

## Student Worksheet or Guide

### CDs and DVDs as Diffraction Gratings

#### Materials

- CD(750MB,)  
DVD-R(4.7GB)
- Quickstick or any other packaging tape
- Razor Blades
- Tweezers
- Meter stick
- Laser pointer
- Stand with clamps
- AFM system and/or Scion software (optional)

#### Caution

**Do not direct the laser pointer into the eye**

**Use it at less than eye level so that the reflected beams are not directed into the eye**

#### Make a Prediction

Read the theory of diffraction gratings before you begin the experiment. CD s and DVD s can act as diffraction gratings because of the way they are made; They have grooves or spacings ranging in micrometers called tracks in which the information can be recorded. These spiral grooves in a CD act like a diffraction grating causing the colors you see when you look at a CD. Knowing what you know about CDs and DVDs make a prediction on which of the two will have the least track spacing? How do you know that?

#### Conduct an Experiment

##### Purpose:

- To determine the track spacing of a CD and DVD by using them as diffraction gratings;
- To verify the results by analyzing the AFM images of a standard CD and DVD that are given

#### Experimental Setup:

##### **Step 1: To prepare CDs and DVD s to use as diffraction grating**

Obtain a regular CD and DVD meeting the specifications mentioned in the materials list. The DVD has two polycarbonate layers which can be easily separated. Use tweezers or a knife edge to split the two layers along a portion of the edge and you can easily pull the two layers apart. Discard the top polycarbonate layer. Use a piece of tape to rip off the

reflective coating from the other layer and you have a clear transparent transmission diffraction grating.

A CD, however, has only one polycarbonate piece of plastic on which the different layers are deposited. Use the label side of the CD and use a piece of tape to rip off the protective coating and the reflecting layer. If it does not peel off use a sharp tool to scratch off a small portion on the edge of the CD and then peel off the rest of the layer using the adhesive tape. The clear plastic can serve as a transmission grating.

## Pictures

### Preparing transmission grating from a DVD



Clockwise from top left

1. Split along the edge
2. Separate into 2 layers
3. Peel off the reflecting layer with tape
4. transmission grating

### Preparing a transmission grating from a CD



Scratch the label surface

Peel off the label and reflecting layer

Transmission grating

## Step 2: Diffraction pattern using the CD

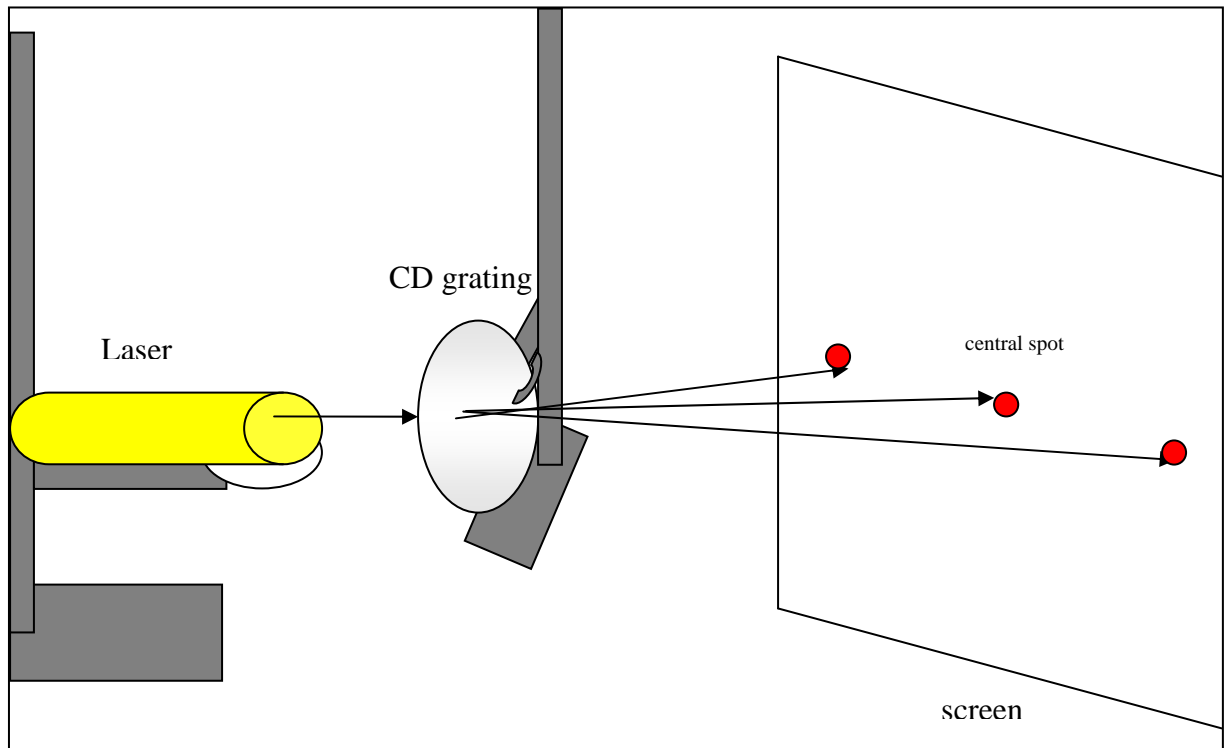
Obtain a laser and fix it to a stand such that the laser is held horizontally and securely using a clamp.

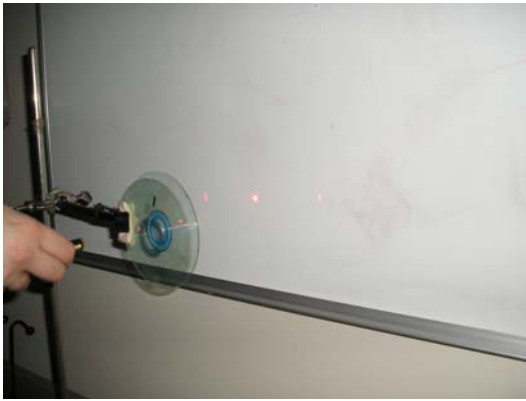
Use another stand to position the CD in front of the laser such that the light from the laser is incident normally (perpendicularly) on the CD. Place the CD as close to the laser as possible.

Use a blank wall or a white board as your screen so that the diffraction pattern can be observed on it. It is preferable that the room be dark so that it is easy to observe the diffraction pattern. The laser should be positioned about a meter (or less) away from the screen. (The position of the laser and CD grating may have to be adjusted according to space limitations).

Switch on the laser and look for the central undiffracted beam spot on the screen. The first order maxima should be visible on either side of the central spot. The second and third order can also be observed but may not be as bright as the first order image. If the images are not on a horizontal on the screen rotate the CD and change its orientation until you get the images on a horizontal line.

### Picture and Diagram of the experimental set up:





### Step 3: Measurement and Analysis

Measure the distance of the first order maxima from the central spot on either side and calculate the average.

Measure the distance of the grating to the screen.

Use the label on the laser to identify the wavelength of the laser beam.

Use the diffraction equation for the first order image and calculate the grating spacing;

Repeat the above procedure for the second and third order images if they are clearly visible.

Determine the average track spacing (pitch) of the CD grating.

### Step 4: Track Pitch of the DVD

Repeat the same procedure for a DVD too; With the DVD, it may be difficult to observe the second and the third order images; It is also advisable to move the laser arrangement much closer to the screen so that the first order image is closer to the central undiffracted spot. Determine by the same method the track spacing of the DVD.

$X$  = distance from maximum on screen

$D$  = distance from grating to screen

$\lambda_{\text{laser}}$  = wavelength of laser

$\theta_{\text{diffraction}}$  = calculated angle of diffraction

$d$  = grating separation (average track spacing)

**Data Table 1: CD**

Order	X <sub>left</sub>	X <sub>right</sub>	X <sub>avg</sub>	D	$\lambda_{\text{laser}}$	$\theta_{\text{diffraction}}$	d
<b>m<sub>1</sub></b>							
<b>m<sub>2</sub></b>							
<b>m<sub>3</sub></b>							

**Average d = \_\_\_\_\_**

**Data Table 2: DVD**

Order	X <sub>left</sub>	X <sub>right</sub>	X <sub>avg</sub>	D	$\lambda_{\text{laser}}$	$\theta_{\text{diffraction}}$	d
<b>m<sub>1</sub></b>							
<b>m<sub>2</sub></b>							
<b>m<sub>3</sub></b>							

**Average d = \_\_\_\_\_**

## Step 5: Analysis of AFM Images of sample CD and DVD

Figures 1a and 2a (on the following page) show the AFM images of a blank CD and DVD respectively; Figures 2a and 2b show the line scan details along a cut section of the image. Measure the horizontal dimension of the image and use it to identify the scale factor (i.e. 1 cm = ? micrometer)

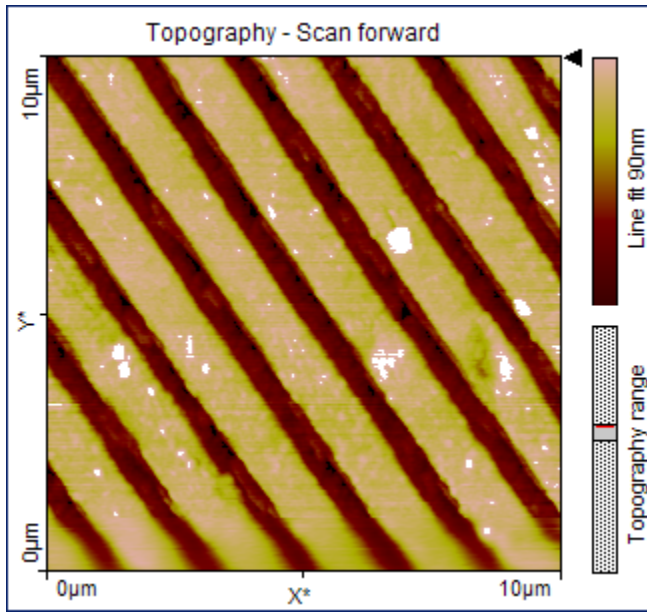
The AFM image is color coded to represent the depth of the different points and the color code is indicated on the bar on the right hand side.

Notice that the grooves or pits will appear darker than the lands or the flat surfaces.

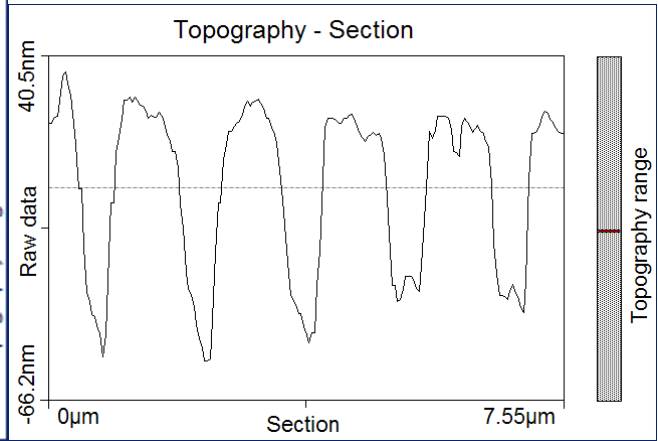
Identify the tracks on the CD by using the color code; Measure the perpendicular distance between two tracks in cm; Use the scale factor to convert the same in micrometer. Repeat this measurement at different points on the image to get an average value of the same. This average measures the average track pitch of a CD.

Repeat the same procedure to measure the average track pitch of a DVD.

The line scans show the graphs of the z value plotted against the horizontal position of the point being scanned. This image is for a single line scan. The points with the lowest z value correspond to the grooves or tracks and the average distance between two tracks can be calculated from the line scan too. Use your values to verify the results obtained from the diffraction pattern obtained in Steps 3 and 4.



**Fig. 1a: AFM sample image: Memorex CD 750 MB; blank; scan size 10 micrometer**

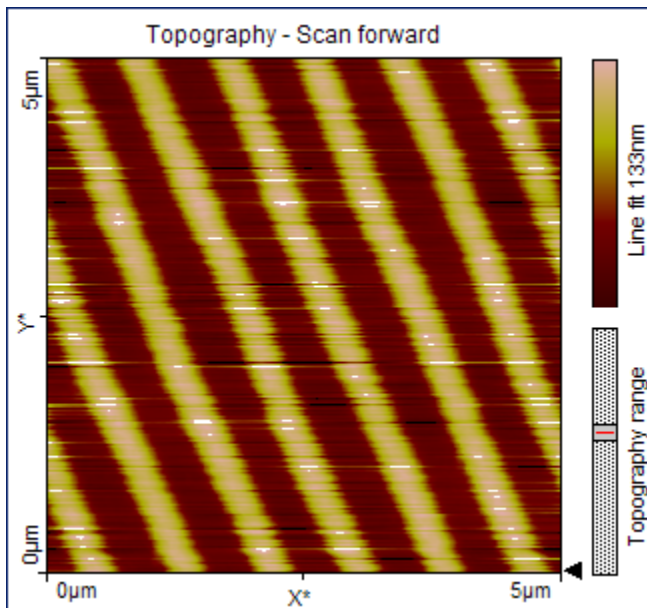


**Fig. 1b: Sectional line scan of the image**

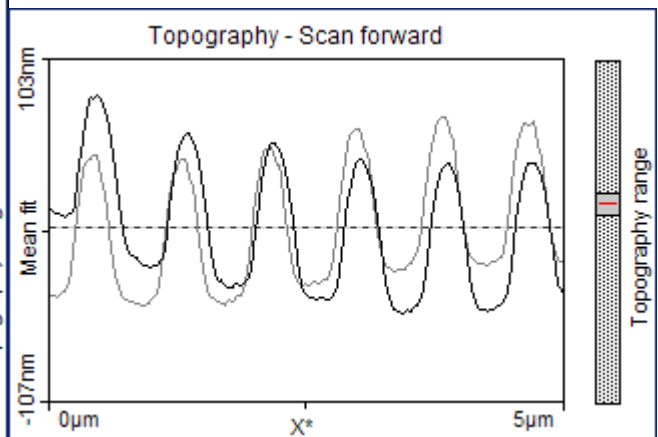
**Calculations for the CD image:**

Scale factor: 1 cm = \_\_\_\_\_ micrometer

**AFM average track pitch of a CD: \_\_\_\_\_**



**Fig. 2a: AFM sample image: Sony DVD-R 4.7 GB; Blank, scan size 5.0 micrometer**



**Fig. 2b: Sectional line scan of the sample**

**Calculations for the DVD image:**

Scale factor: 1 cm = \_\_\_\_\_ micrometer

**AFM average track pitch of a DVD: \_\_\_\_\_**



## Analyze the Results

1. Explain why the CD or the DVD acts like a transmission grating?
2. Is the CD grating any different from the plane transmission grating you use to study the spectrum of different elements? If so, in what ways is it different?
3. How did the experimental result agree with your prediction?
4. How did the experimental results agree with your calculated values of the track spacing from the AFM pictures of the sample CD and DVD?
5. Determine the number of tracks per mm on a CD and on a DVD.

## Draw Conclusions

6. A DVD can store 7 times as much data as a CD. Given the results of your experiment about the track pitch on a CD and DVD, is the above statement justified? If not, what other factors should be considered to explain why a DVD has 7 times more capacity than a CD.
7. What physical limitations arise in trying to reduce the track pitch to even smaller values for increasing the capacity? How else can the capacity be improved?





selection tool, choose **Analyze** → **Measure** to indicate the new measurement. You can average your measurements of the separation of adjacent tracks to determine the average track pitch of a CD.

8) **Use the toolbar and the Main Menu to explore other options.** If your image is messed up close the file without saving and reopen the file again to work on it.

## **Image Analysis Questions**

- 1. Determine the average track pitch of a CD and compare it to that of a DVD and a Blu-ray disc.**
- 2. What is the depth of the track in a CD?**
- 3. How is the image of the recorded CD any different from the blank CD?**
- 4. How is the information on a CD or DVD read by the CD /DVD player?**
- 5. Compare and contrast the images of a DVD to a Blu-ray DVD.**

