Quartz tuning fork vibration amplitude as a limitation of spatial resolution of shear force microscopes

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Why ?

- SPM usually use the physical quantity under investigation as probe-distance indication
- this is fine on homogeneous surface (constant physical quantity)
- shear-force microscopy uses a resonator for independent probe-distance feedback
  → usable for a wide range of applications (SNOM, SECM, STM ...)

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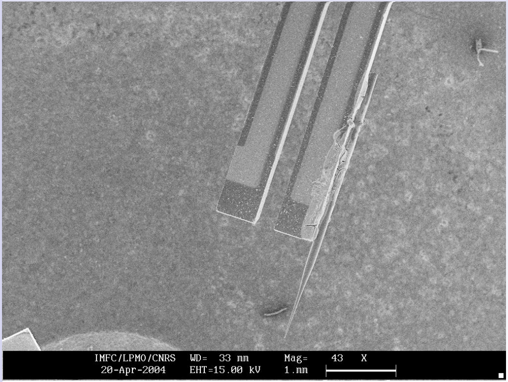
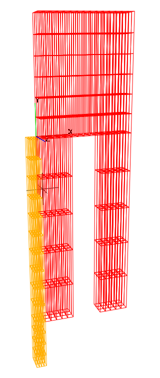
Shear force microscopy

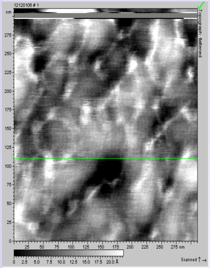
Feedback on one property of a quartz resonator (current magnitude or phase) to keep the probe-surface distance constant : the resonator is disturbed by the forces acting on the tip
⇒ modification of the transfer function of the resonator. The feedback signal (probe-distance) is recorded for topography monitoring.

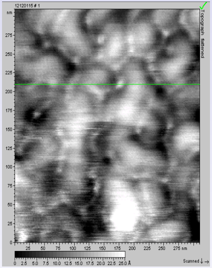


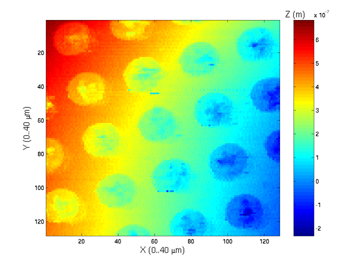


But ...

Shear force microscopy has not displayed the excellent resolution of other scanning probe microscopies
⇒ requires a good understanding of the behavior of the probe and its interaction with the surface



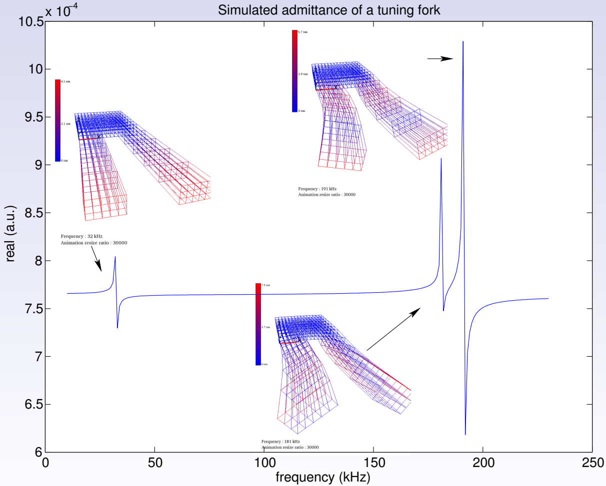




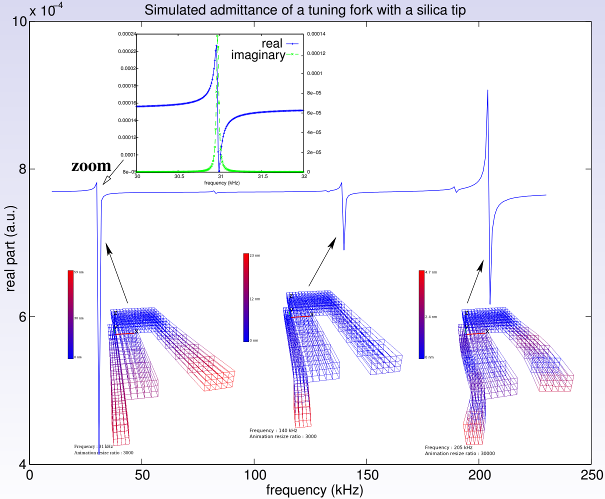
- size of the probe ?
- “leakage” of the near field (evanescent) physical property ?
- vibration amplitude of the probe ?

K. H. Choi, J.-M Friedt, F. Frederix, ... *Simultaneous Atomic Force Microscope and Quartz Crystal Microbalance Measurement* Applied Physics Letters (Vol 81, No 7, 12 Aug 2002)

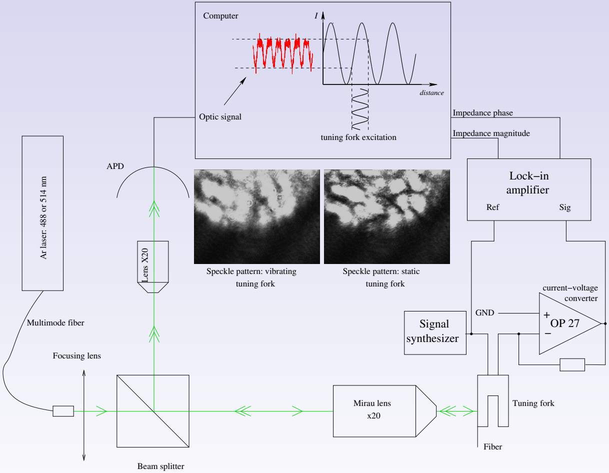
Modulef based dynamic simulation : free tuning fork



Modulef based dynamic simulation : loaded free tuning fork



Interferometric methods



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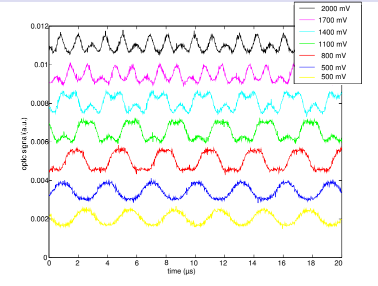
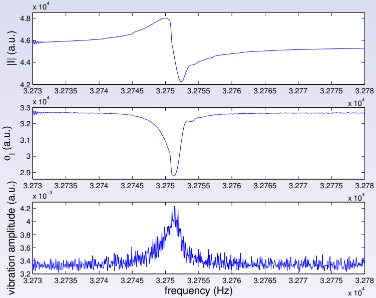
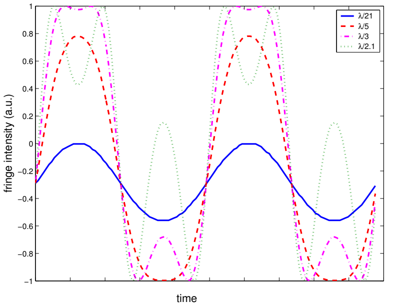
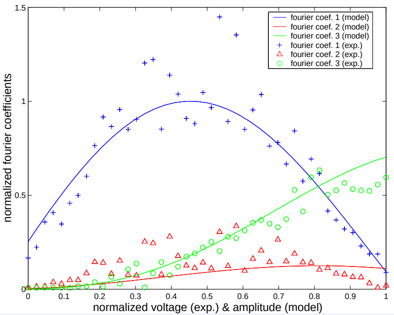
Raw data





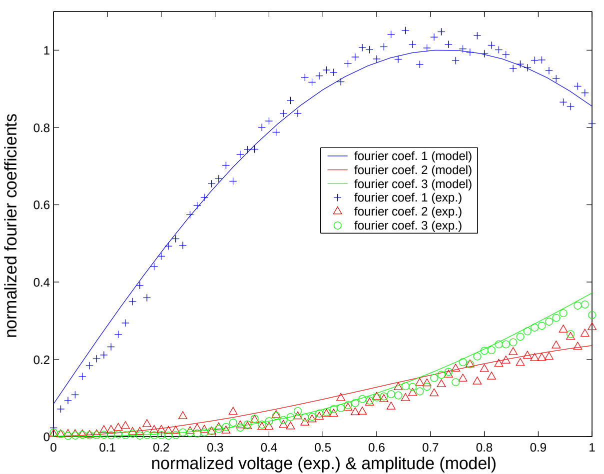
Linking model and experimental data





abscissa is graduated in voltage from 400 to 9000 mV (experimental data), which is also equal to (simulated data) a vibration amplitude of $\lambda/21 = 23$ nm to $\lambda/1.7 = 290$ nm ($\lambda = 488$ nm in this experiment).

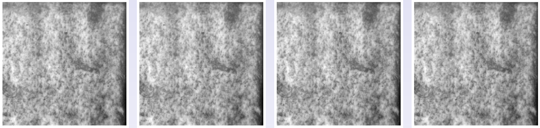
Loaded tuning fork

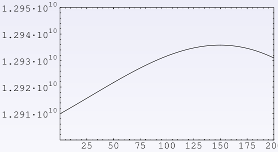


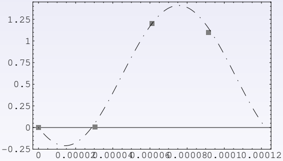
abscissa spans from 100 mV to 7600 mV amplitude (experiment) which is also equal to $\lambda/126$=4 nm to $\lambda/5$=97 nm (here $\lambda = 488$ nm).

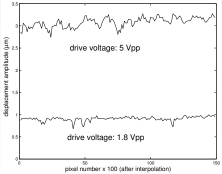
Stroboscopic method

1. acquire images of the moving surface phase-synchronized with the driving voltage
2. oversample each line and intercorrelate images
3. look for the maximum of intercorrelation and find the best sine-wave fit
4. repeat for each line of the image









Results : 0.5 V_{pp}–1.8 V_{pp}–5 V_{pp} $\rightarrow$ displacement amplitude 350 nm–850 nm–3000 nm ($Q = 4500$).

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Conclusion and perspectives

- we have developed the basic Finite Element Model of a tip-loaded tuning fork
- we have experimentally measured the vibration amplitude of a tuning fork

Further developments include :

- measuring the vibration amplitude as a function of probe-surface distance
- adding an external force acting on the tip of the probe to our model
- experimentally observe possible spatial resolution loss at high driving-voltage amplitude
- is the tuning for usable as a scanner ? (for an $N \times N$ pixel image, we must sample at $N \times 32768$ Hz to get a framerate of $32768/N$ image/s : $N = 128 \Rightarrow 8.5$ Msamples/s and 512 fps !)

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