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 know 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.

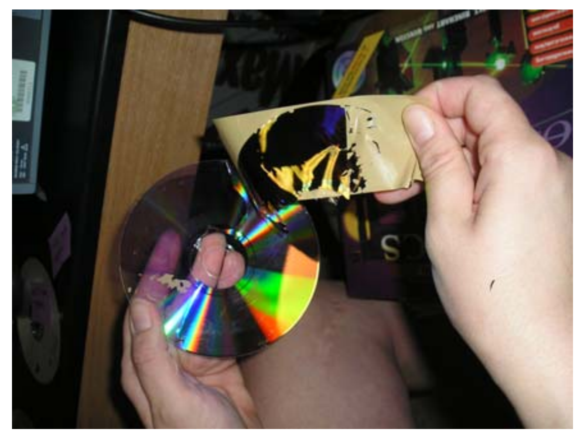
3: CD ready to use as transmission diffraction grating

Creating Transmission Gratings from a DVD

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

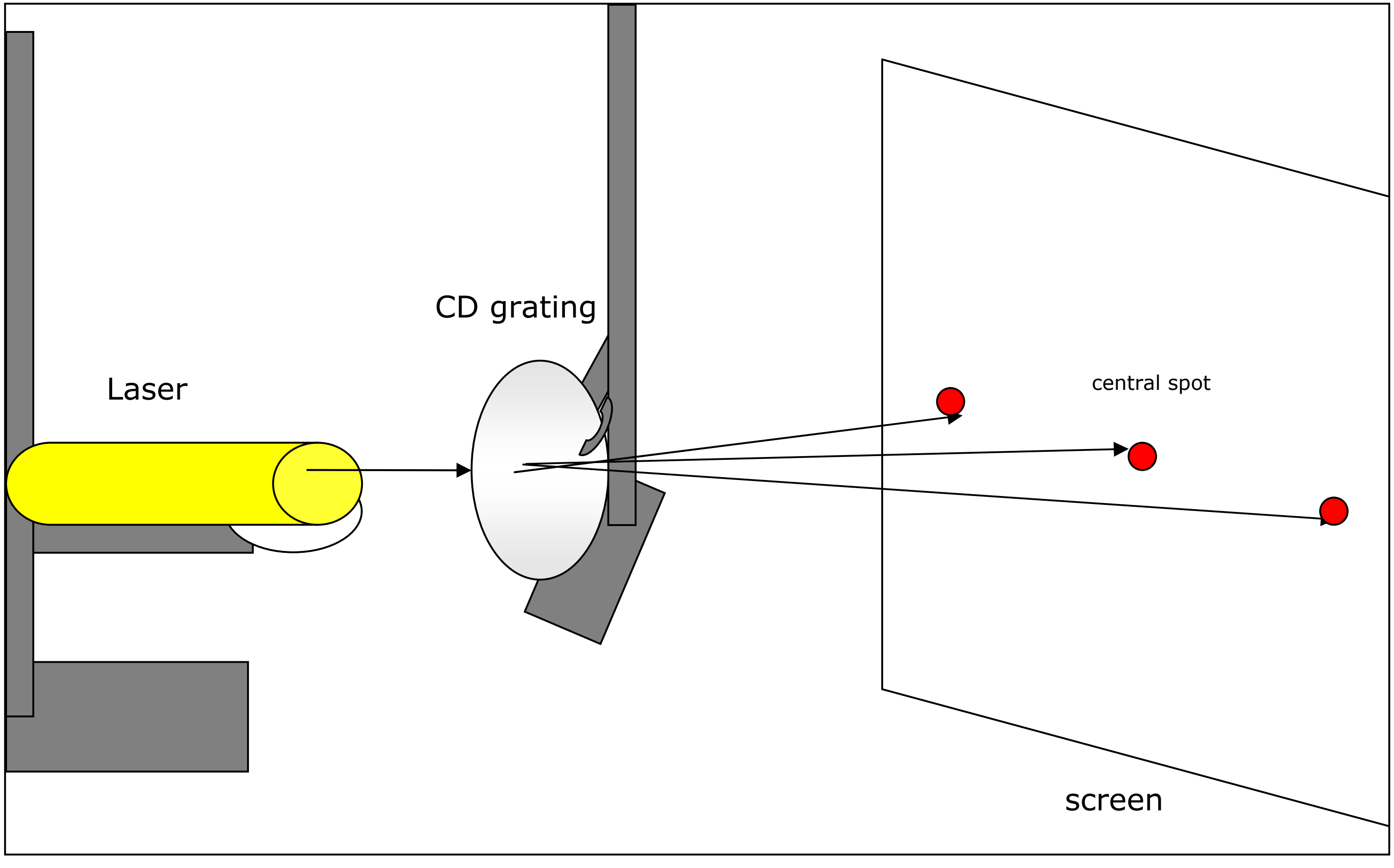
2: Separate the two polycarbonate layers

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

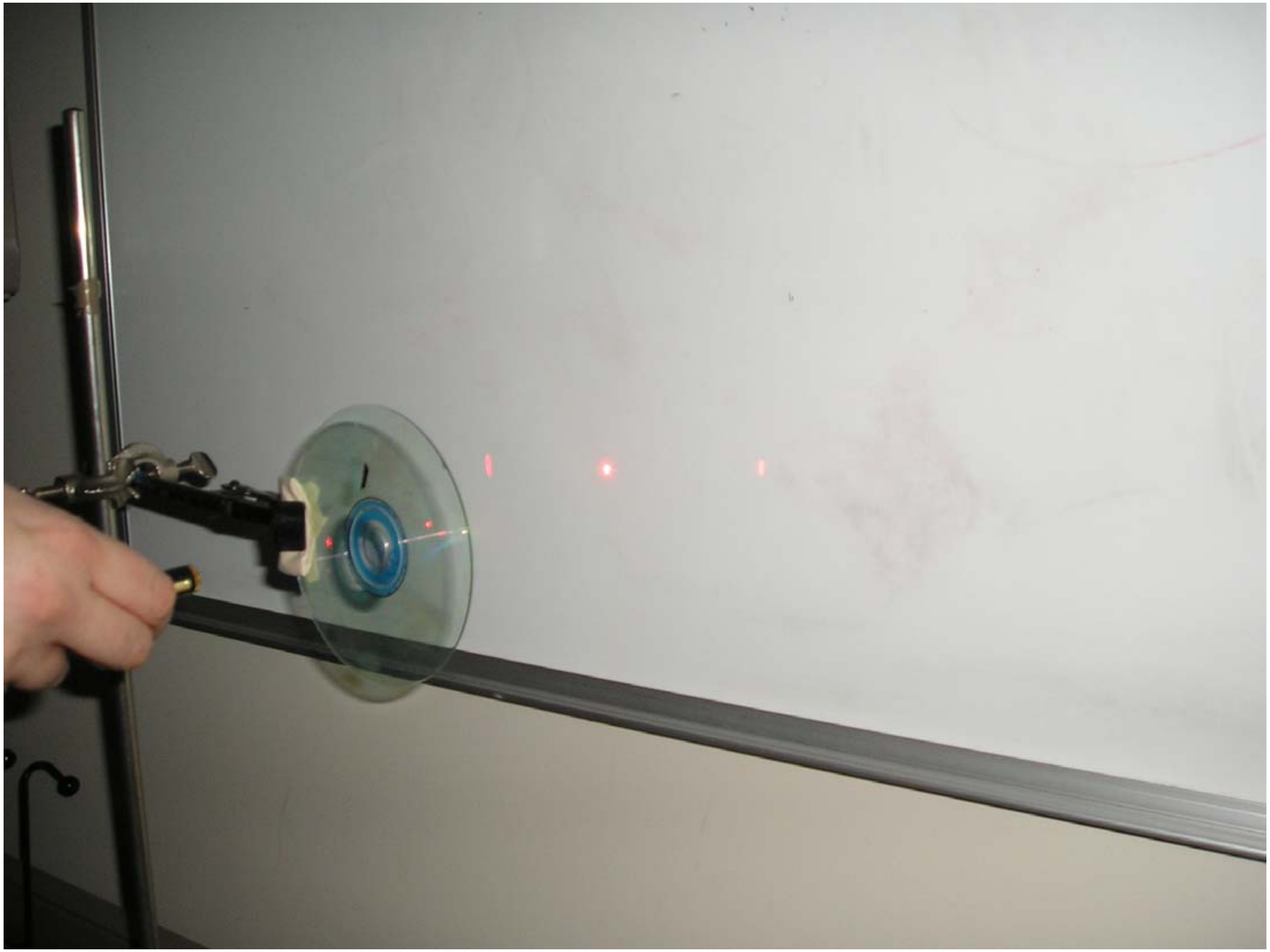


4: The transparent piece acts as a transmission grating.

Experiment Set-up: Diffraction Pattern



Diffraction Images



Equations

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

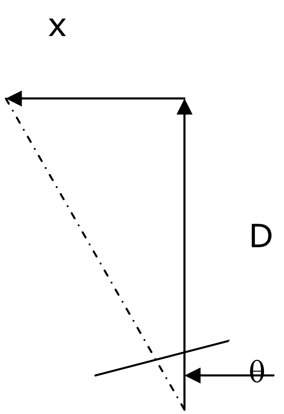
d = distance between slits

θ = angle of diffraction

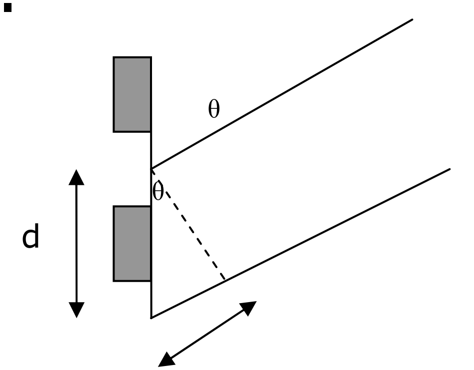
λ = wavelength of light

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

<u>Equation</u> : dsinθ=mλ

x_{avg} = <u>13.95 cm</u>   D = <u>29.5 cm</u>

θ=angle of diffraction = tan-1 (x/D)

→ tan-1(13.95/29.5) = <u>25.3°</u>

m=1 (first order)

λ= 650 nm ± 10

d = (1)(650 E -9 m)/(sin 25.3°) =

1.52 μm

Calculations: DVD and Laser

<u>Equation</u> : dsinθ=mλ

x_{avg} = <u>42.5 cm</u>   D = <u>20 cm</u>

θ=angle of diffraction = tan-1 (x/D)

→ tan-1(42.5/20) = <u>64.8°</u>

m=1 (first order)

λ= 650 nm ± 10

d = (1)(650 E -9 m)/(sin 64.8°) =

0.72 μm

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

- **CD_{AFM} = 1.57 μm**
- **CD_{CALC} = 1.52 μm**
- **CD_{ACTUAL} = 1.6 μm (tolerance = 0.1 μm)**

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

Experimental Results

- The grating element calculations from the diffraction pattern will agree very well with the spacing measured from analyzing the AFM images.

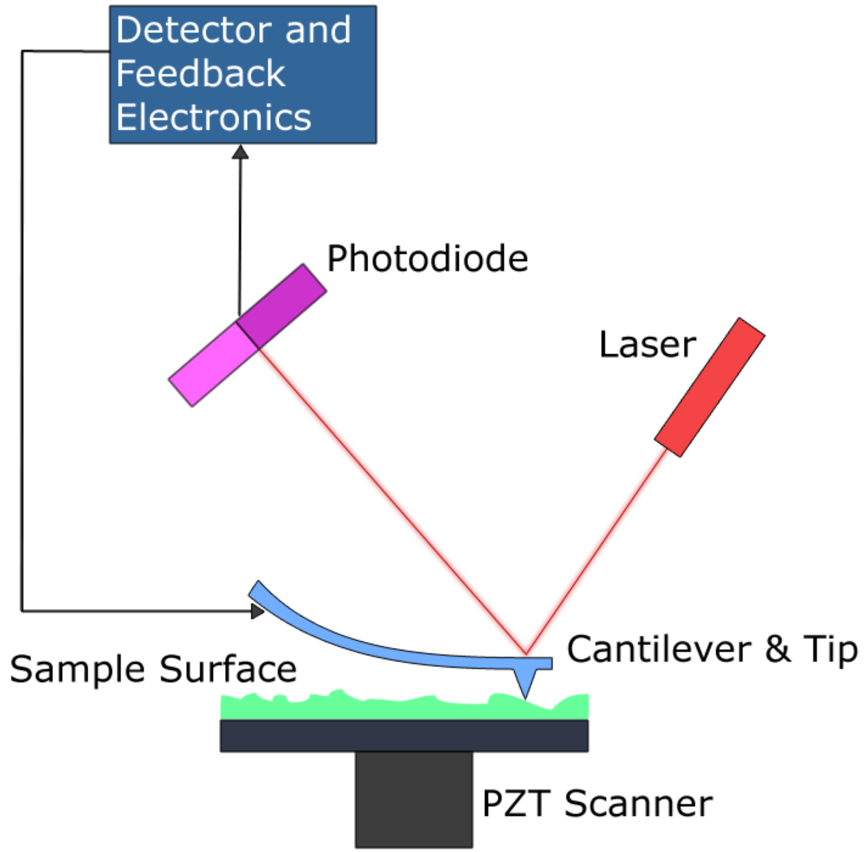
- The spacing of tracks in a DVD is about half as that in a CD giving it twice as many tracks per mm. This accounts for about a two fold gain in the capacity of a DVD relative to CD.

- 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.

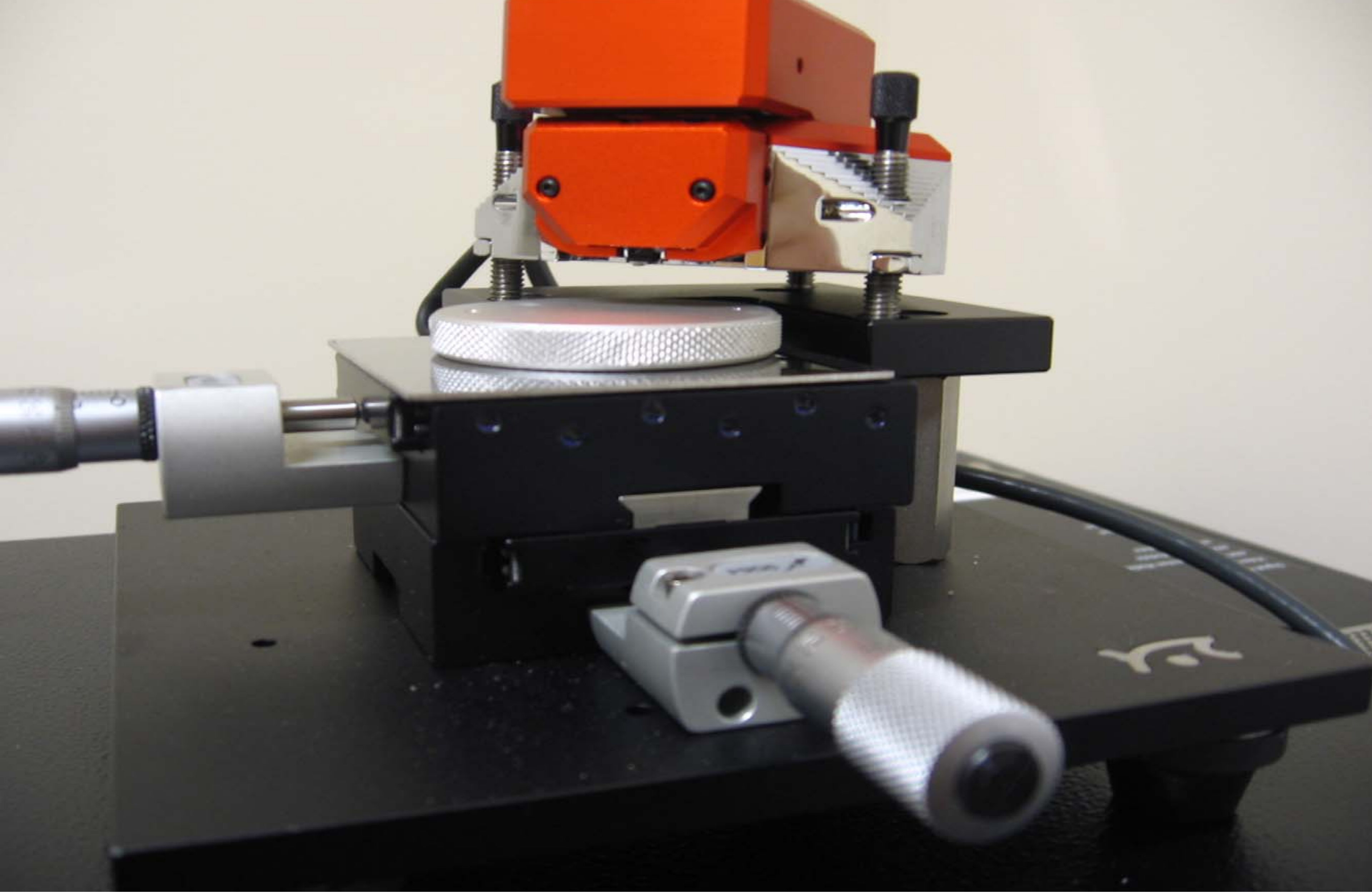
Atomic Force Microscope

- 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

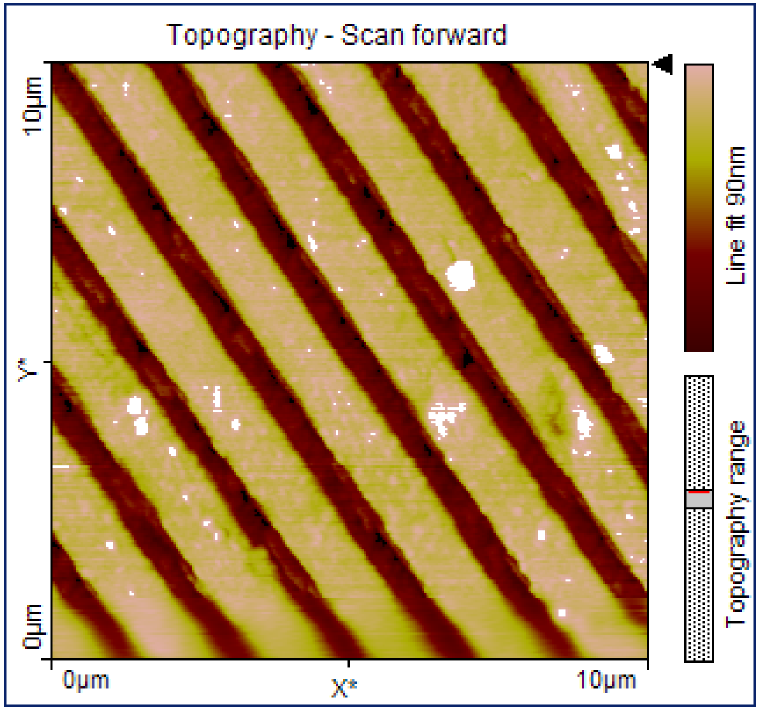


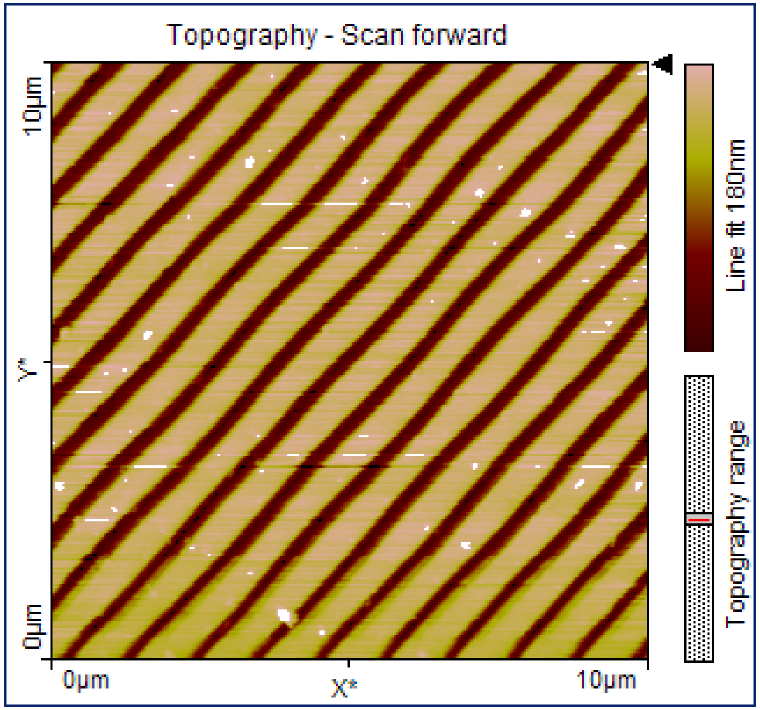
http://wills-nanotech.blogspot.com/2006_04_01_archive.html



Nanosurf® easyScan 2 AFM System

AFM Images of CD and DVD (unrecorded)





CD-Blank

(10 µm scan)

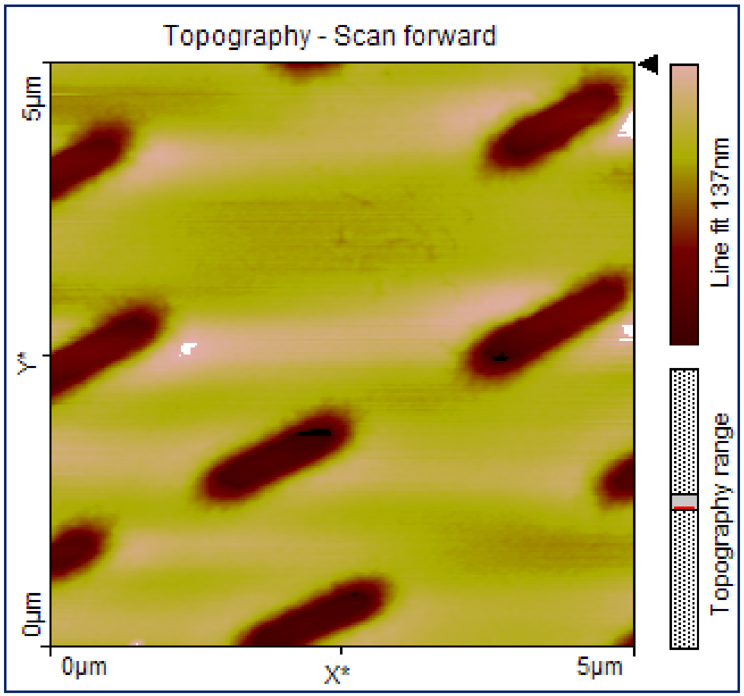
Track pitch = 1.57 µm

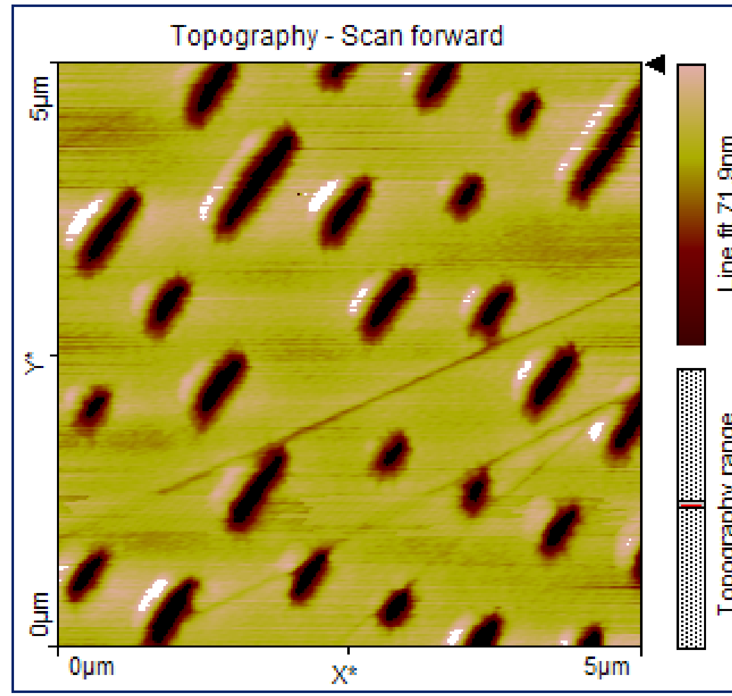
DVD- Blank

(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