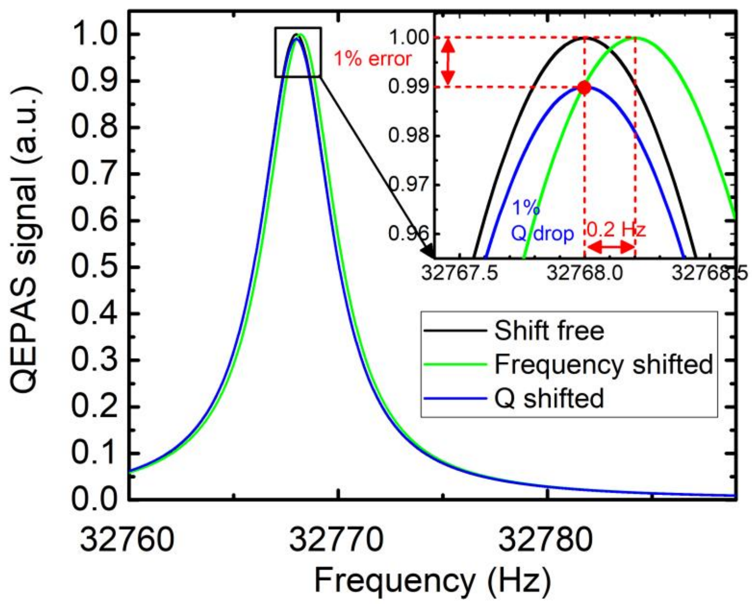

Figure S1. The frequency response of the shift-free QEPAS signal (black) is represented. It is a Lorentzian curve centered at 32768 Hz, having a quality factor of 8000. The QEPAS signal reaches a maximum value at $f = f_0$. The frequency response is also shown for a frequency shift of 0.28Hz (green) and Q shift of 80 (blue). The two curve intersects (red dot) at $f = f_0$, corresponding to a 1% QEPAS signal error as calculated.

The objective here is to quantify the error on the resonant frequency and the quality factor for a fixed error value on the QEPAS signal, as it is used in Section 3. In terms of expected accuracy for the measurement, the error on the QEPAS signal must be within 1% of the relative signal.

$$\frac{\Delta S}{S(f_0)} < 0.01$$

Then, the frequency response of the QEPAS signal can be described as a Lorentzian profile (Figure S1 black):

$$S^2 = C\frac{Q^2}{1+\left(\frac{2Q(f-f_0)}{f_0}\right)^2}\ , \tag{1}$$

where C is a constant.

This 1% amplitude error can be converted in an error on the measured frequency Δf:

$$\Delta f = |f(S(f_0) - \Delta S) - f_0|\ , \tag{2}$$

Isolating f in (1) :

$$f(S) = \pm\frac{f_0}{2Q}\sqrt{\frac{CQ^2}{S^2} - 1} + f_0\ , \tag{3}$$

Using (2) and (3), and noting that $S^2(f_0) = C \cdot Q^2$, one can find the frequency error :

$$\Delta f = \frac{f_0}{2Q}\sqrt{\frac{1}{\left(1-\frac{\Delta S}{S(f_0)}\right)^2} - 1} = \frac{32\,000}{2 \cdot 8000}\sqrt{\frac{1}{(1-0.01)^2} - 1} = 0.28\,Hz$$

It corresponds to the green curve on Figure S1.

This amplitude error can be converted in an error on the quality factor as well. At $f = f_0$, the QEPAS signal has a linear relationship with Q, thus the error is quickly obtained with :

$$\frac{\Delta Q}{Q} = \frac{\Delta S}{S(f_0)} \ \rightarrow \Delta Q = 0.01Q = 80$$

It is represented by the blue curve on Figure S1.

From those calculations, it can be concluded that a frequency shift of 0.28 Hz and Q shift of 80 lead to a 1% relative error on the QEPAS signal.