Analysis of *Q*-controlled Dynamic Force Microscopy in Air and Liquids

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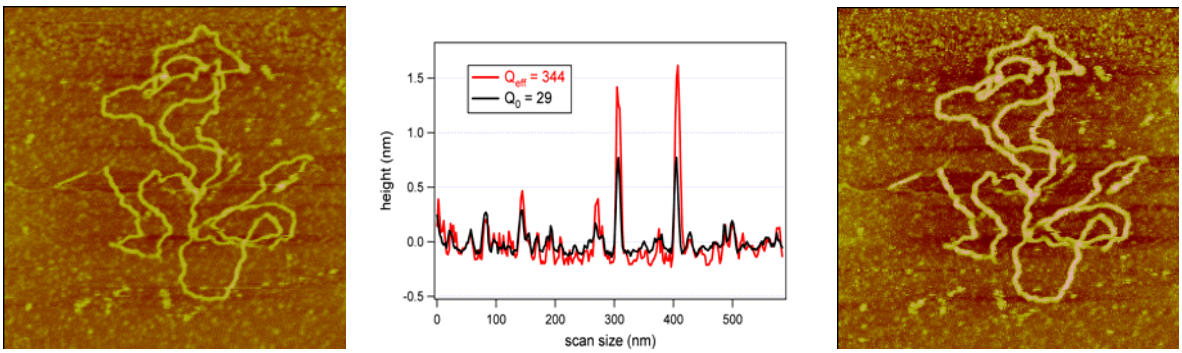
In *dynamic force microscopy* (DFM), the cantilever can be oscillated as an externally or self-driven oscillator, respectively. The so-called *Q-control* method allows the active modification of the effective cantilever damping by increasing or decreasing the *Q*-value of the cantilever [1]. This feature can be used in different ways to improve the imaging capabilities of DFM under ambient conditions as well as in liquids. Depending on the specific goals for the measurements, an increase of the scan speed or a reduction of tip-sample forces can be achieved. The latter is illustrated in the pictures below showing DNA on mica imaged in aqueous solution (EB buffer). The left image was taken with standard tapping mode (Q_0 = 29), while the right image was taken with increased *Q*-factor (Q_{eff} = 344). The two scan lines in the middle reveal an increased height of the DNA scanned with *Q*-control as a result of the reduced tip-sample forces.

Even though the *Q*-control method has been frequently applied in numerous experimental studies in recent years (see, e.g., [1-4]) and the necessary driving electronics are commercially available, it is striking that an in-depth analytic description that would allow a rigorous theoretical explanation of the various features of *Q-controlled dynamic force microscopy* (QC-DFM) is still missing. Here, we present an analysis of QC-DFM based on the analytical solution of the equation of motion and on numerical simulations considering a model tip-sample interaction force in both cases. Explicit formulas allowing the calculation of all relevant parameters like gain, phase, and amplitude are given. The detailed analysis of these formulas explains all above-mentioned features of QC-DFM. To further check on the quality of the predictions derived from our theory, a quantitative as well as a qualitative comparison with results from experimental control measurements has been performed.



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