Lecture: P1_Wk3_L4

AFM Calibrations

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Four Calibrations

1. Spring constant of cantilever
2. Sensitivity of PSD (optical system)
3. X,Y calibration
4. Z calibration

1. How do you know the spring constant of the cantilever?

Manufacture specifications should allow direct calculation of k since

$$k = \frac{Ewt^3}{4L^3}$$

(will be derived in P1_Wk4_L1)

The calculation is highly sensitive to the thickness "t" of the cantilever, which is difficult to control accurately. The thickness "t" may not be uniform over the entire length of the cantilever! Also, many issues arise if cantilever is coated with a metal film.

Four techniques have been developed to independently calibrate k:

- Sader dynamic method
- Added mass
- Thermal noise
- Deflection of reference cantilever

} more in Part 2

Hutter and Bechhoefer, Rev. Sci. Instrum. **64**, 1868 (1993) and
Butt, Cappella and Kappl, Surf. Sci. Rep. **59**, 1 (2005).

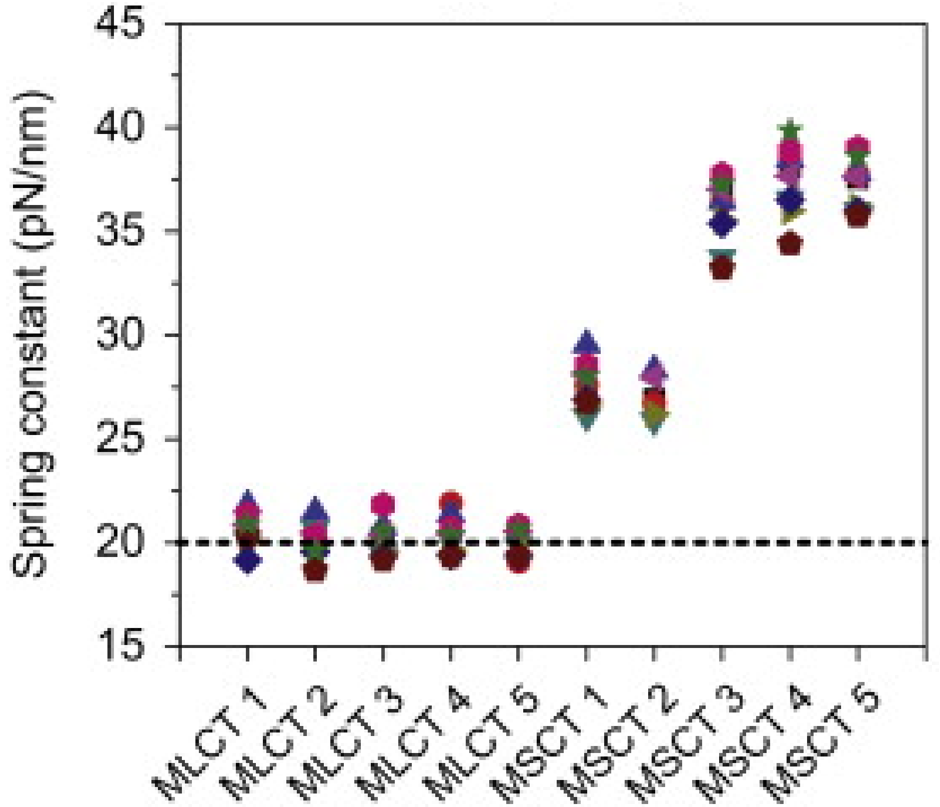
Why the variability in k?

Wafer of cantilever chips

http://probe.olympus-global.com/en/product/omcl_ac160ts_w2/

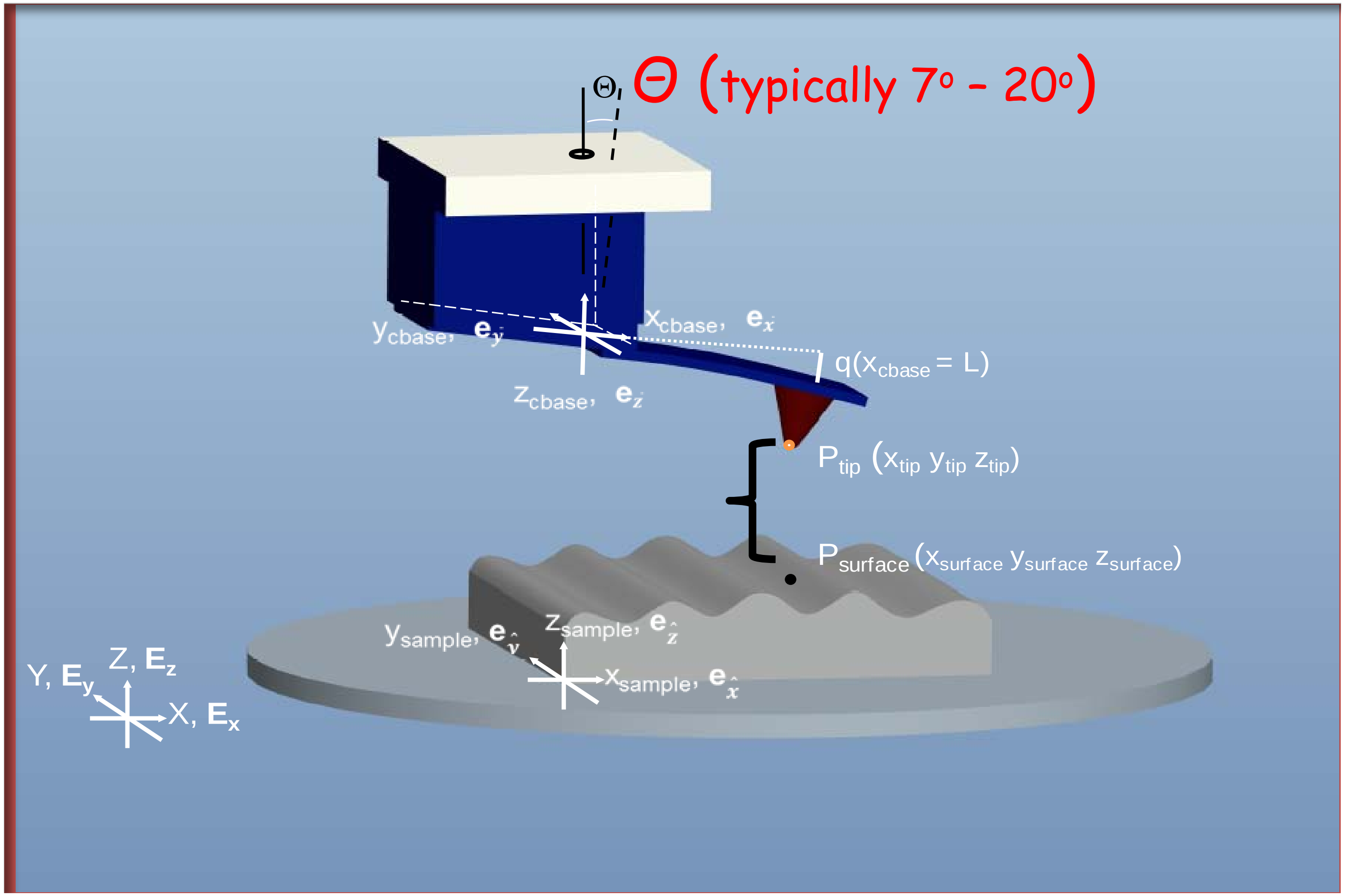
Recent Study Involving Ten Different AFMs

Results for rectangular cantilevers



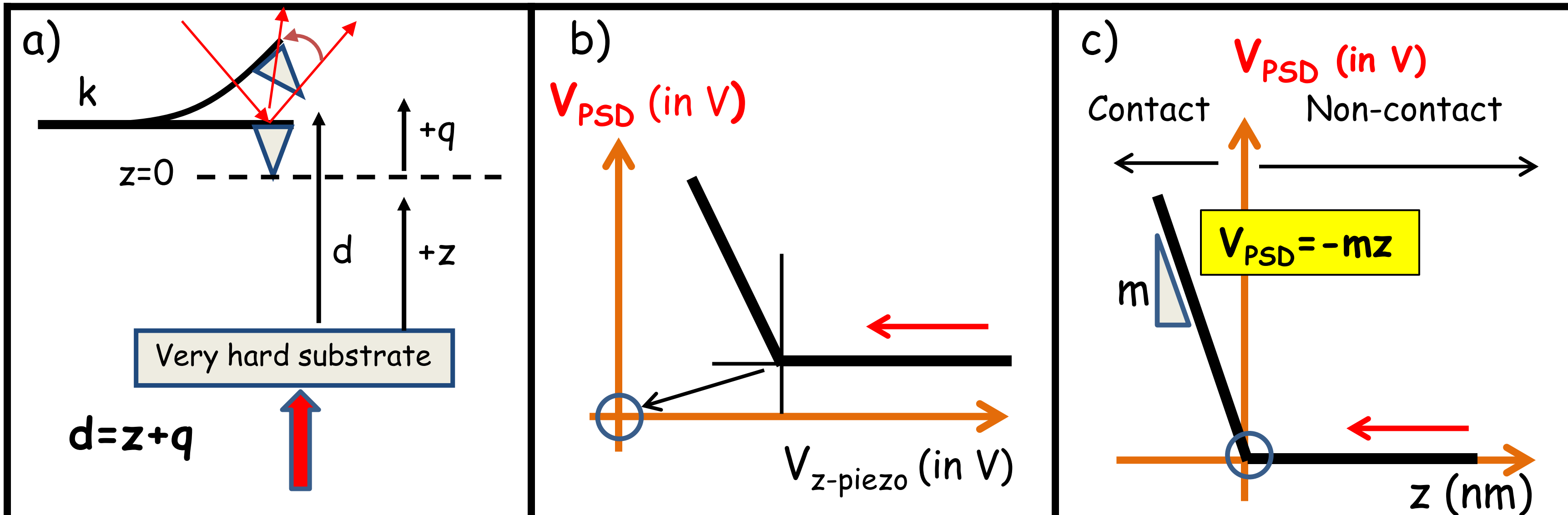
te Reit, et al., Ultramicroscopy **111**, 1659–1669 (2011).

Remaining Issues for Careful Work



Cantilever tilt angle **θ** increases measured k. Must divide measured k by $\cos^2\theta$.
Where is the force applied? May need to define L_{eff}.
Where is the laser focused when k is calibrated?

2. Calibration of the sensitivity S of the optical system
(PSD output voltage produced by a known cantilever deflection)

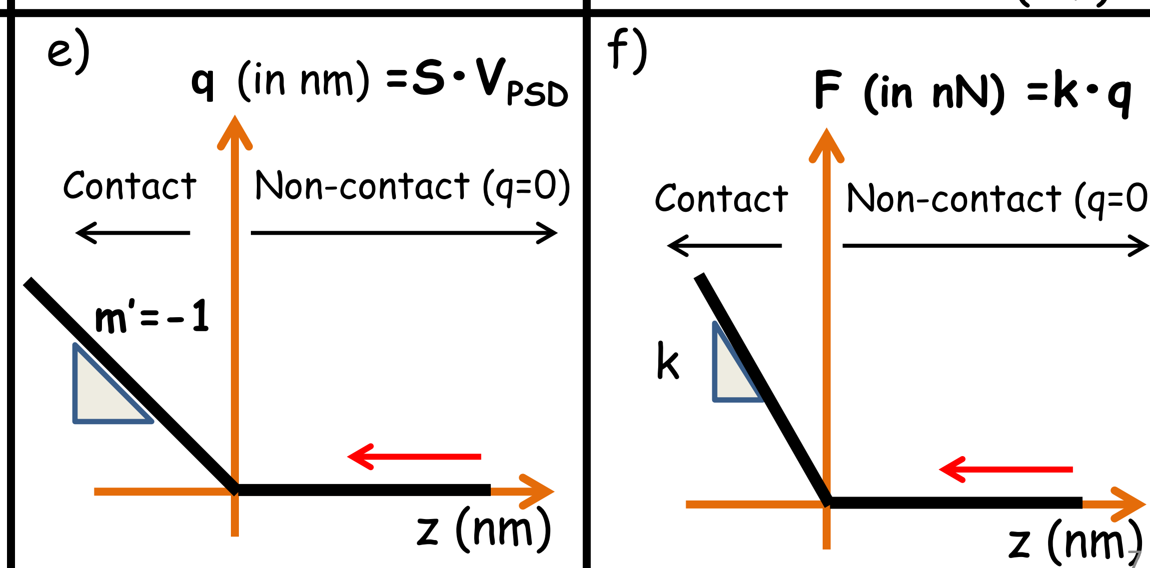


d)

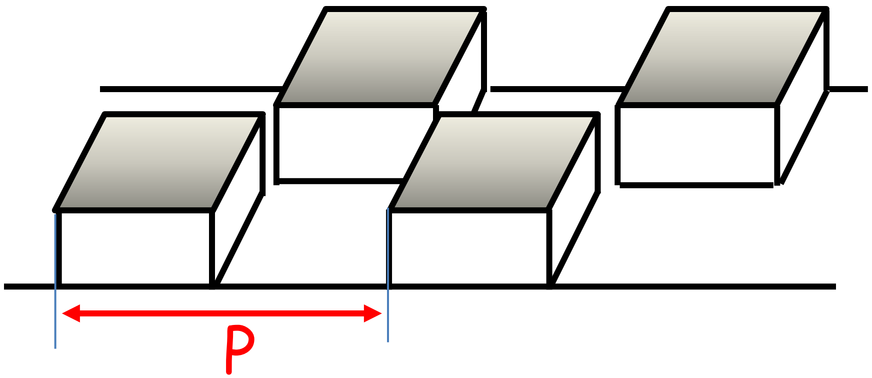
During contact q=-z
(infinitely hard sample,
no deformation: D=0)

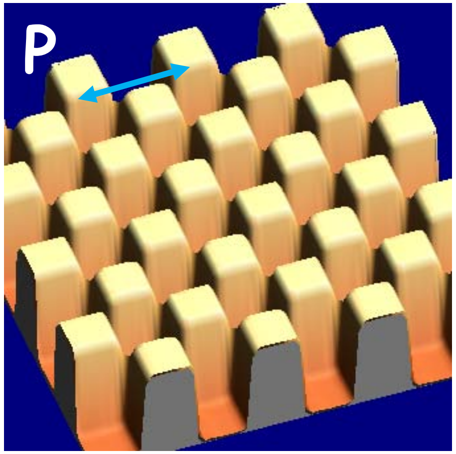
Find S such that:
$S \cdot V_{PSD} = S(-mz) = q$

m'=-mS=-1; S=1/m
Units: S = [nm/V]

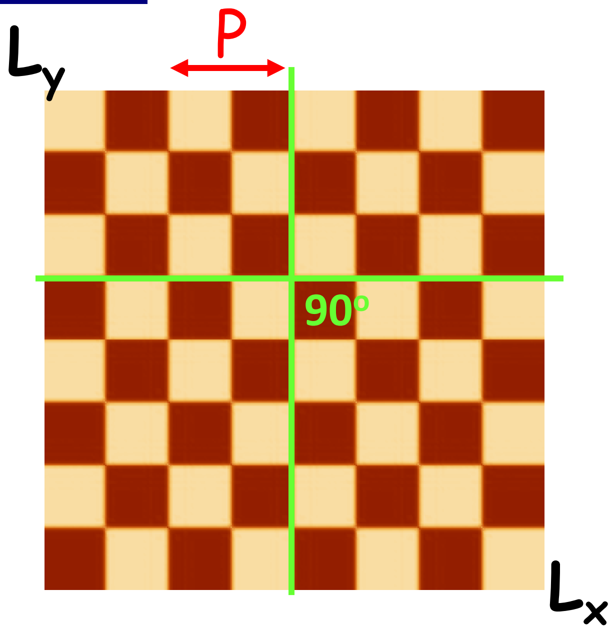


3. Calibration and orthogonality of X and Y scanners





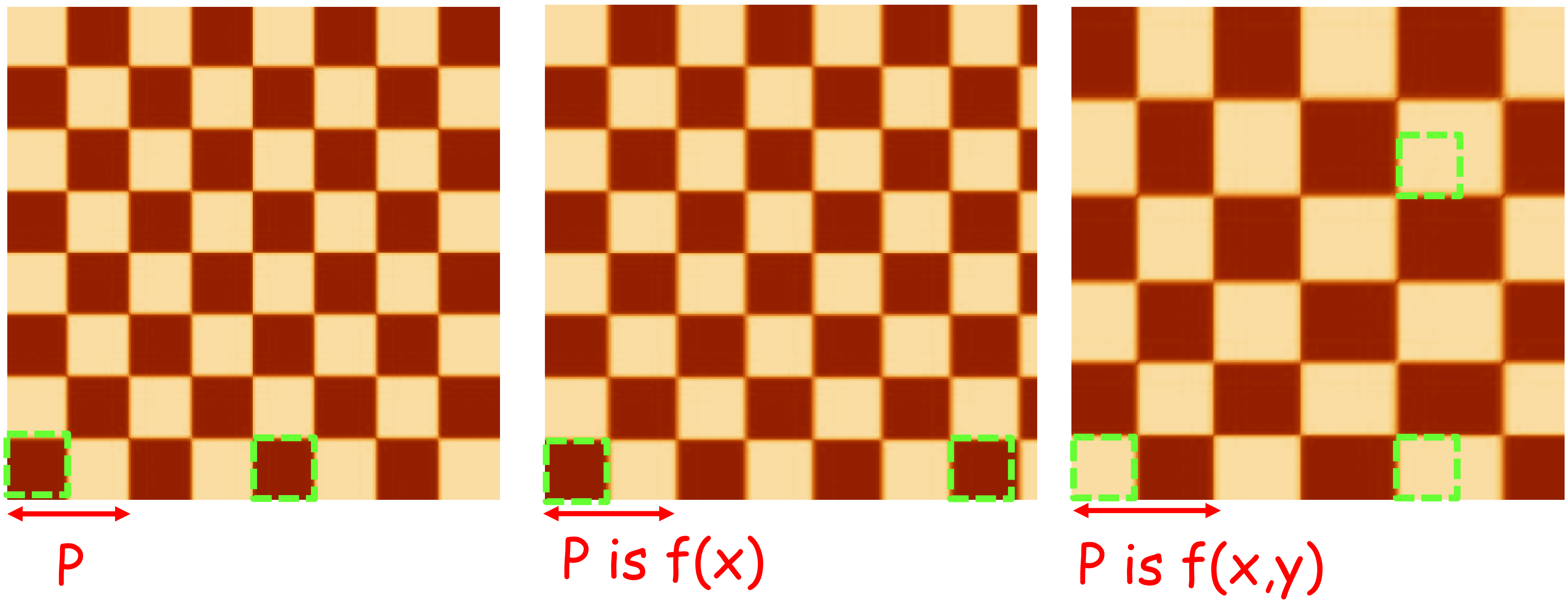
1. Obtain a checker-board calibration sample, with periodic square features of known dimension. Perform an AFM scan to obtain a reliable image.
2. Measure periods in the X and Y directions, using different regions of the image, obtain multiple values for these two quantities. Calculate the mean, the standard deviation, and the error in the mean.
3. Compare the values obtained to the known periodicity.
4. If necessary, adjust the X,Y calibration constants in the AFM control software to make the measured period equal to the known period.



5. After calibration, perform a second scan. Using the pattern alignment, check whether the angle between the X and Y scan direction is 90°. Deviations from a right angle indicate non-orthogonality between the X and Y scanners. This is especially important if your experiment requires that you **accurately measure angles**.

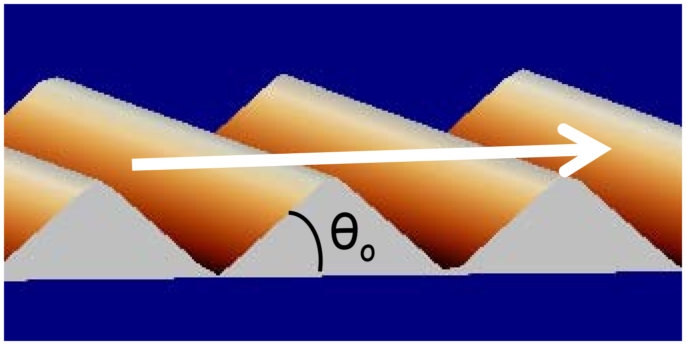
Non-linearity in the X and Y piezo scanners

Linear scan | 10% non-linear in x | Non-linear in both x and y

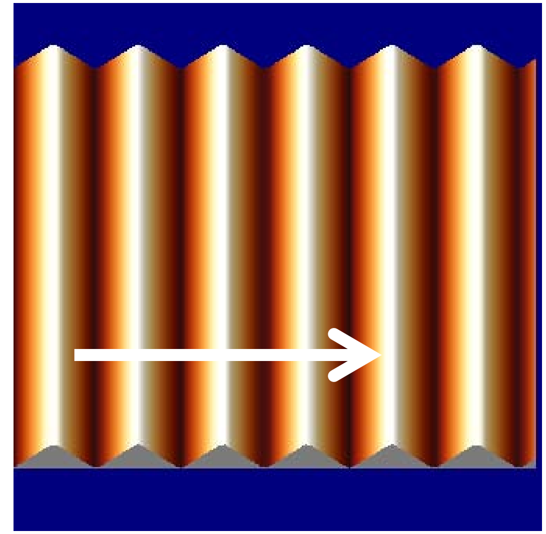


X-Z and Y-Z coupling of scanners

1. Obtain a calibration sample with periodic triangular features defined by the crystallography of Si(111) - $\theta_o = 55^o$

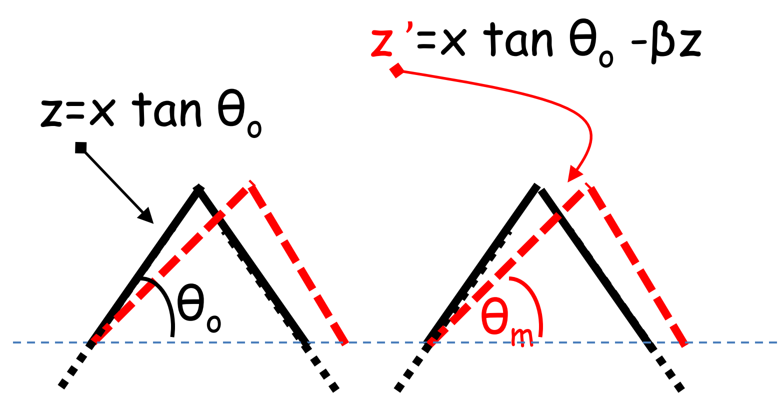


x-scan direction



2. Align sample in AFM so the x-scan direction is perpendicular to the triangular ridges. Perform an AFM scan and obtain a reliable image.
3. From the AFM image, determine the angle θ_m and compare to the known value of θ_o. If they are not the same, there is a coupling β between x and z scanner given by:

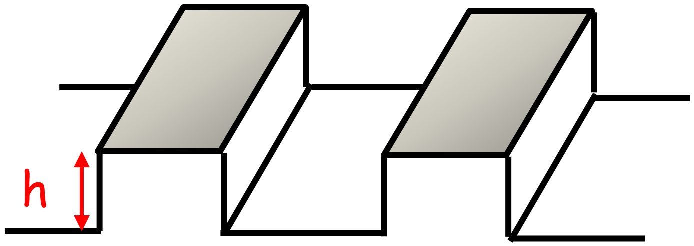
$$\beta = 1 - \frac{\tan(\theta_m)}{\tan(\theta_o)}$$

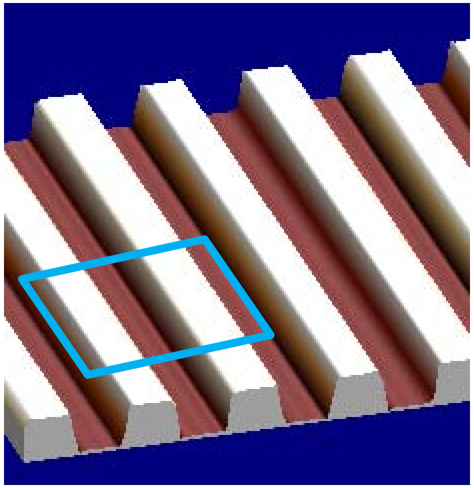


4. Remove sample and rotate through 90°, so the y-scan direction is now perpendicular to the triangular ridges.
5. Repeat steps 2 and 3.

4. Calibration of Z piezo

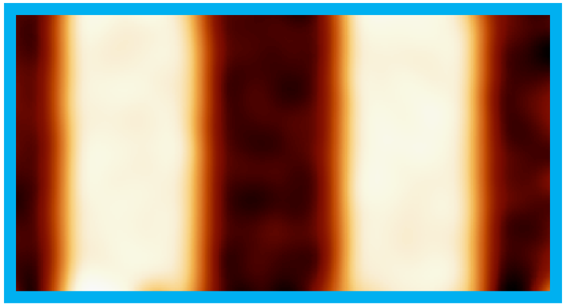
1. Obtain a calibration sample with periodic 1D steps of known height etched into SiO_2. Perform an AFM scan and obtain a reliable image.



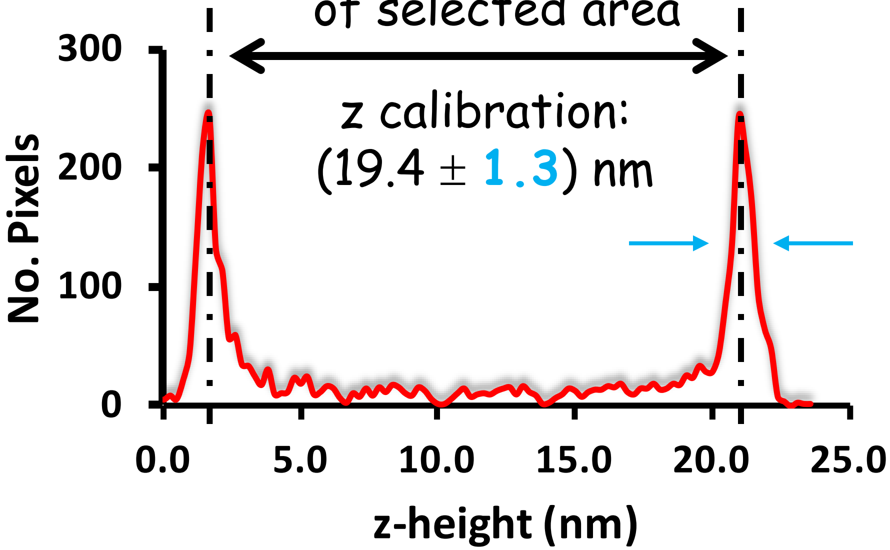


Select step height to match application, e.g.: h=25 nm; 100 nm; 500 nm; 1000 nm; 1500 nm

selected area

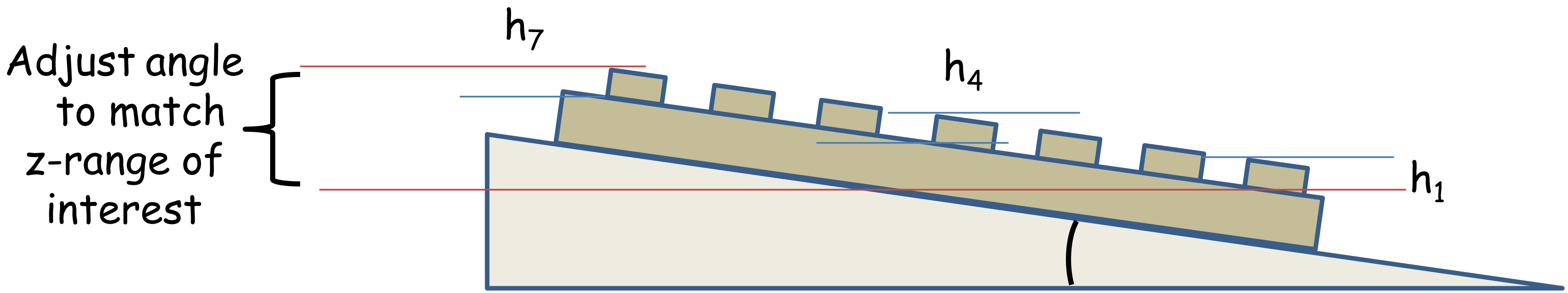


z-height **histogram** of selected area

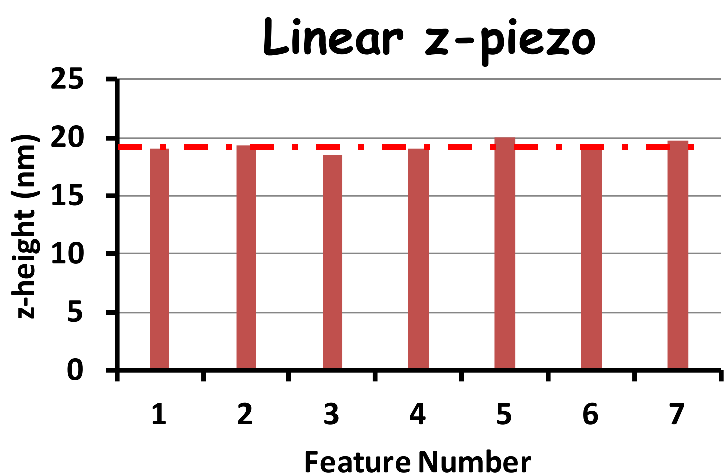


Non-linearity in the z-piezo

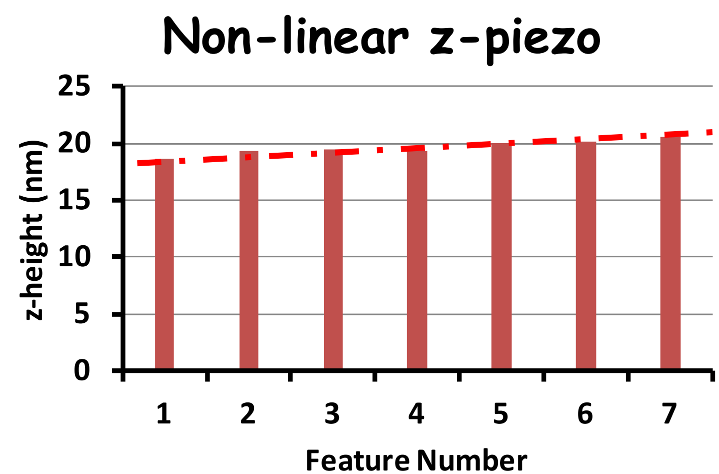
1. Machine a triangular wedge of known angle and mount the calibration sample with periodic 1D steps of known height etched into SiO_2.



2. Obtain AFM image and measure height of several features along sample.



vs.



P. Eaton and P. West, Atomic Force Microscopy, Oxford Press (2010)

Important Issue: AFMs located in multi-user central facilities – when was the calibration last checked?

Remember: Just because you are trying to be careful doesn't mean that you will not make a mistake.

Acknowledgement: Many of the images used in this lecture were processed by the free AFM software WSxM. See I. Horas, et al. Rev. Sci. Instrum. 78 013705 (2007).

Up Next: Contact Mode Scans