GROUP : C2_1

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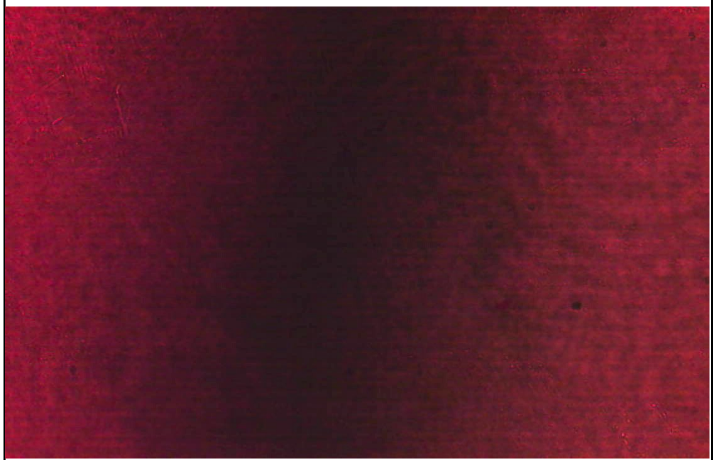
Interferometer

1. Zero optical path difference (OPD)

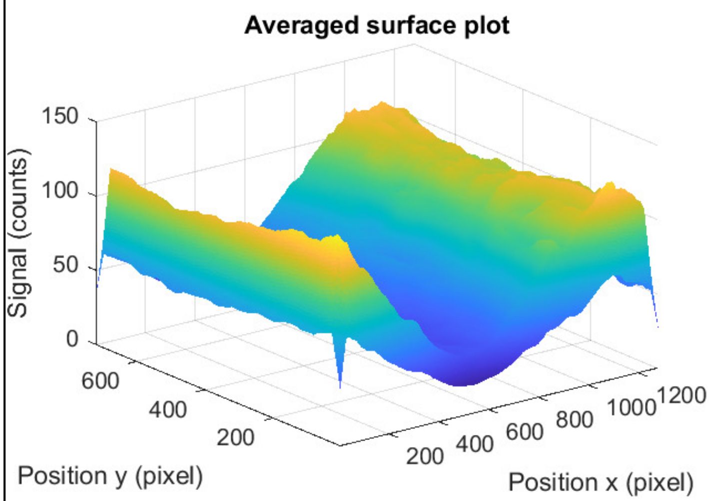
Find the zero OPD position and plot the intensity profile as well as a surface plot for the destructive and the constructive interference cases (**4 plots**). Take care that you use **equal exposure** conditions for both states to show the contrast correctly.

Picture 1 – Destructive interference

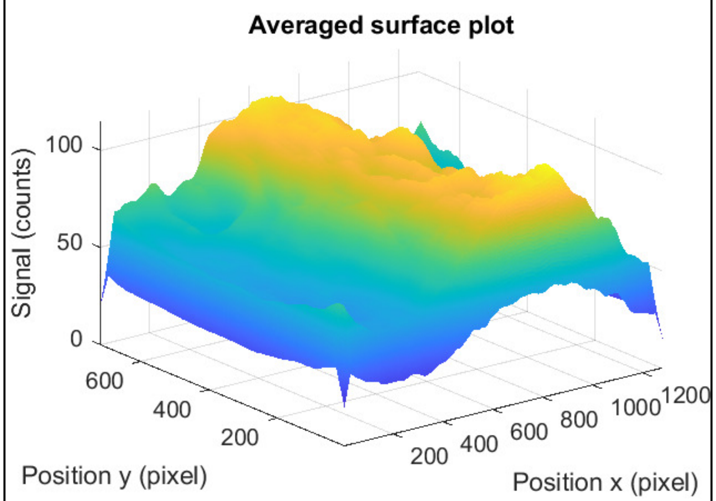


Picture 2 – Constructive interference

Graph 1 - Surface plot destructive interference



Graph 2 - Surface plot constructive interference



Explain why it is so difficult to align for the zero OPD.

The distance difference between a constructive and a destructive interference is $\frac{\lambda}{2} \cong 315,7$ nm for the laser we used. Therefore, any vibrations or micro-movements can throw off the alignment

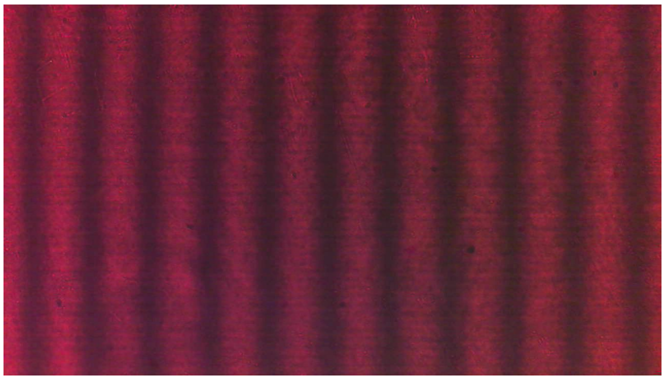
Moreover, we are working with a translation stage that has μm precision.

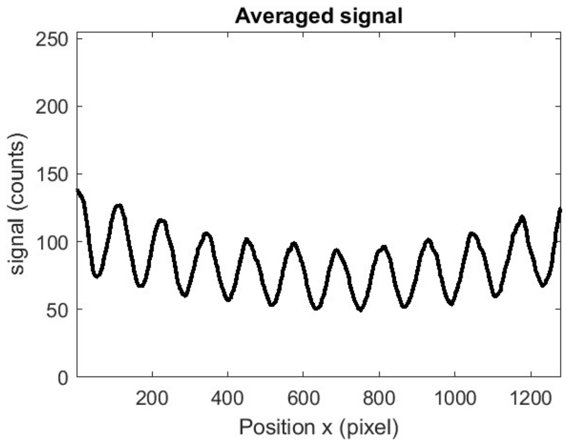
What is the minimum OPD to go from a constructive to a destructive interference?

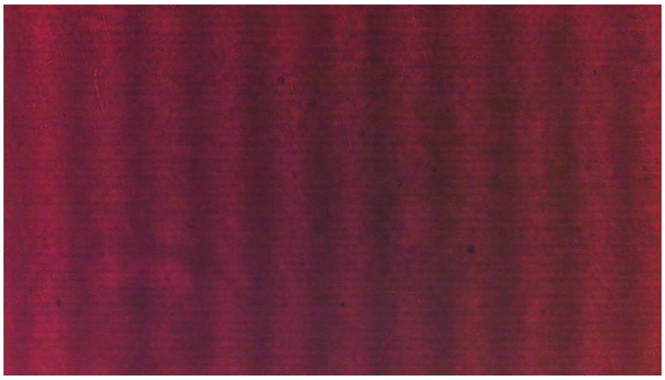
The minimum OPD to go from a constructive to a destructive interference is half a wavelength. $\frac{\lambda}{2} \cong 315{,}7$ nm.
This corresponds to a translation of $\frac{\lambda}{4} \cong 158{,}75$ nm because the light makes a round trip.

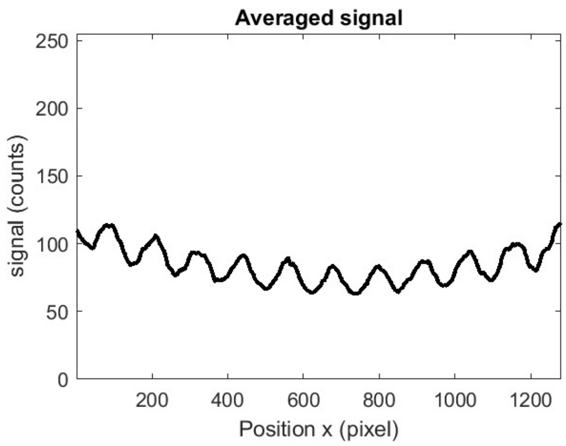
2. Measurement of laser fringe contrast

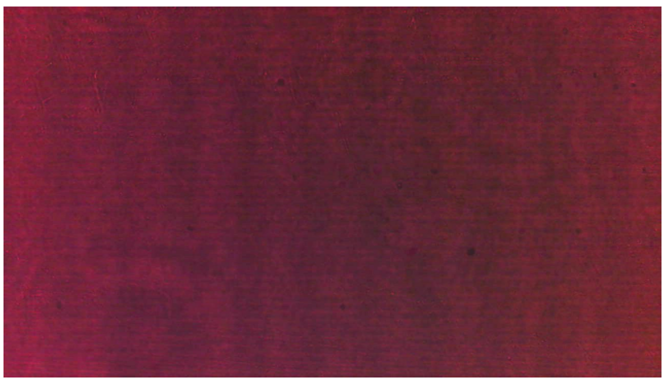
Show **three pictures** with different contrast and plot their line curve.

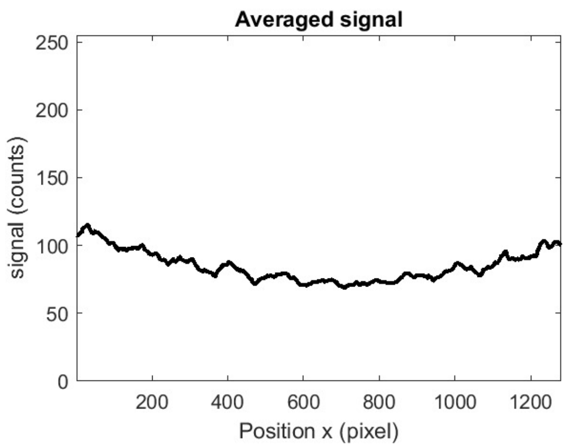












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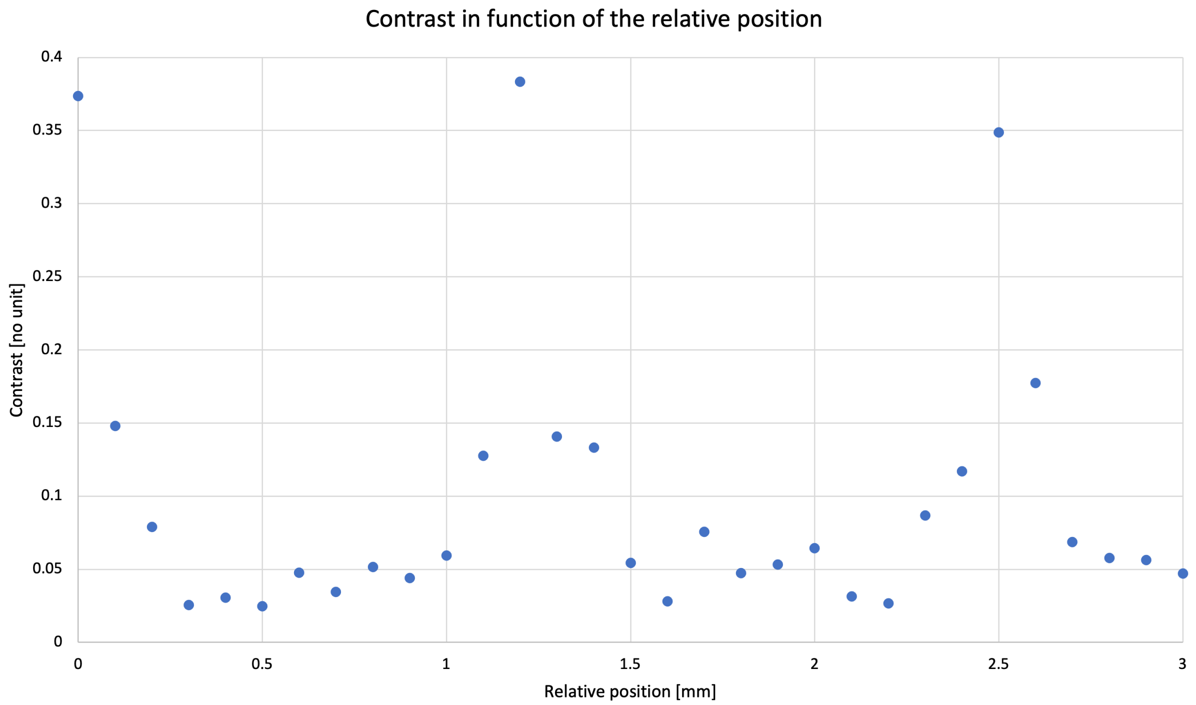
Measure the contrast as a function of position of the translation stage (over more than 1 full cycle of contrast variation, minimum 30 points, use the table below). **Step size 0.1 mm!**

Relative position on the micrometer screw in mm	Contrast $C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$	Relative position on the micrometer screw in mm	Contrast $C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$
0 → 2,13	0,3736	1,6	0,0281
0,1	0,1480	1,7	0,0756
0,2	0,0709	1,8	0,0473
0,3	0,0256	1,9	0,0532
0,4	0,0306	2	0,0643
0,5	0,0248	2,1	0,0313
0,6	0,0477	2,2	0,0266
0,7	0,0345	2,3	0,0867
0,8	0,0516	2,4	0,1171
0,9	0,0440	2,5	0,3486
1	0,0595	2,6	0,1773
1,1	0,1277	2,7	0,0686
1,2	0,3834	2,8	0,0576
1,3	0,1407	2,9	0,0563
1,4	0,1334	3	0,0471
1,5	0,0543	3,1	0,0685

Plot the values (**one graph**).



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EPFL

You will now calculate the spectral width of the source using the period of the variation. (Eq. 12, where Δz is the period found in your measurement). **You must estimate the error on your measurement** knowing that the spectral width is expressed as

$$\Delta\lambda = \frac{\lambda^2}{\Delta z} = \frac{(635\cdot 10^{-9})^2}{1,2\cdot 10^{-3}} = 0,336\,nm$$

To do so, one needs to evaluate the error $\delta\Delta z$ on the peak distance from your contrast measurement plot that you have obtained above.

$$\delta\Delta z = 0,2\,mm$$

Explain how you have obtained this value.

Explanation : From the plot, we have that $\Delta z = 1,2\,mm$. As the step size is 0,1 mm, the maximum peak value could be between two measurements. We can then estimate the error to be equal to $2\times 0,1$, because the period is between two peaks.

You also have to find the error on the wavelength: $\delta\lambda = \pm 5\,nm$

This is **not** the spectral width! It is the wavelength uncertainty from the datasheet.

Now, using $\delta\Delta z$ and $\delta\lambda$, find the **analytical** expression for the error on the spectral width $\delta\Delta\lambda$.

$$\delta\Delta\lambda = \left|\frac{\partial \frac{\lambda^2}{\Delta z}}{\partial \lambda}\right|\cdot\delta\lambda + \left|\frac{\partial \frac{\lambda^2}{\Delta z}}{\partial \Delta z}\right|\cdot\delta\Delta z = \frac{2\lambda}{\Delta z}\delta\lambda + \frac{\lambda^2}{\Delta z^2}\delta\Delta z$$

$$= 0,0507\,nm$$

Finally, the spectral is: $\Delta\lambda = 0,336$ $(\Delta\lambda) \pm 0,0507$ $(\delta\Delta\lambda)$ nm

Explain why the contrast exhibits such a modulation versus the mirror position.

From the irradiance formula, we have that the irradiance peak can be 4 times the intensity of the source depending on the phase difference.

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3. WEB - Example

Find an example of an application where interferometry is the key technique. Print a picture; give a **short explanation** and parameters that are measured. Cite correctly.

LIGO, "Laser Interferometer Gravitational-wave Observatory", is the word's largest gravitational wave observatory. It uses two laser interferometers located at 3000 m apart.

The greater this distance is, the smaller the measurement it can obtain. It sends light from a single laser source and splits it into two resonnance chambers.

This resonnance builds up the laser which increases the LIGO's sensitivity and increases, as well, the effective distance from 3km to 1200km.

This precision enables to see a fluctuation of $\frac{1}{1000}$ of a proton. The gravitational-wave will slightley move the mirror when hitting the LIGO. This will result in a phase difference that is enough to create an interference pattern with the other beam.

Two LIGO work together to eliminate local disturbances.

https://www.ligo.caltech.edu/page/ligo-gw-interferometer

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(Optional) Personal feedback:

Was the amount of work adequate?

What is difficult to understand?

What did you like about it?

How can we do better?