

USING CDS AND DVDS AS DIFFRACTION GRATINGS

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Purpose of CDs and DVDs as Diffraction Gratings Activity

- Observe diffraction of light waves through a CD and DVD
- CDs and DVDs are well known to students so they are likely to be interested in the lab and participate in discussion
- Easy to transition into a discussion about current technology and trends involving data storage devices
- Incorporates nanotechnology by including AFM (Atomic Force Microscope) images of a CD and DVD for the students to compare with their macro-scale data

CDs and DVDs as Diffraction Gratings

- CDs/DVDs display streaks of colors when white light falls on them
- The digital information (alternating pits and smooth reflecting surfaces) stored on the discs form closely spaced rows acting like a reflecting diffraction grating
- The rows do not reflect nearly as much light as the portions of the disc that separate them
- In these portions the light reflected undergoes constructive interference in certain directions. Therefore, when white light is reflected from the disc each wavelength of light can be seen at a particular angle with respect to the disc's surface producing a light spectra

Creating Transmission Gratings from a CD



1: Scratch the label surface of the CD to begin especially with painted labels (Blank CDs work best).



2: Use Quik-stic or any other tape to peel off the label and reflecting layers.



3: CD ready to use as transmission diffraction grating

Creating Transmission Gratings from a DVD



1: Use a razor blade to split the two layers of the DVD along the edge.



3: Use Quik-stic or any other tape to peel off the reflecting layer.

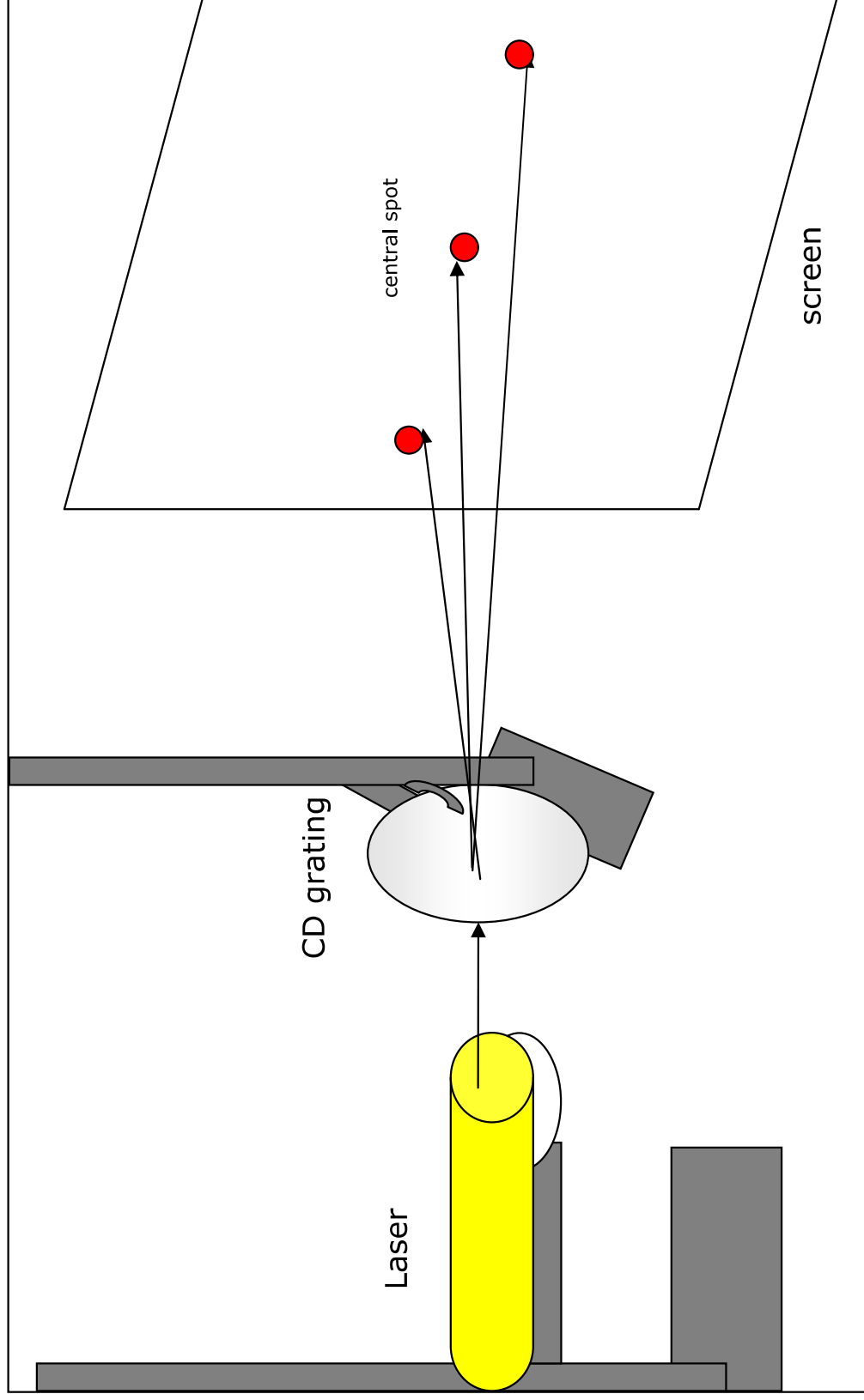


2: Separate the two polycarbonate layers



4: The transparent piece acts as a transmission grating.

Experiment Set-up: Diffraction Pattern



Diffraction Images



Equations

$$d (\sin\theta) = m\lambda \quad m = 0, \pm 1, \pm 2, \dots$$

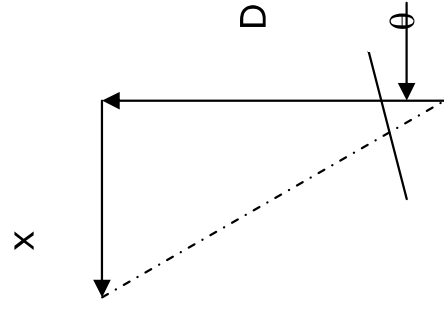
d = distance between slits

θ = angle of diffraction

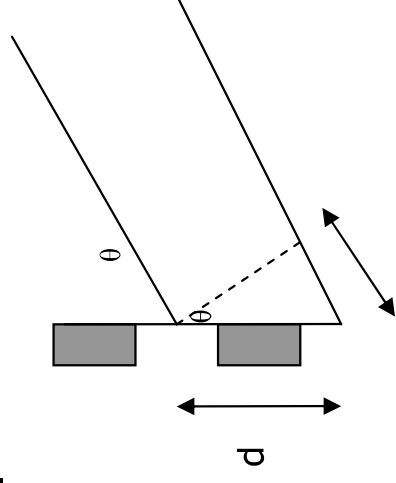
λ = wavelength of light

m = the order # for the bright fringes

- To find θ measure distance from grating to screen and the first order distance and then by using trigonometry calculate the angle.



$$\theta = \tan^{-1}(x/D)$$



Calculations: CD and Laser

Equation : $d \sin \theta = m \lambda$

$$x_{\text{avg}} = \underline{13.95 \text{ cm}}$$

$$D = \underline{29.5 \text{ cm}}$$

$\theta = \text{angle of diffraction} = \tan^{-1} (x/D)$

$$\rightarrow \tan^{-1}(13.95/29.5) = \underline{25.3^\circ}$$

$m = 1$ (first order)

$$\lambda = 650 \text{ nm} \pm 10$$

$$d = (1)(650 \text{ E } -9 \text{ m}) / (\sin 25.3^\circ) =$$

1.52 μm

Calculations: DVD and Laser

Equation : $d \sin \theta = m \lambda$

$$x_{\text{avg}} = \underline{42.5 \text{ cm}}$$

$$D = \underline{20 \text{ cm}}$$

$\theta =$ angle of diffraction = $\tan^{-1} (x/D)$

$$\rightarrow \tan^{-1}(42.5/20) = \underline{64.8^\circ}$$

$m=1$ (first order)

$$\lambda = 650 \text{ nm} \pm 10$$

$$d = (1)(650 \text{ E}^{-9} \text{ m}) / (\sin 64.8^\circ) =$$

0.72 μm

AFM Image Measurements and Comparisons of Track Pitch: CD and DVD

- **$CD_{AFM} = 1.57 \mu\text{m}$**
- **$CD_{CALC} = 1.52 \mu\text{m}$**
- **$CD_{ACTUAL} = 1.6 \mu\text{m}$ (tolerance = $0.1 \mu\text{m}$)**

- **$DVD_{AFM} = 0.797 \mu\text{m}$**
- **$DVD_{CALC} = 0.72 \mu\text{m}$**
- **$DVD_{ACTUAL(4.7 \text{ GB})} = 0.74 \mu\text{m}$**

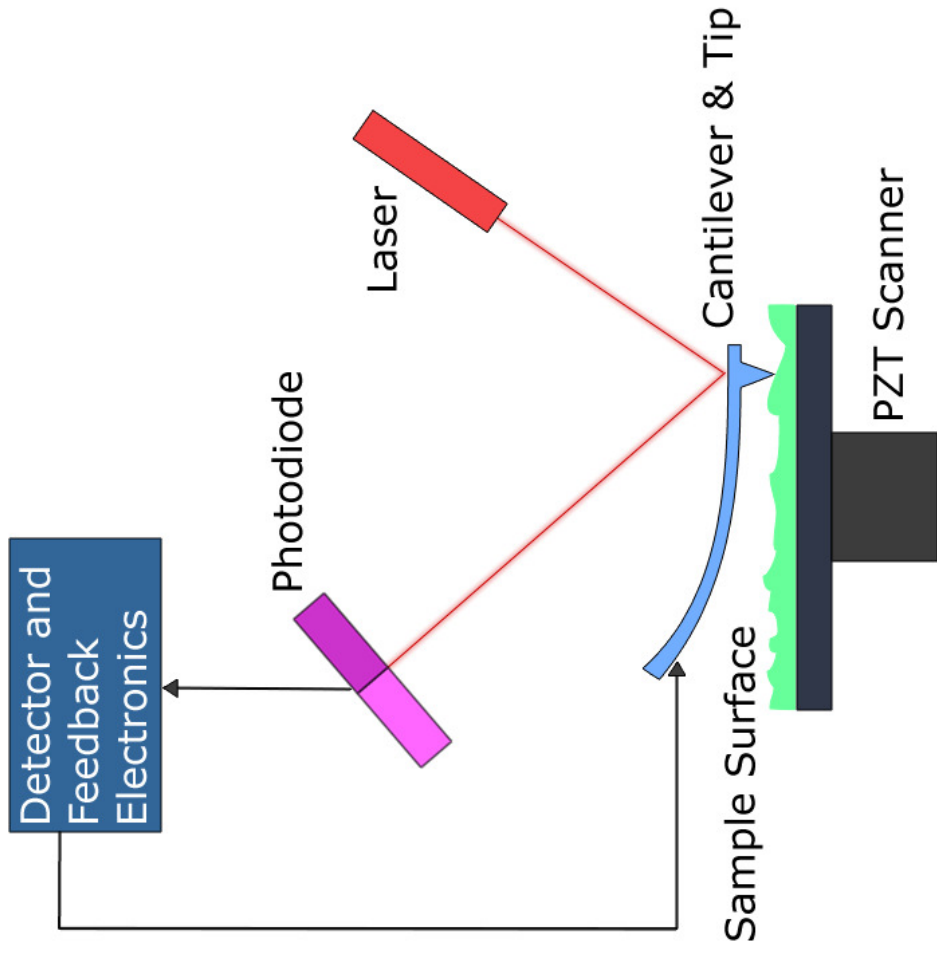
Experimental Results

- ❖ The grating element calculations from the diffraction pattern will agree very well with the spacing measured from analyzing the AFM images.
- ❖ The spacing of tracks in a DVD is about half as that in a CD giving it twice as many tracks per mm. This accounts for about a two fold gain in the capacity of a DVD relative to CD.
- ❖ The average bit length and the data area of a DVD relative to a CD gives it about a 3 fold gain and the other 2 fold gain comes from its improved error correction procedures.

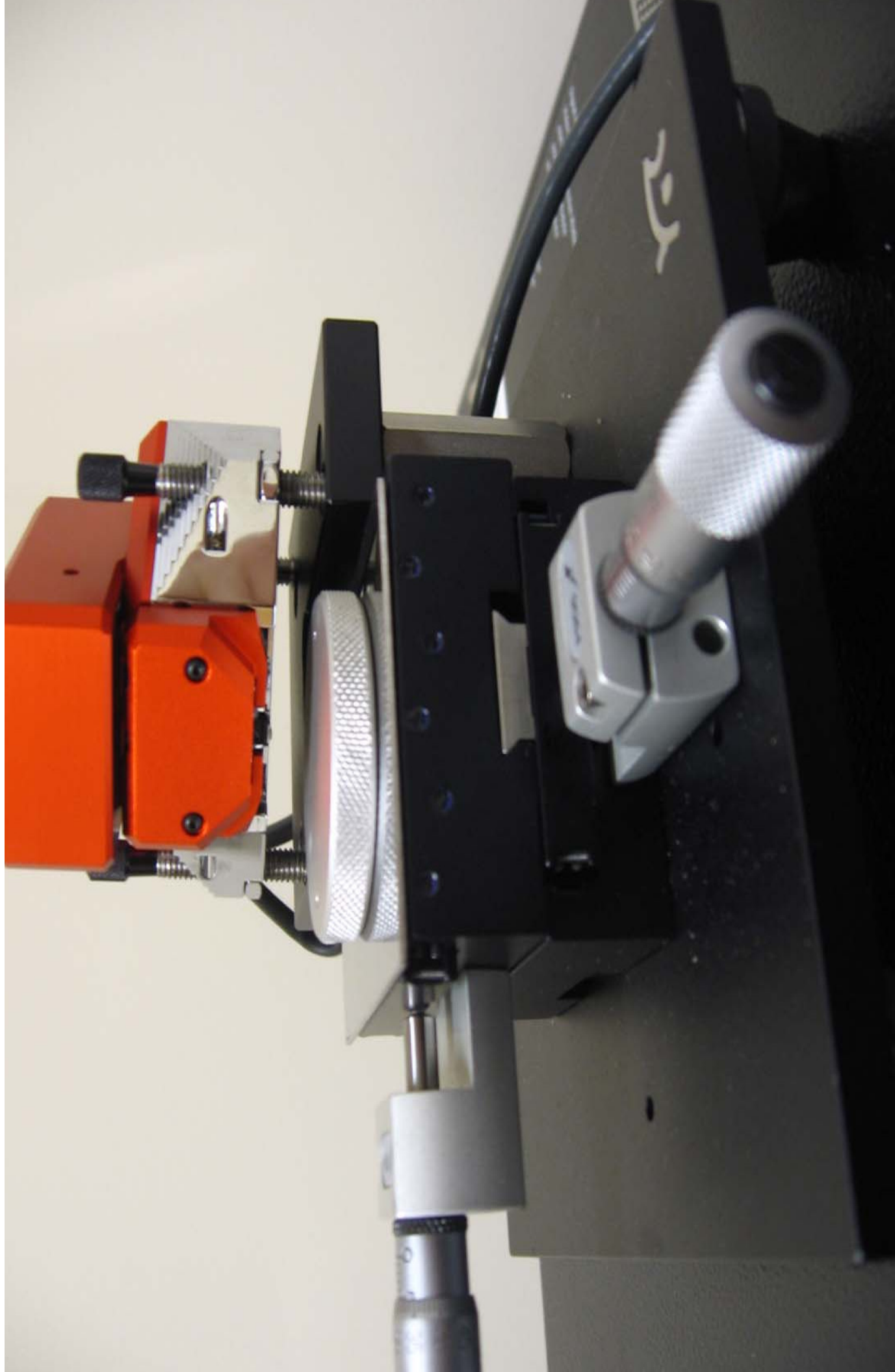
Atomic Force Microscope

- Atomic Force Microscopes (AFMs) are devices that measure the surface topography of a sample on a nanometer/micrometer scale and turn those measurements into an image.
- The basic principle behind the AFM is based on the interaction between a probe (a sharp tip attached to a cantilever) and the atomic surface of the sample.
- The forces on the tip can be attractive or repulsive and cause the tip to deflect due to a change in these forces. This deflection is detected by the reflection of a laser beam shone on the back surface of the cantilever.

AFM

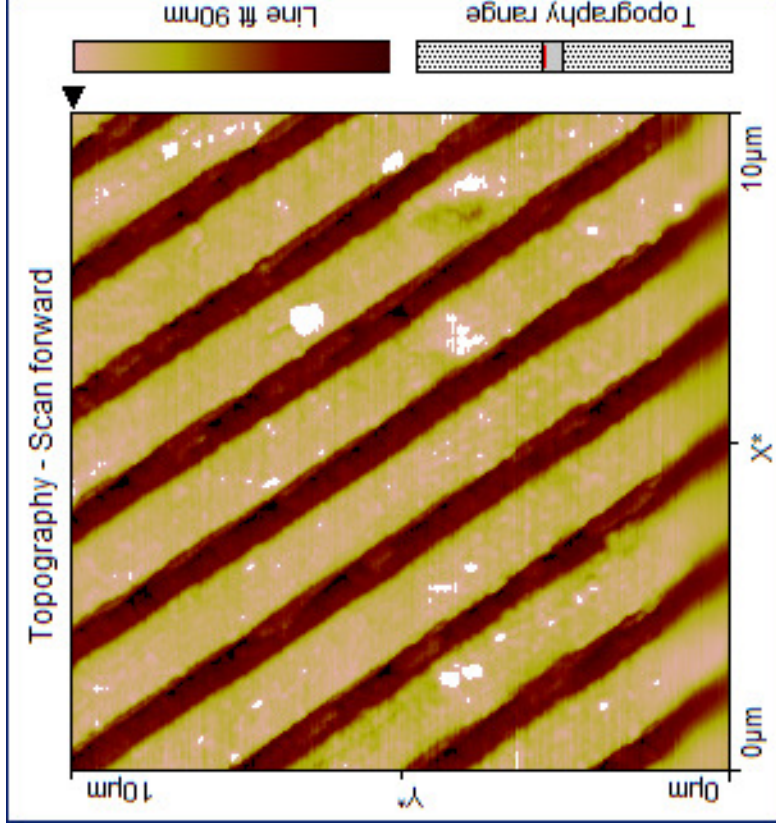


http://wills-nanotech.blogspot.com/2006_04_01_archive.html



Nanosurf® easyScan 2 AFM System

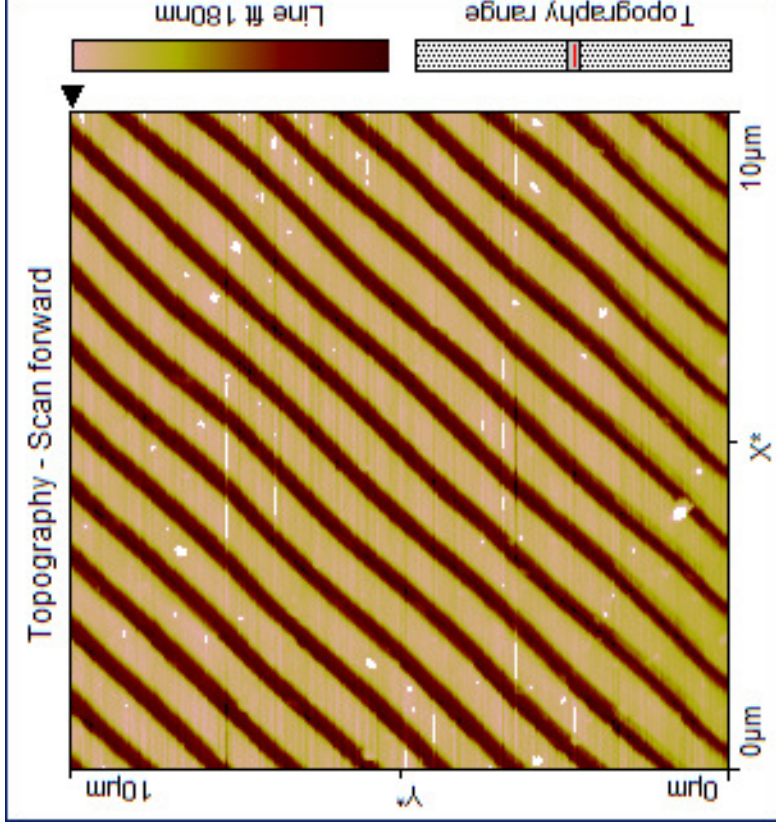
AFM Images of CD and DVD (unrecorded)



CD-Blank

(10 μm scan)

Track pitch = 1.57 μm

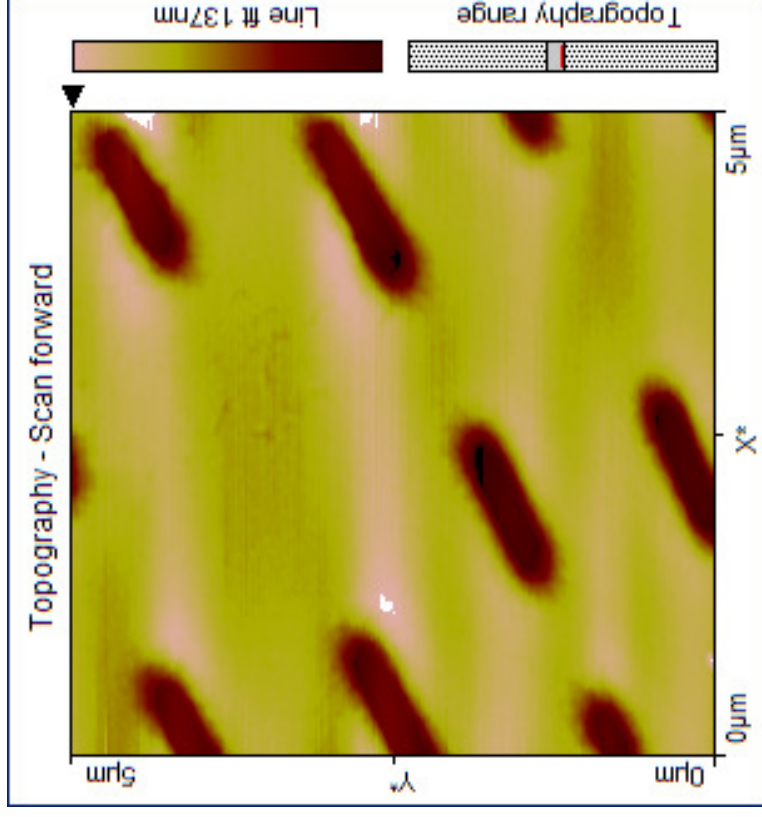


DVD- Blank

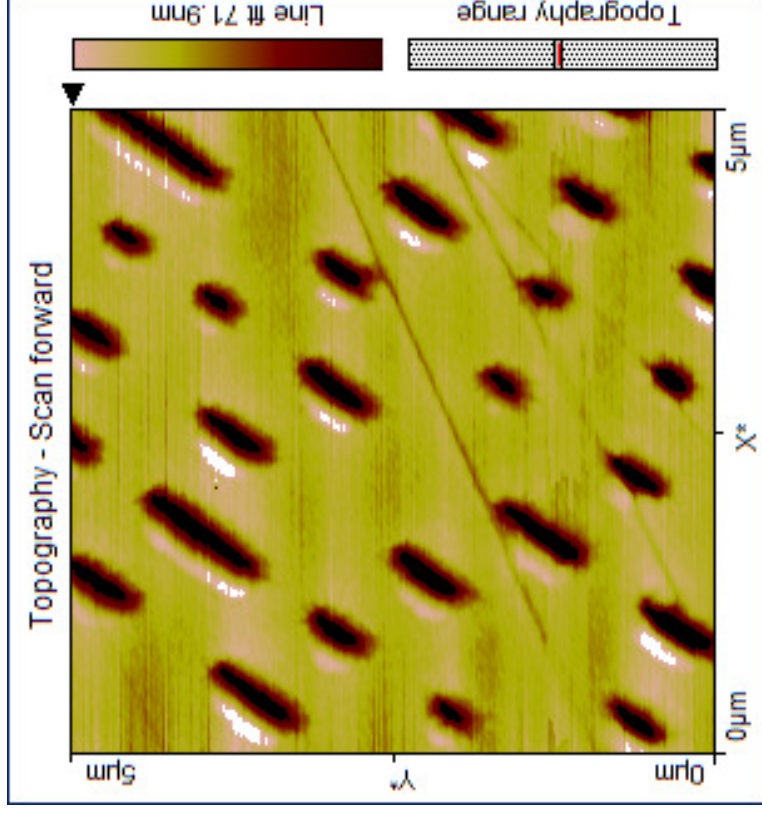
(10 μm scan)

Track pitch = 0.780 μm

AFM Images CD/DVD (recorded)



CD - data encrypted
scan size : 5 µm



DVD - data encrypted
scan size : 5 µm

Further Investigations

- Obtain interference pattern with double layered DVD with the two layers acting like double slits and use it to determine separation of the information layers
- Investigate average data bit length in Blu-ray DVD relative to DVD
- Use light sensors and optical levers to investigate oscillating systems