Fundamentals of Atomic Force Microscopy
Part 2: Dynamic AFM Methods

Week 3, Lecture 5
Phase Contrast in Tapping Mode Scans in VEDA

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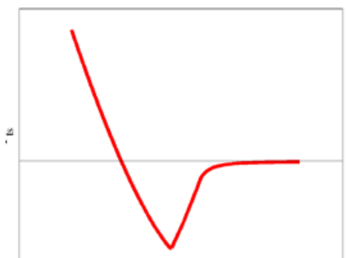
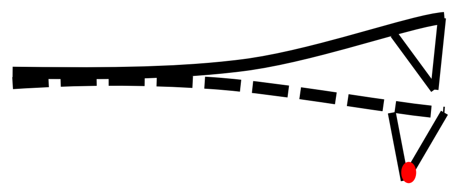
From the last lecture

- Scanning instabilities in tapping mode

Problem 1: AM-Scanning in the repulsive regime with no dissipation

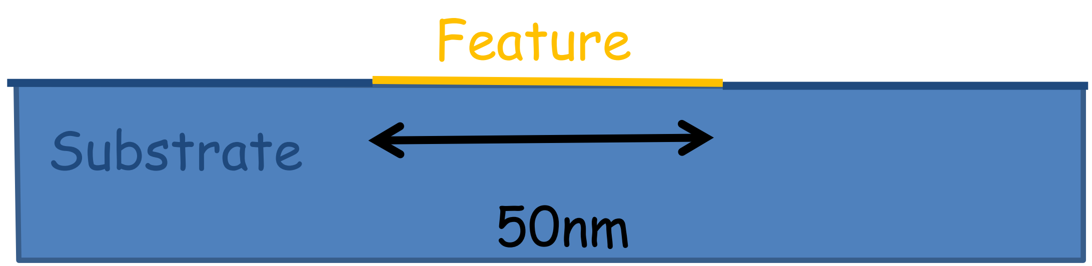
- What happens to the phase contrast when there is no dissipation in the two samples having different Young's modulus?





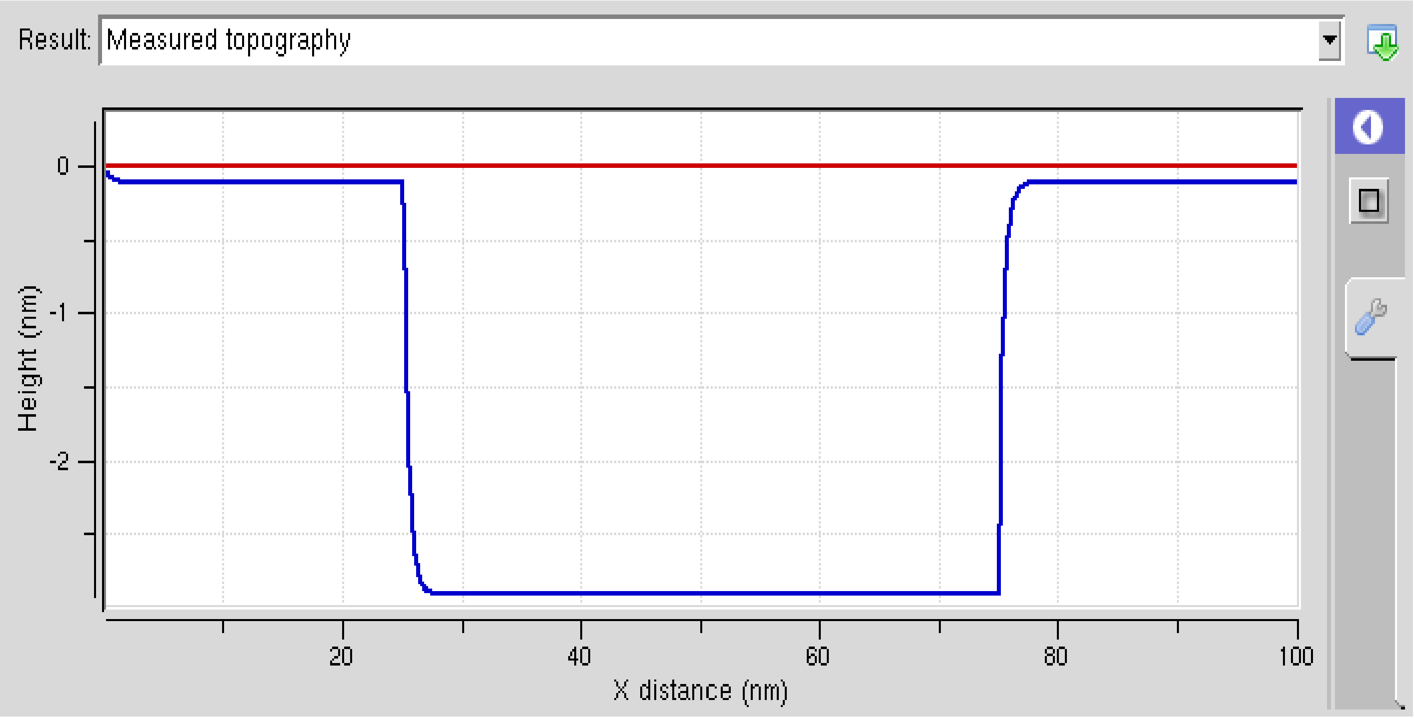
k=2N/m
Q=100
f_0= 40 kHz

Tip-sample interaction model for substrate: DMT
Young's modulus : 1 GPA



Tip-sample interaction model for substrate: DMT
Young's modulus : 0.1 GPA

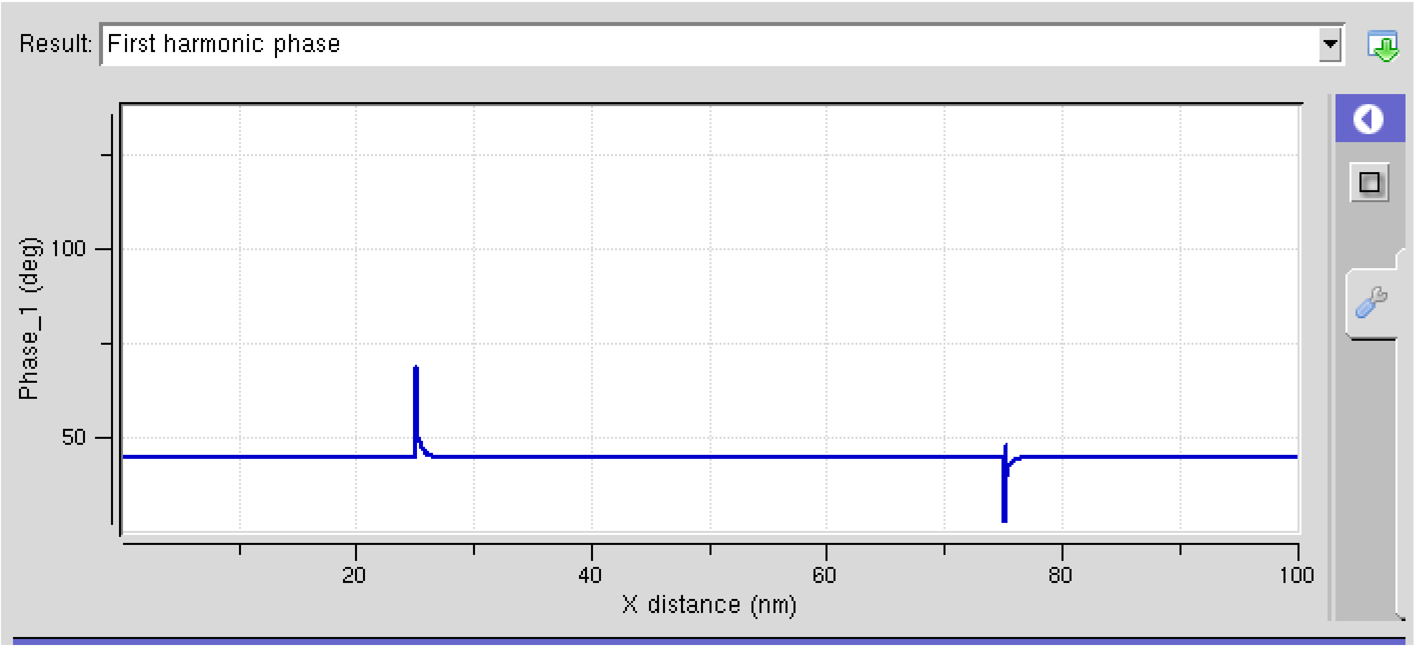
Measured topography



- A contrast is seen between the softer and stiffer materials in the measured topography image.

Phase image

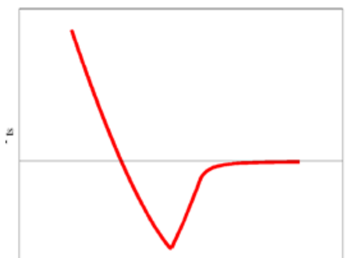
- No contrast is seen in the phase image (no dissipation).
- The phase $\phi = \sin^{-1}(A/A_{far}) = \sin^{-1}(0.7) = 44.27$

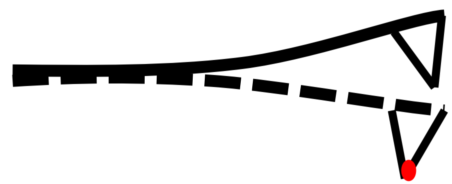


- Note that we are imaging in the repulsive regime (ϕ <90 deg)

Problem 2: AM-Scanning in the repulsive regime with dissipation

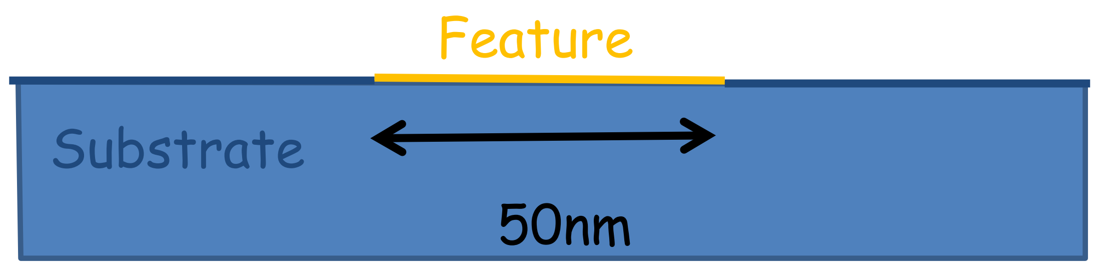
- What happens to the phase contrast when there is dissipation in the feature?





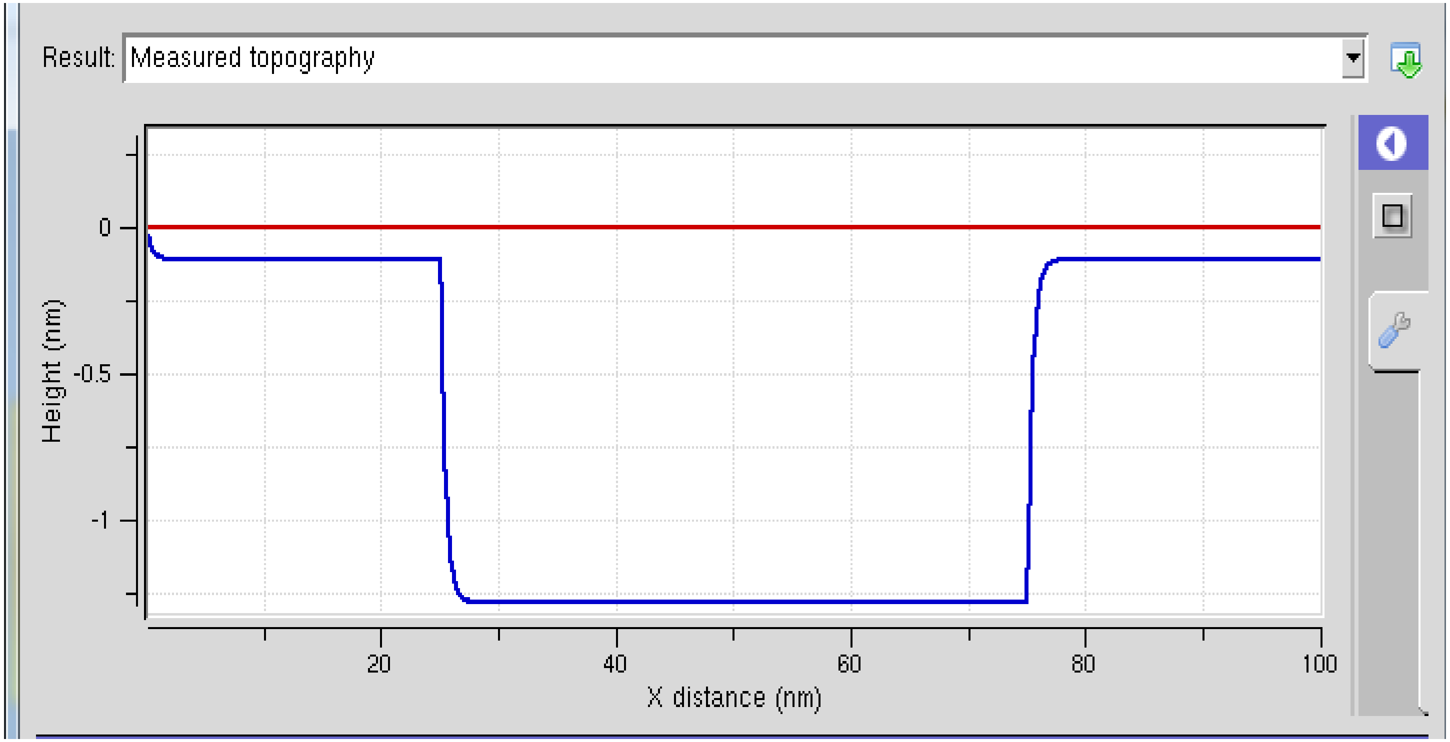
k=2N/m
Q=100
f_0= 40 kHz

Tip-sample interaction model for substrate: DMT
Young's modulus : 1 GPA



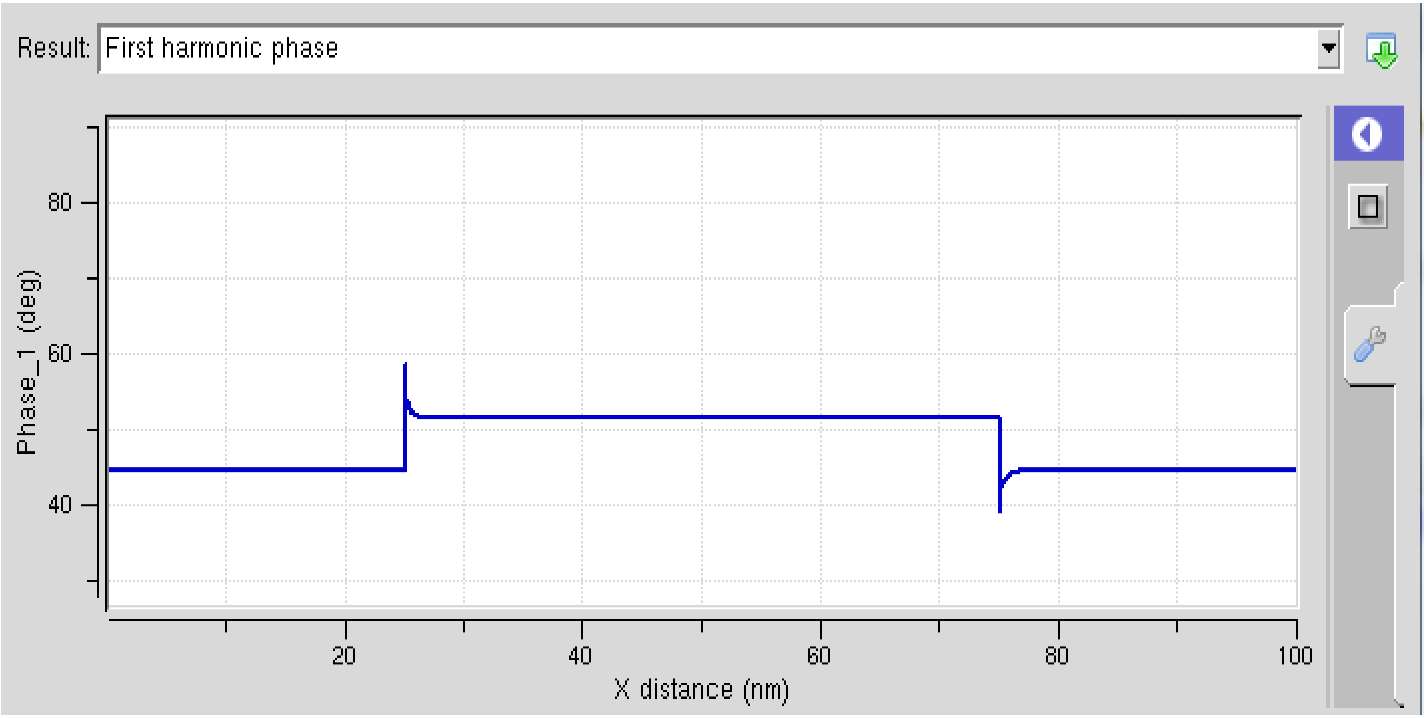
Tip-sample interaction model for substrate: DMT
Young's modulus : 0.1 GPA with visco-elastic forces

Measure topography



- Note that we are imaging in the repulsive regime (ϕ <90 deg)

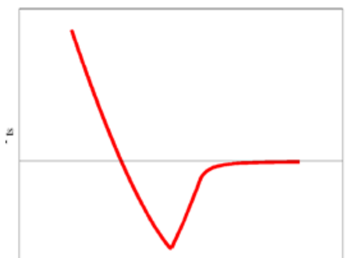
Phase image



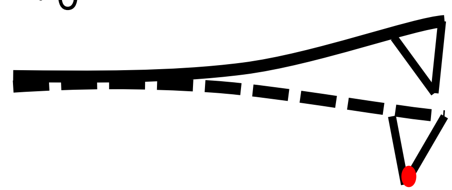
- A phase contrast is seen due to dissipation in the feature.
- The phase has increased.

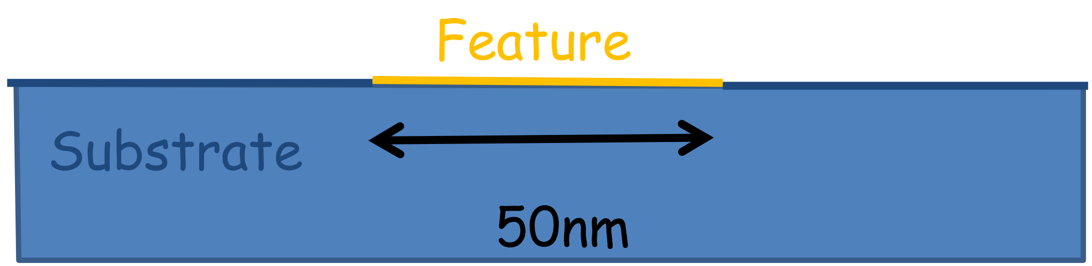
Problem 3: AM-Scanning in the attractive regime with dissipation

- What do you observe in the phase contrast on scanning in the attractive regime?
- Dissipation is achieved by modeling interactions in the feature using the JKR model.



k=2N/m
Q=100
f_0= 40 kHz

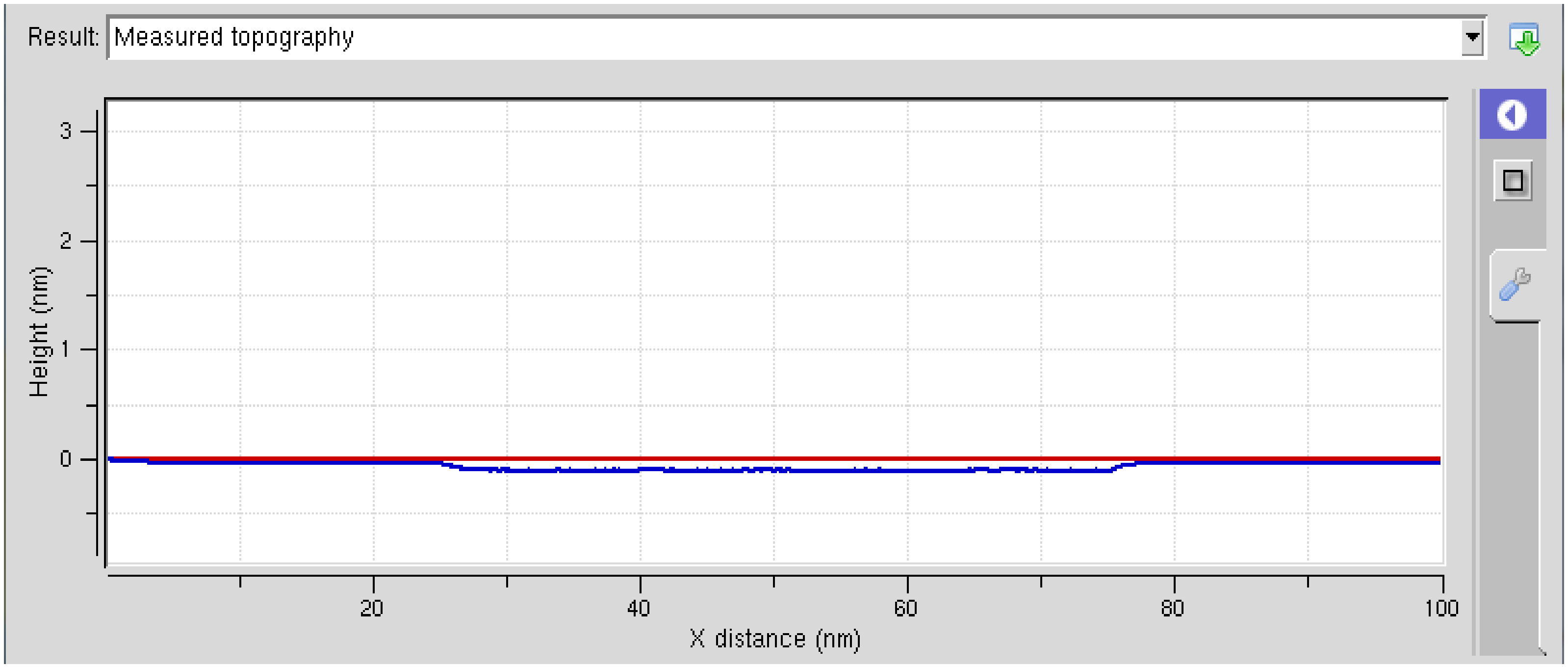




Tip-sample interaction model for substrate: DMT
Young's modulus : 150 GPA

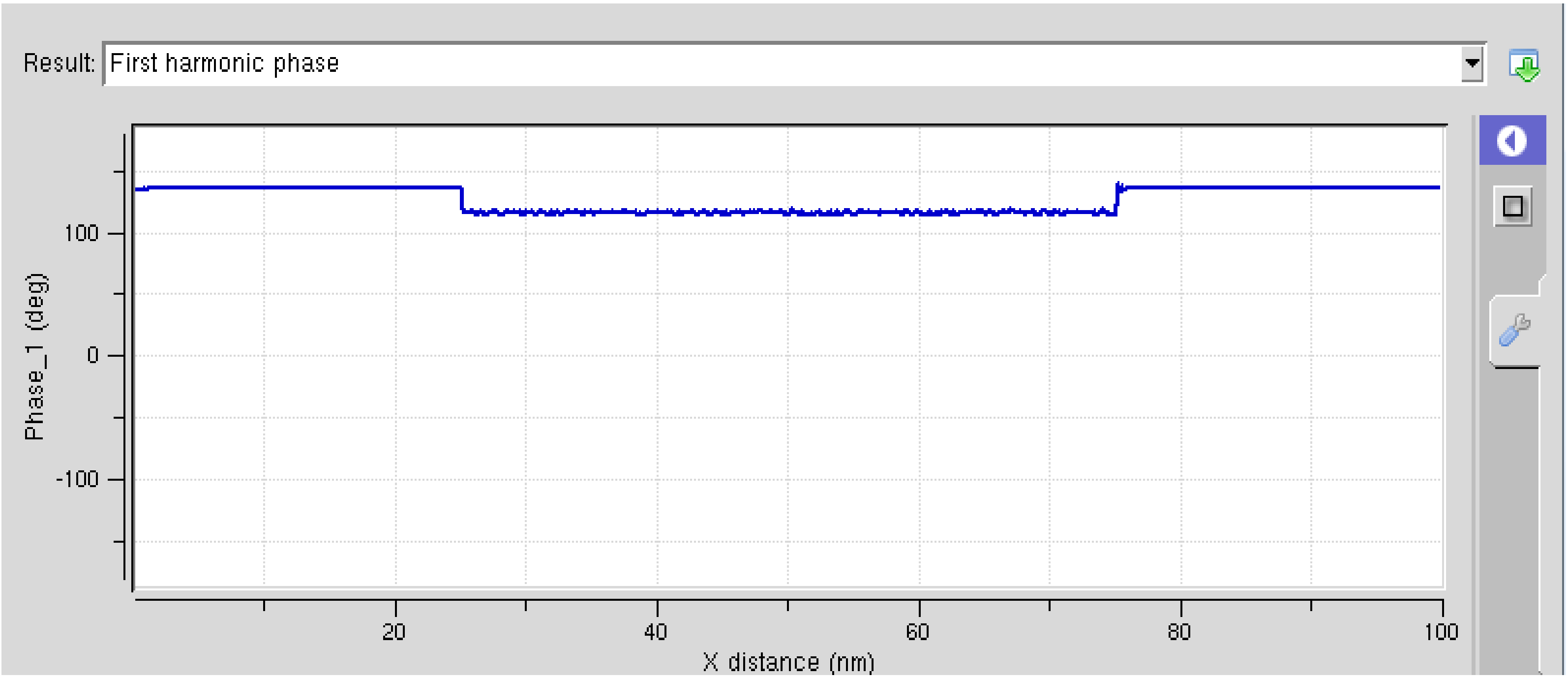
Tip-sample interaction model for substrate: Hertz
Young's modulus : 150 GPA with Capillary forces

Measure topography



- We can see a contrast in the topography image.

Phase image



- Note that we are imaging in the attractive regime.
- A phase contrast is seen due to dissipation in the feature.
- The phase has decreased.

Appendix: Parameter values for problem 1

PARAMETER	PROBLEM 1
Operating condition and cantilever properties	
Choose excitation source	Magnetic
Unconstrained amplitude (nm)	20
k (N/m)	2
Q	100
f	40
f_d	40
Tip mass	0
Set point ratio	0.7
Scan lines per second	1
Proportional gain	0.09
Integral gain	0.001
Sampling frequency (MHz)	1
Lockin filter order	2
Lockin time constant (us)	Auto calculate

Appendix: substrate properties and simulation parameters

PARAMETER	PROBLEM 1
Tip-sample interaction properties	
Tip sample interaction model	DMT
Tip radius (nm)	10
Young's modulus of tip (GPa)	130
Poisson's ratio of tip	0.3
Van der waals adhesion force (nN)	1.4167
Modulus of sample (Gpa)	1
Substrate Poisson's ratio	0.3
Simulation parameters	
Number of points plotted	1000
Accuracy vs speed	Standard speed
Scan length (nm)	10

Appendix: simulation parameters

PARAMETER	PROBLEM 1
Feature Properties	
Feature shape	Step
Feature height (nm)	0
Length of feature (nm)	50
Tip-sample interaction properties: feature	
Tip sample interaction model	DMT
Tip radius (nm)	10
Young's modulus of tip (GPa)	130
Poisson's ratio of tip	0.3
Auto calculate intermolecular distance	Yes
Van der waals adhesion force (nN)	1.4167
Young's modulus of sample (GPa)	0.1
Poisson's ratio of sample	0.3
Include Capillary forces	Yes
Critical gap (nm)	0.1
Energy dissipated (ev)	5

Only for including dissipation force. Else select 'No'

Appendix: Parameter values for problem 2

PARAMETER	PROBLEM 1
Operating condition and cantilever properties	
Choose excitation source	Magnetic
Unconstrained amplitude (nm)	10
k (N/m)	2
Q	100
f	40
f_d	40
Tip mass	0
Set point ratio	0.7
Scan lines per second	1
Proportional gain	0.09
Integral gain	0.001
Sampling frequency (MHz)	1
Lockin filter order	2
Lockin time constant (us)	Auto calculate

Appendix: substrate properties and simulation parameters

PARAMETER	PROBLEM 1
Tip-sample interaction properties	
Tip sample interaction model	DMT
Tip radius (nm)	10
Young's modulus of tip (GPa)	130
Poisson's ratio of tip	0.3
Van der waals adhesion force (nN)	1.4167
Modulus of sample (Gpa)	1
Substrate Poisson's ratio	0.3
Simulation parameters	
Number of points plotted	1000
Accuracy vs speed	Standard speed
Scan length (nm)	100

Appendix: simulation parameters

PARAMETER	PROBLEM 1
Feature Properties	
Feature shape	Step
Feature height (nm)	0
Length of feature (nm)	50
Tip-sample interaction properties: feature	
Tip sample interaction model	JKR
Auto calculate intermolecular distance	Yes
Van der waals adhesion force (nN)	1.4167
Young's modulus of sample (GPa)	0.1
Poisson's ratio of sample	0.3
Include Capillary forces	Yes
Critical gap (nm)	2
Energy dissipated (ev)	20