

Q-Control



Phase
Shift



deg

Feedback
Amplitude



V

Source
Amplitude



Get better images

When operating a scanning force microscope in a dynamic mode the oscillation of the cantilever is influenced by non-linear interaction forces between the probing tip and the surface. In principle the instantaneous forces exerted on the sample while scanning the surface can be either repulsive or attractive.

With the help of the Q-Control module it is possible to reduce the damping of the dynamic system, i.e. to increase the effective quality factor of the oscillating cantilever and thereby to enlarge the regime of net-attractive interaction forces.

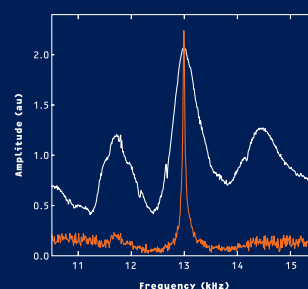
This method allows the user to minimize the forces exerted by the probing tip on the sample surface. Therefore, by applying Q-Control, delicate and highly sensitive surface structures that could not be scanned with a standard scanning force microscope can now be characterized with high resolution.

Furthermore, Q-Control often allows to improve the maximum achievable resolution in topographic measurements and to increase the overall sensitivity for magnetic or electrostatic fields.

The Q-Control module has a broad range of possible applications:

- minimizing the forces exerted by the probing tip on the surface and thereby improving image resolution while scanning samples in air or under liquid. $Q \uparrow$
- improving the overall sensitivity in magnetic or electrostatic force microscopy and increasing the signal-to-noise ratio. $Q \uparrow$
- increasing the maximum scan speed by reducing the quality factor and thereby reducing the time constant of the oscillating probe. $Q \downarrow$

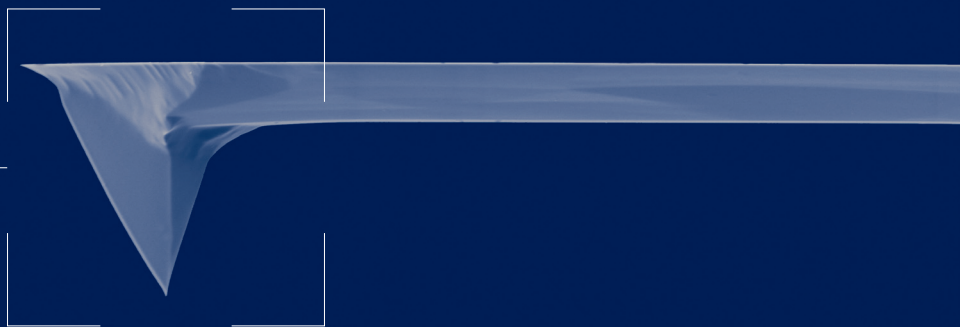
The Q-Control module is an add-on module available in different versions, covering a maximum frequency range of 5 - 500 kHz. It is equipped with general purpose BNC-type connectors or with customized connectors compatible with scanning probe microscopes from various manufacturers. Q-Control can therefore easily be combined with shearforce-based microscopes (SNOM, SICM etc.) as well as atomic force microscopes for scanning in liquids, air, and UHV.



in liquid

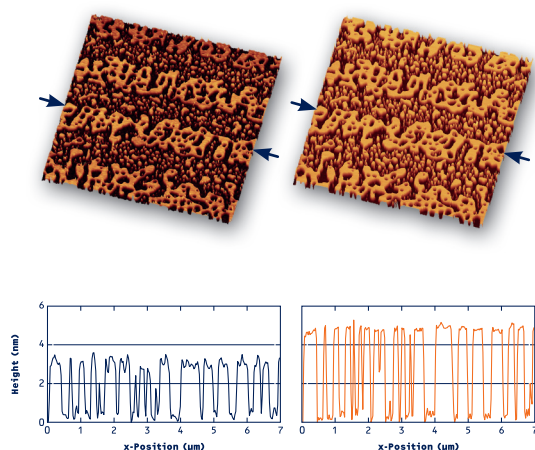
Q-Control off
Q-Control on

In a liquid medium the oscillation of a cantilever is strongly affected by hydrodynamic damping. This leads to quality factors in the single digit range and a loss in force sensitivity. The Q-Control technique as a countermeasure allows increasing the effective quality factor up to three orders of magnitude in liquids.



Q-Control off

Q-Control on

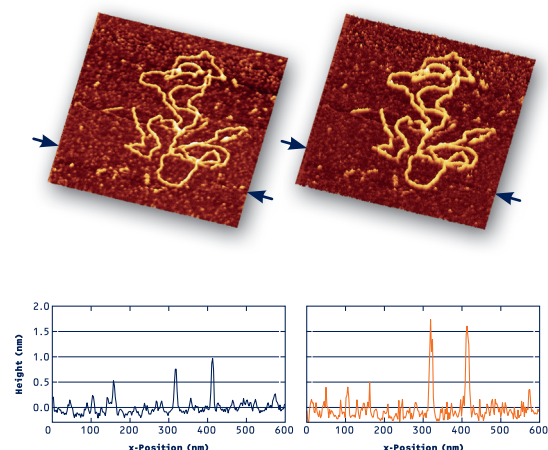


sample: Langmuir-Blodgett film on mica in H₂O (DPPC double layer)
scan range: 7 μm × 7 μm
data type: topography
data range: 6 nm

Each image line was scanned twice – in standard tapping mode during the first scan of the line (left data) and with Q-Control being activated by a trigger signal during the subsequent scan of the same line (right data). This interleave technique allows a direct comparison of the results of the two modes obtained on the same surface area while minimizing drift effects. The observed height of the DPPC layer is significantly larger in case of imaging with Q-Control, i.e. the film is compressed less by the probing tip.

Q-Control off

Q-Control on



sample: DNA on mica in buffer solution
scan range: 600 nm × 600 nm
data type: topography
data range: 2.3 nm

Being able to minimize the interaction forces during scanning is of great relevance for imaging delicate biological samples in environments such as water or buffer solution. The cross sections of the topographic data reveal that the measured DNA height is significantly larger when Q-Control is activated. The difference in the observed DNA height indicates that the imaging forces were reduced by employing Q-Control.

[data courtesy D. Ebeling et al., University of Münster]

Specifications

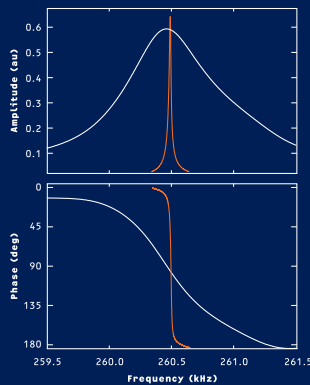
The Q-Control module is available in different versions:

Frequency Range	Typical Application	Q-Control II	Q-Control III
100 kHz - 500 kHz	Tapping Mode in air	✓	✓
20 kHz - 100 kHz	Magnetic / Electrostatic Force Microscopy	✓	✓
5 kHz- 20 kHz	Tapping Mode in liquid		✓

Compliance: CE

Power Supply: 100 – 240 V_{ac}, 0.8 A, 47 – 63 Hz, IEC connector

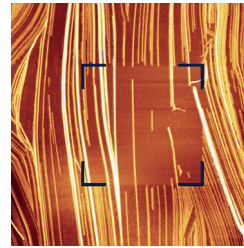
Q-Control



in air

Q-Control off
Q-Control on

Typical resonance curve of a free oscillating silicon cantilever in air. By applying Q-Control the effective quality factor was increased from about 450 to almost 20000. The high quality factor implicates a steep slope of the phase signal.



Q-Control on **off**

sample: Langmuir-Blodgett film on mica in air (ethyl-2,3-dihydroxyoctadecanoate)

scan range: 8.6 μm \times 8.6 μm

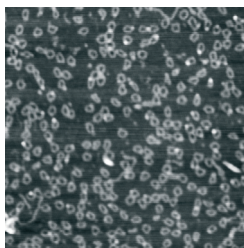
data type: topography

data range: 25 nm

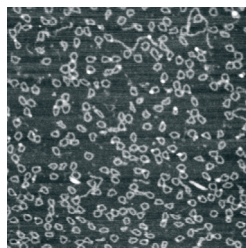
This highly sensitive sample surface could only be imaged non-destructively with active Q-Control, whereas the periodic repulsive contact with the probe in standard mode led to a significant modification or destruction of the surface structure.

[data courtesy L. F. Chi et al., University of Münster]

Q-Control off



Q-Control on



sample: DNA ring structures on mica in air

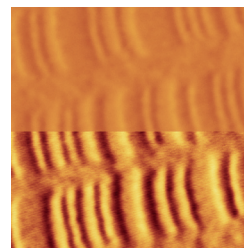
scan range: 1 μm \times 1 μm

data type: topography

data range: 8 nm

Even though non-destructive imaging of the DNA ring structures in air was also possible in standard mode, applying Q-Control resulted in a clear improvement in resolution.

[sample courtesy chimera biotec GmbH,
data courtesy L. F. Chi et al., University of Münster]



Q-Control off

Q-Control on

sample: harddisk with magnetic data structures

scan range: 5 μm \times 5 μm

data type: MFM phase

data range: 10 deg

The upper part of the image shows magnetic data structures as they were recorded in standard mode, whereas in the lower part of the image Q-Control was activated. The application of Q-Control led to an improvement of the overall sensitivity and thereby to an amplification of the magnetic contrast. In fact, the signal-to-noise ratio of the magnetic data was improved significantly.

Specifications

Version	Connection	Connector Type
General Purpose	Detector (in), Drive (in), Drive (out), Trigger (in)	BNC
DI / Veeco	NanoScope Extender / Quadrex, Microscope	37-way D Sub
Shimadzu	SPM Controller, SPM Stage	37-way D Sub

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