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light interference

Materials:

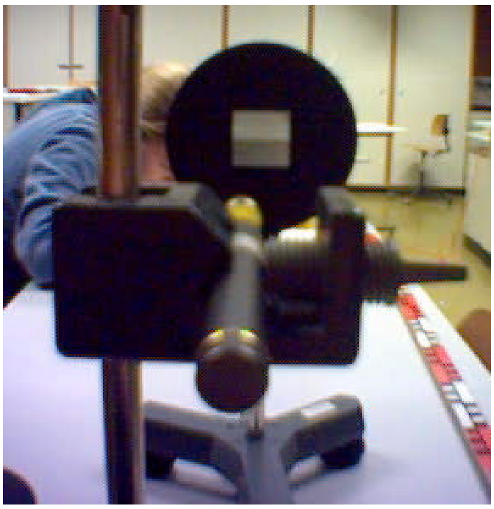
Laserpointer
mounting material
diffraction grating with 40 slits per centimetre,
CD-ROM (and DVD),
cardboard

security advise:
Never let the direct beam of a laser hit your eyes!

Purpose:

First we want to determine the wavelength of the red light from a laserpointer. Then we measure the distance of two neighbouring tracks on a CD. Because a CD-ROM acts like a reflecting grating we can calculate with the determined wavelength of the first experiment this distance between two tracks. Finally we also estimate the memory of a CD-ROM.

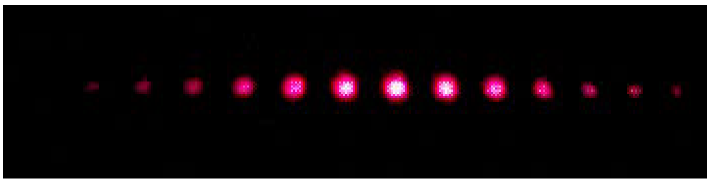
Figure of experiment:



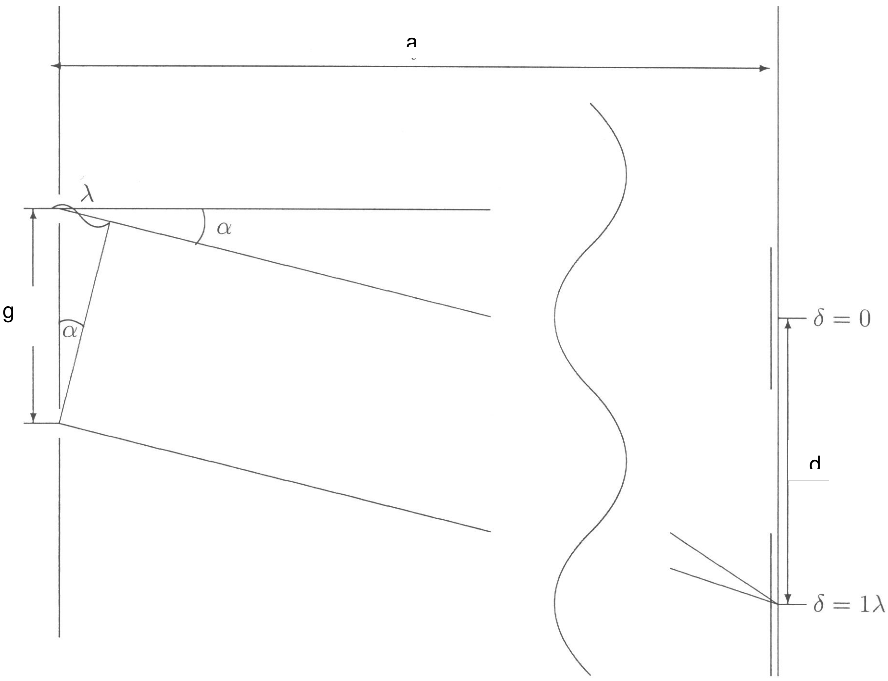
Procedure:

<u>1. wavelength of the red laserlight</u>

For this experiment we build up an experiment like shown in “figure of experiment”. The light from the laserpointer goes through a diffraction grating. On every single slit in the grating, in our experiment 40 slits per cm, arises an elementary wave. The elementary waves superimpose and so you can index alternate maximums and minimums on the wall.
In our experiment we had 13 maximums on the wall:



Drawing:



You can read off this drawing these two formulas:

$n \bullet \lambda = \sin\alpha \bullet g$; $\tan\alpha = d/a$ $n = (0,1,2...)$

Because the angle α is very small ($\alpha < 10°$) we can assume that $\sin\alpha = \tan\alpha$
So we get the formula:

$n \bullet \lambda = d/ a \bullet g$

We want to determine the wavelength, so we first have to calculate the angle alpha. We measured the distance l = 6,30m and then the distance between the Maximums 4th order. There we get for d_8= 13,1 cm $\Rightarrow$ d_1= d_8/ 8 = 1,6375 cm. The distance between two slits is given from the grating and is g = 1/40 • 10^{-2} m. Now we can calculate the wavelength by putting in the measured values:

$n \bullet \lambda = d/ a \bullet g$ $\qquad$ n = 1

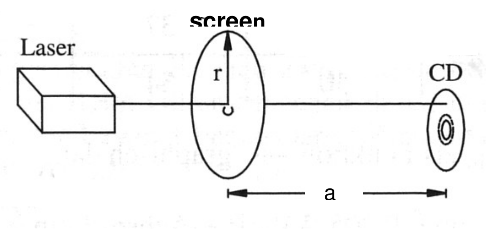
$1 \bullet \lambda = 0.0164/ 6,30 \bullet 1/40 \bullet 10^{-2}$

λ = 650 nm

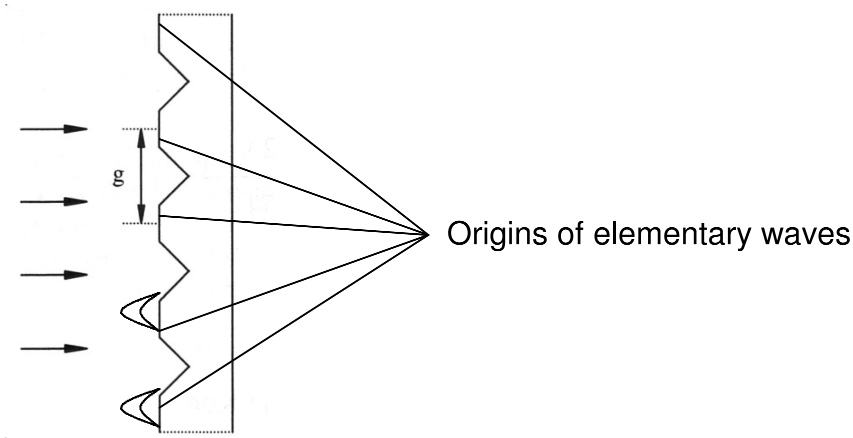
On the laserpointer a wavelength about 630 – 680 nm is given. Our measured value is therefore quite good.

2. CD-ROM: distance of two neighbouring tracks and its memory

Figure of experiment 2



For the second experiment we need a screen with a hole in the middle as big as the laser beam. Now the laser beam goes through the hole and will be reflected on the CD. You have to hit the CD perpendicular that the same conditions apply as for the grating. The reflection of the laser light can only work if the light waves hit a vertical part of the CD surface because here are the origins of elementary waves. The elementary waves superimpose and we register maximums on the screen.



We measured the distance d_2 = 38,6 cm ⇒ d_1= d_2/ 2 = 19,3cm between the maximums first order and the distance between the screen and the CD a = 39,5 cm. Because the angle α is this timer bigger than 10° we have to calculate the angle α first .

$\tan \alpha = d/a$; $n \bullet \lambda = \sin \alpha \bullet g$; n=(0,1,2,...)

$\tan \alpha$ = 18 cm / 39,5 cm = 0,49

α = 26°

We get the wavelength λ from our first experiment λ = 650 nm.

$n \bullet \lambda = \sin \alpha \bullet g$; n = 1

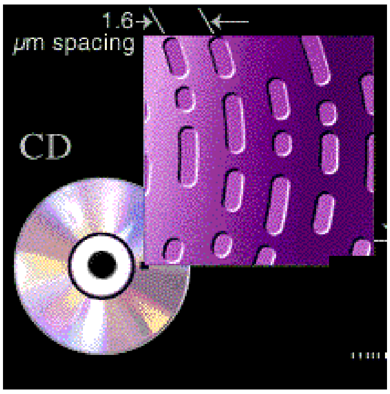
$g = \lambda / \sin \alpha$

$g = 650 \bullet 10^{-9}$ m / sin 26°

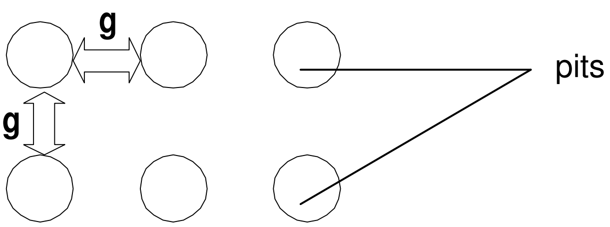
$g = 1{,}48 \bullet 10^{-6}$ m

The number of tracks per mm is: 1 / 1,48 • 10^{-6} m = 675675 bits/ m → 676 bits /mm

Finally we calculate the approximate memory of a CD. For that we should know that a CD is a disk, which contains of recesses in a layer, the pits. Like shown in the picture on the left. The pits represent the data information on a CD and are applied circularly on a CD. The lowest distance between two pits is the g, which we calculate before g = 1,48 • 10^{-6} m (in the picture the spacing) For our calculation it is reasonable to presume that the distance of two pits has about the same distance.



Simplified one can accept this picture:



In order to calculate the memory of a CD we need the numbers of tracks on the CD and multiply them with the writable length of one average track.

We get the numbers of tracks by dividing the length l of the writable area by the track with g.

$l = 3{,}6\ cm = 0{,}036m$
$g = 1{,}48 \bullet 10^{-6}\ m$

$N = l / g$
$= 0{,}036m / 1{,}48 \bullet 10^{-6}\ m = 24500$

There are 24500 loops on the CD

Now we need the average length U of one track. For that we have to determine the middle extent by multiply the average radius with 2 π. Than we divide the middle extent through the distance g to get the pits of one track.

$r_{whole} = 8{,}10\ cm$
$r_{average} = 8{,}10\ cm / 2 = 4{,}05\ cm = 0{,}045\ m$

$U = 2\ \pi\ r$
$U = 2\ \pi \bullet 0{,}045m = 0.28m$

$n = U / g = 0{,}28m / 1{,}48 \bullet 10^{-6}\ m = 190000$

190000 pit are on one track

Now we multiply the numbers of tracks with the pits of one track to get the numbers of pits on the CD.

$N \bullet n = 24500 \bullet 190000 = 4{,}66 \bullet 10^{-9}$

One pit can carry out one information that means one pit is one bit. We know that one byte is 8 bits so:

$4{,}66 \bullet 10^{-9}$ pits are $583 \bullet 10^{-6}$ bytes or **583 MB**

On the CD was a printed value: 700MB
So our percentage error is: (100% • 117 MB) / 700MB = 16,7%

Sources of error:

We have a deviation of 16,7 %, because we assumed e.g. simplified that the distances between two pits are always same that is however not the case. In addition small measured errors can develop by determine the values.

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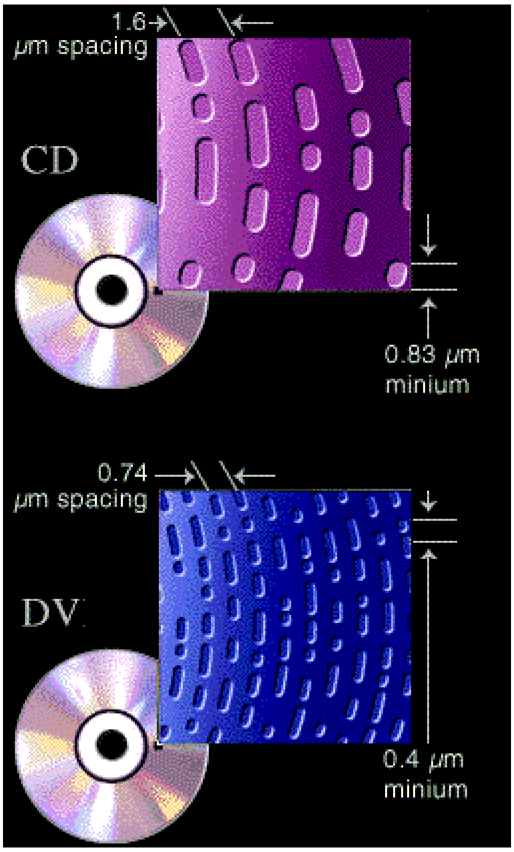
Additional information:



The DVD:

A DVD has a higher capacity than a CD.The reason for this is that the trackwidth of a DVD is smaller than on a CD.
You can see that on the picture on the left.
The DVD with 1.2 mm has the same thickness as a CD, although she also consists of two in each case 0.6 mm thick parts, which are stucked together back to back.

Some values:

	CD	DVD
Smallest pit size	0.834 micrometers	0.4 Micrometer
track width	1.5 -1.7 micrometers	0.74 micrometers

Tracks distance in a 4,7GB DVD

$$C_{DVD} \approx 40372692582\text{bits}$$

$$\mathrm{A}_{\mathrm{DVD}} = A_{CD} = 9000mm^2$$

$$N_{bit} = \frac{C_{DVD}}{A_{DVD}}$$

$$N_{bit} = \frac{40372692582\text{bits}}{9000\text{mm}^2} = 4485855\frac{\text{bits}}{\text{mm}^2}$$

$$g = \frac{0.001m}{\sqrt{4485855\frac{\text{bits}}{\text{mm}^2}}} = 4.7 \cdot 10^{-7}\,m$$

Conclusion:

We determined the wavelength of a red laserpointer. And with the measured value we calculated the distance of two tracks on a CD and its memory.