Session 3 - Tasks 8 - 9

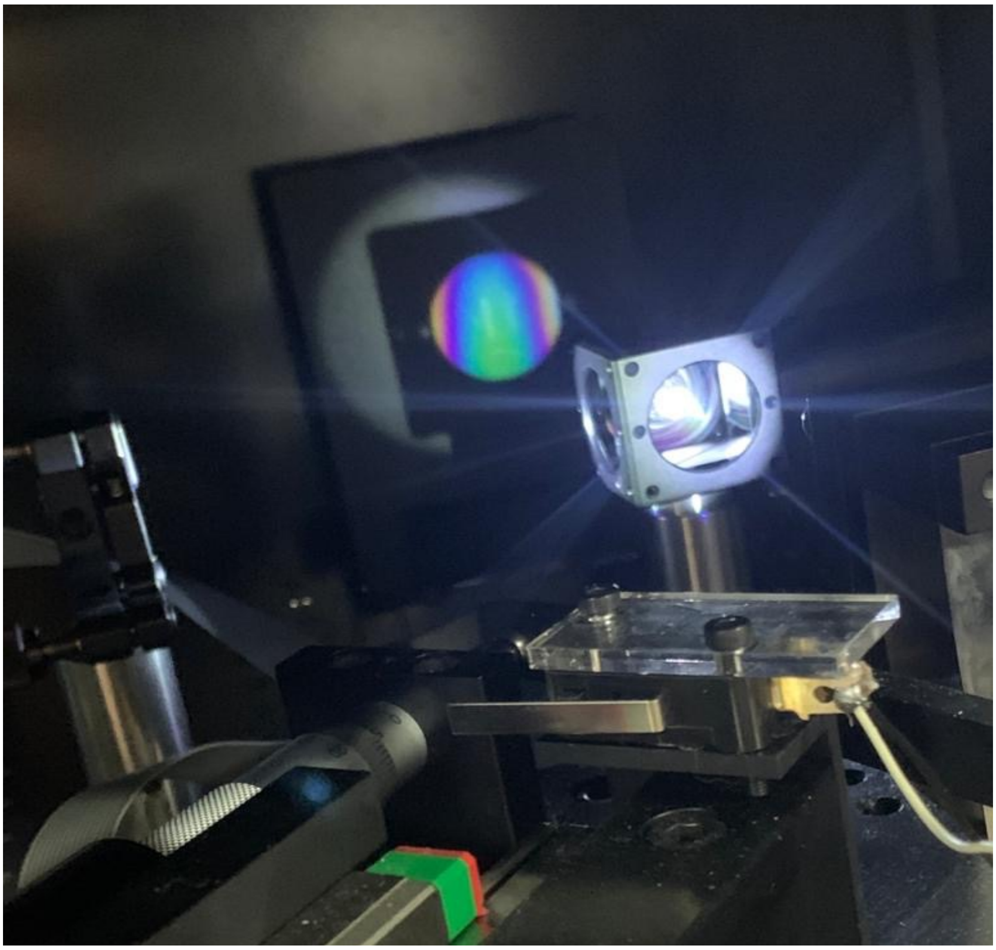
Tuesday, January 10, 2023 9:00 AM

Aims for sessions-
Find the actual null point using our range and scanning through
Take interferograms for white light, blue light and filtered light

Task 8 cont

Now we're going to find the actual null point by scanning through the range of 5.71 - 5.80 mm which should only take approx 5 mins.

Unfortunately, someone has touched our set up and now the null point is not within the range we specified.
Therefore, we have recalibrated it with a preliminary reading at 6.15 mm which is pictured in **fig 28.** and so we've decided to put our range is between 5.97 mm and 6.20 mm.



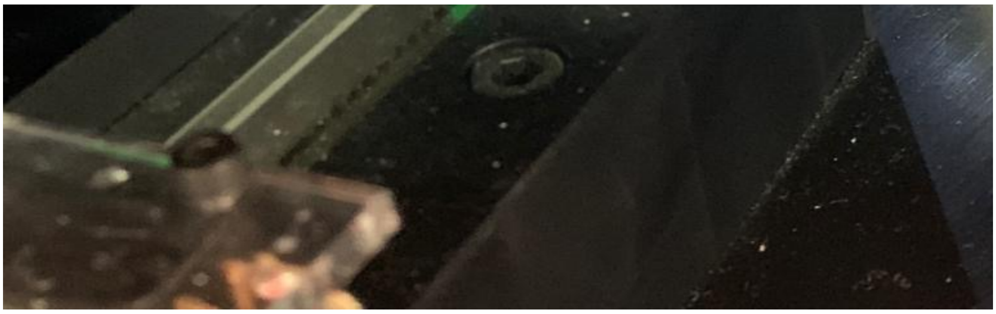


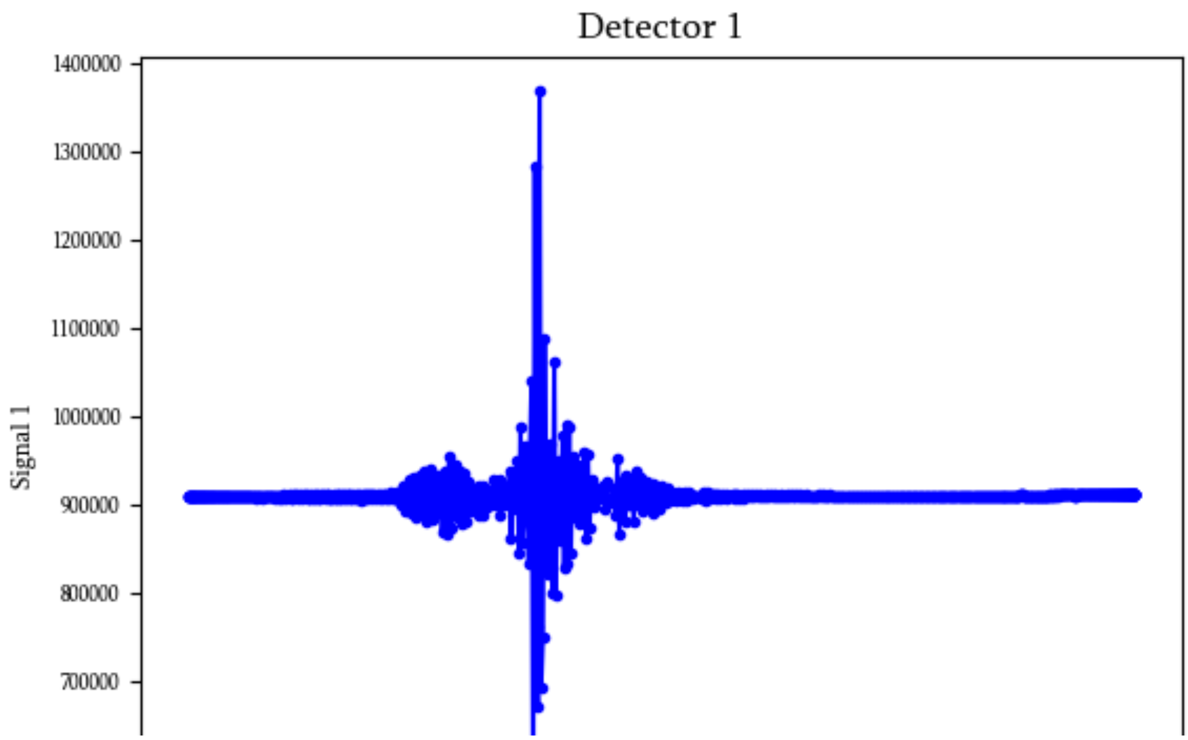
Fig 28. Recalibration - preliminary null point found just by looking and slowly turning the micrometre by hand until the rainbow like interference is clear and visible.

However, discovered that the motor was moving too quickly for us to then see the pattern and lowering the speed would mean turning the motor would take too long to run.

Therefore, we're limiting the range further to 6.10 to 6.17.

Replacing the screen with the detector we decided to look at what interferogram we get when we pass through this range. This is because we've realised it's hard to find the null point precisely judging by eye and even then it's always going to be a bit of a range as it's hard to discern exactly when it's most visible. we figure that if we take an interferogram it will be a sinusoidal graph modulated by a since function- therefore we could look at the peak and work out our null point more precisely from this.

We decided to take a preliminary reading of the interferogram shown in **fig 29.**



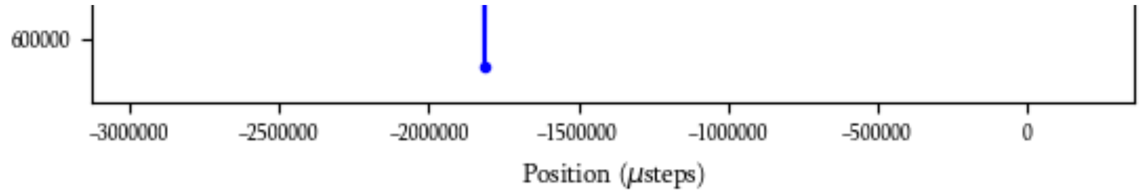
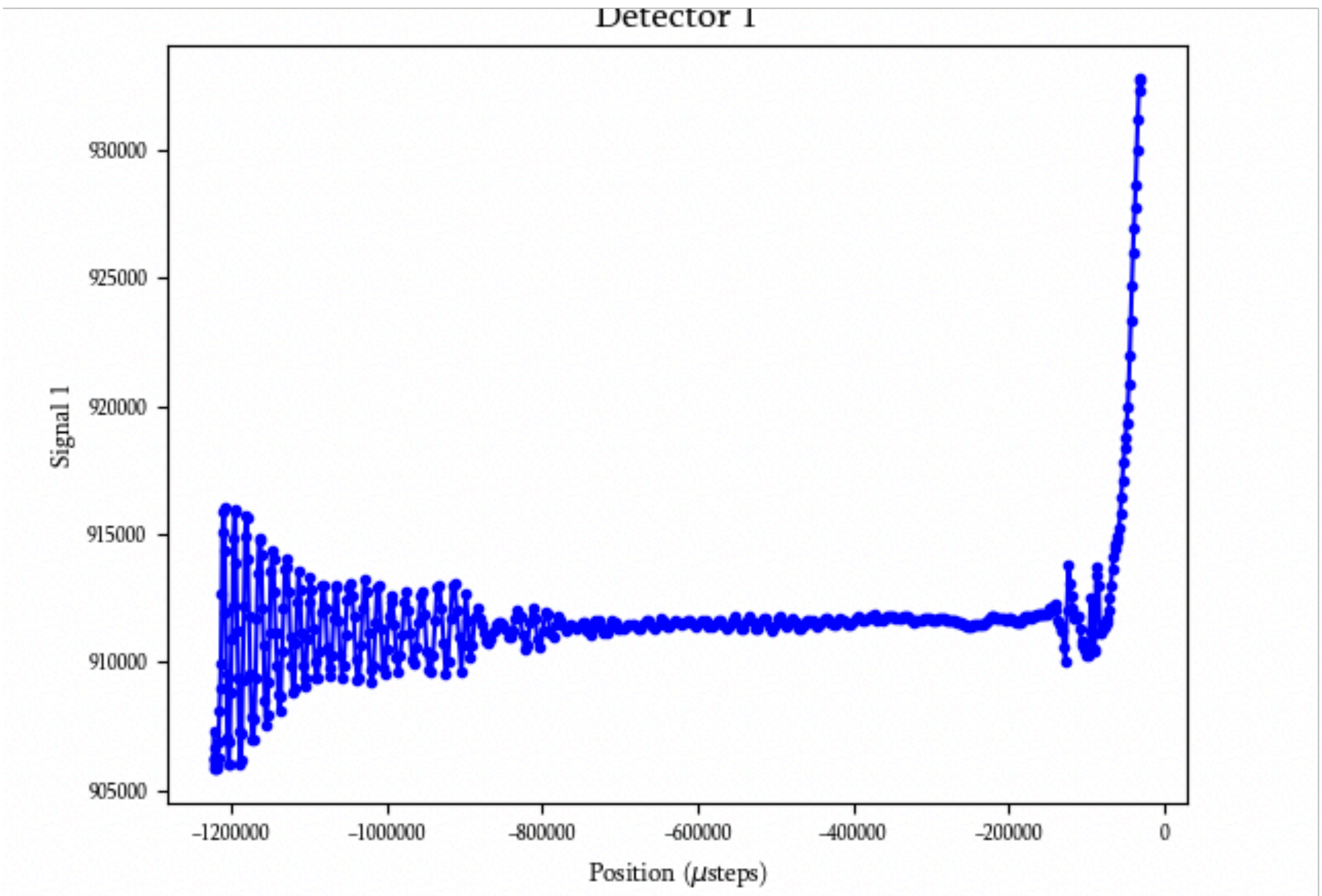


Fig 29. plot of signal (intensity) against the position in micro steps - we did this for preliminary data

The interferogram shown in **fig 29.** is preliminary run at a higher motor rate so that we have a rough idea of how long to run the motor for in order to ensure we pass through the null point.

Our idea is that since we know the exact range in mm we will be travelling and the micro steps we travel we can find the peak of the amplitude in micro steps from the interferogram and hence work out the null point eactly.

Next we returned to the start and ran it again at a slower rate, for completeness I'm including our first attempt here where we didn't run the interferogram for long enough, shown in **fig 30.**



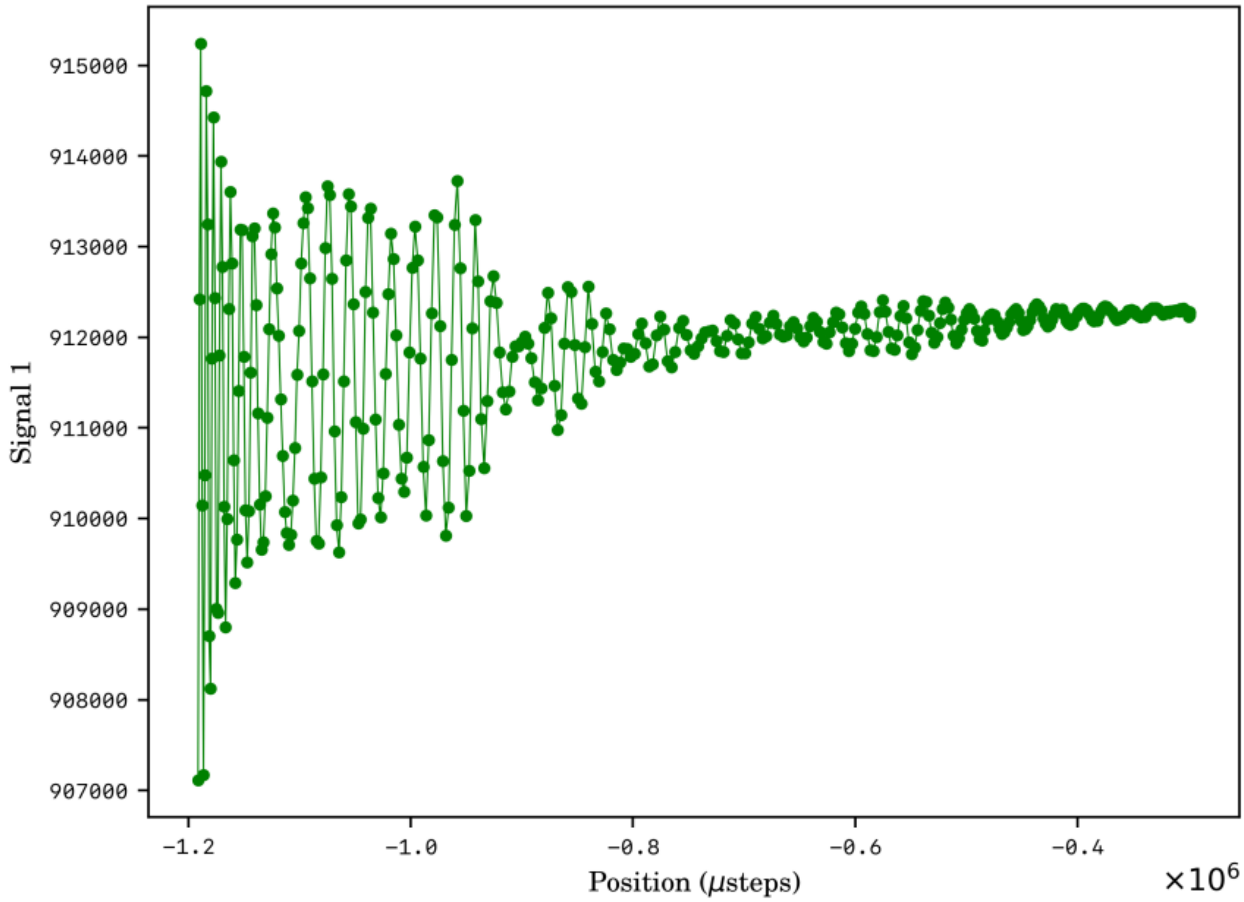
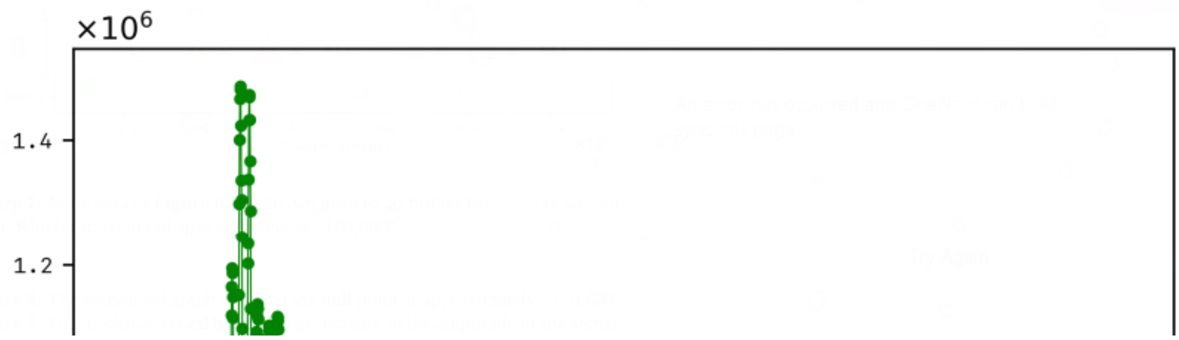


Fig 30. plots of signal (intensity) against position in micro steps - clear to see that we didn't run it for long enough but these allowed us to better work out how many microsteps we need to run for. Included for completeness.

From the interferograms shown in **fig 30.** we've realised that the theoretical value we calculated for microsteps to mm of 1 micros step to 1.5625 x 10^-8 wasn't correct. This makes sense to us when we reflect on what we did in task 6. This understanding helped us so we thought it prudent to include it as it was a helpful learning point for us.

Now we our true interferogram is shown in **fig 31.** where we have returned to the point where we started and run a long enough interferogram to go from 6.10 to 6.17 mm.



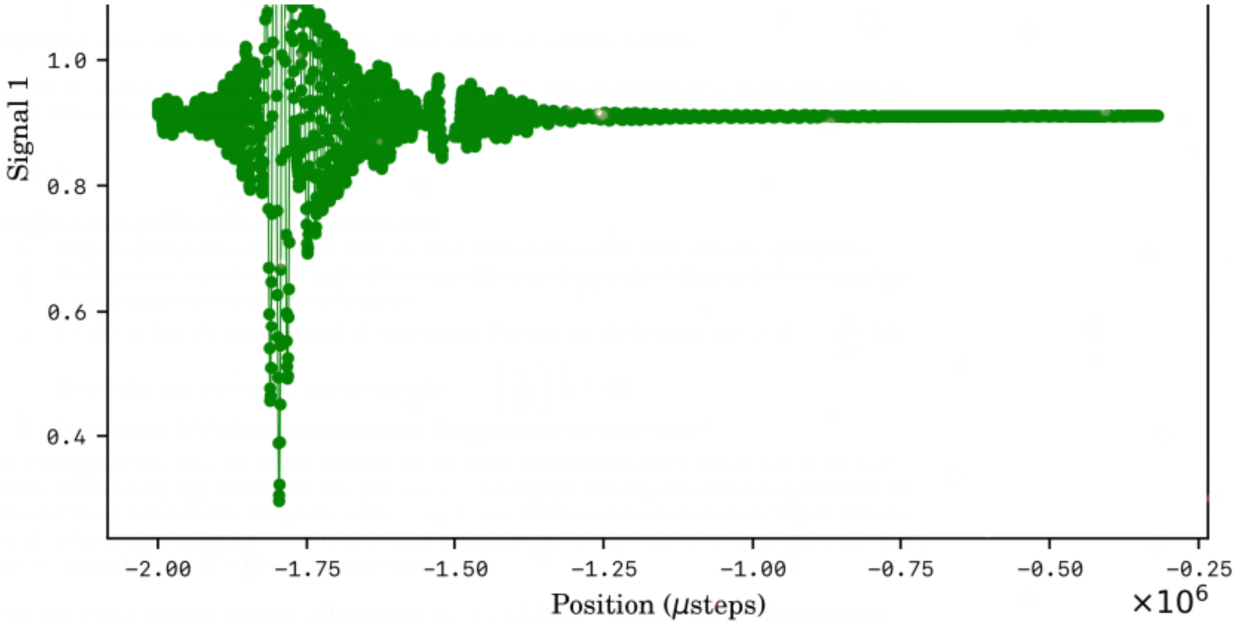


Fig 31. plot of signal (intensity) against position. Here we can clearly see that we have run it past the null point. From this we have taken the null point to be at 1,800,000 micro steps from our starting point (the lower end of our range 6.00 to 6.17 mm). This is equal to 0.063 mm Note, we trimmed this plot so that the data irregularities due to the motor accelerating are not included but it started at 0.

Therefore, we can calculate our null point to accurately be at **6.16 mm** along our micrometre.

Note, upon reflection we think this was unnecessary for what the task was asking of us but we decided to include it all for completeness.

<u>Task 9</u>

We have already found the interferogram of white light as shown in **fig 29** and **31.** As we used it to find our exact null point, we decided to redo white taking more data points by using smaller steps and using a larger range.

We dont need to alter the setup at all for this task, only replace the different LEDs we're using.

We also don't need to take any preliminary data as it's the same process as the previous tasks in which we have already made adjustments.

We then used the exact same set up and range for the blue light and white light again and then white light with a green filter. The quickplots for these are shown in **fig 32. Fig 33.** And **fig34 .** Respectively.

$\times 10^6$

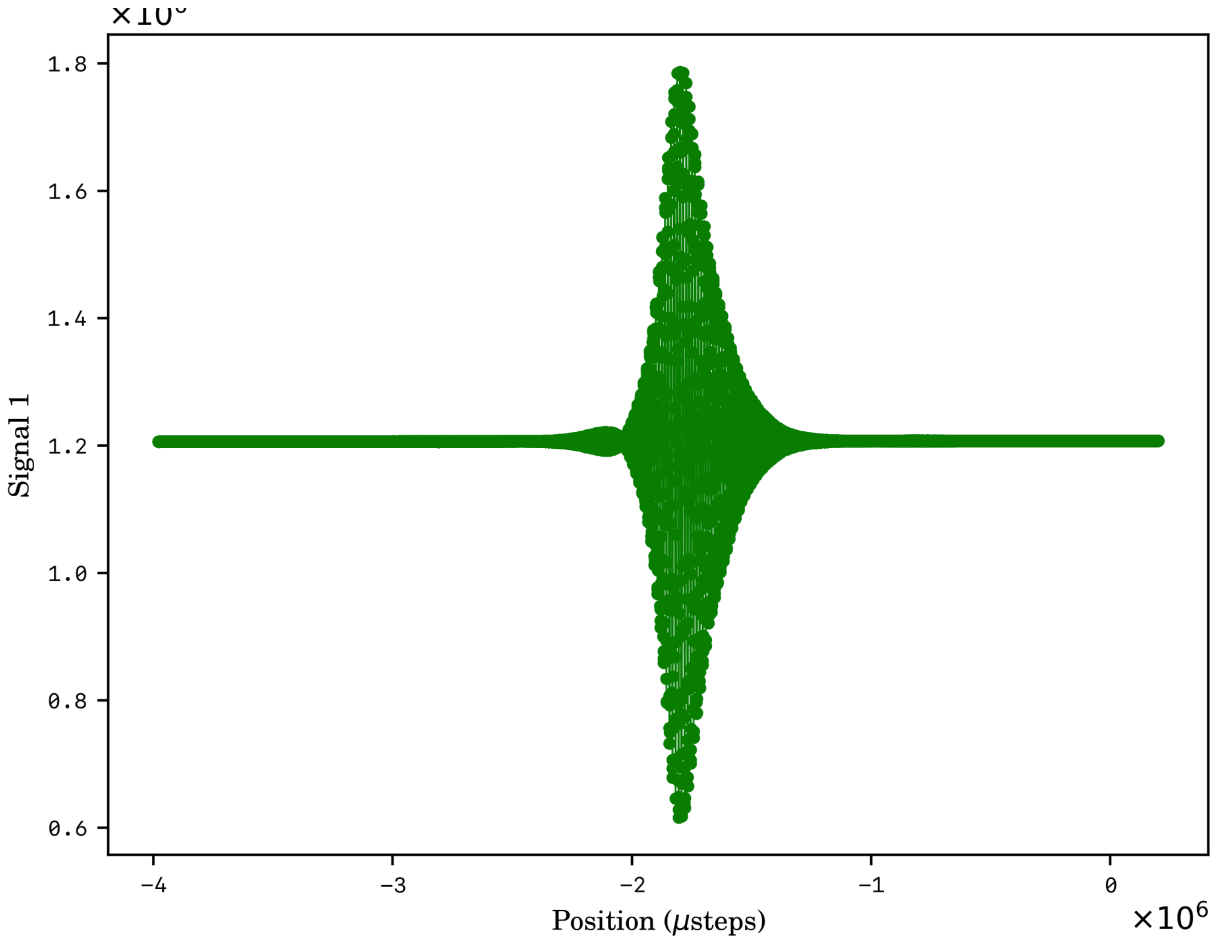
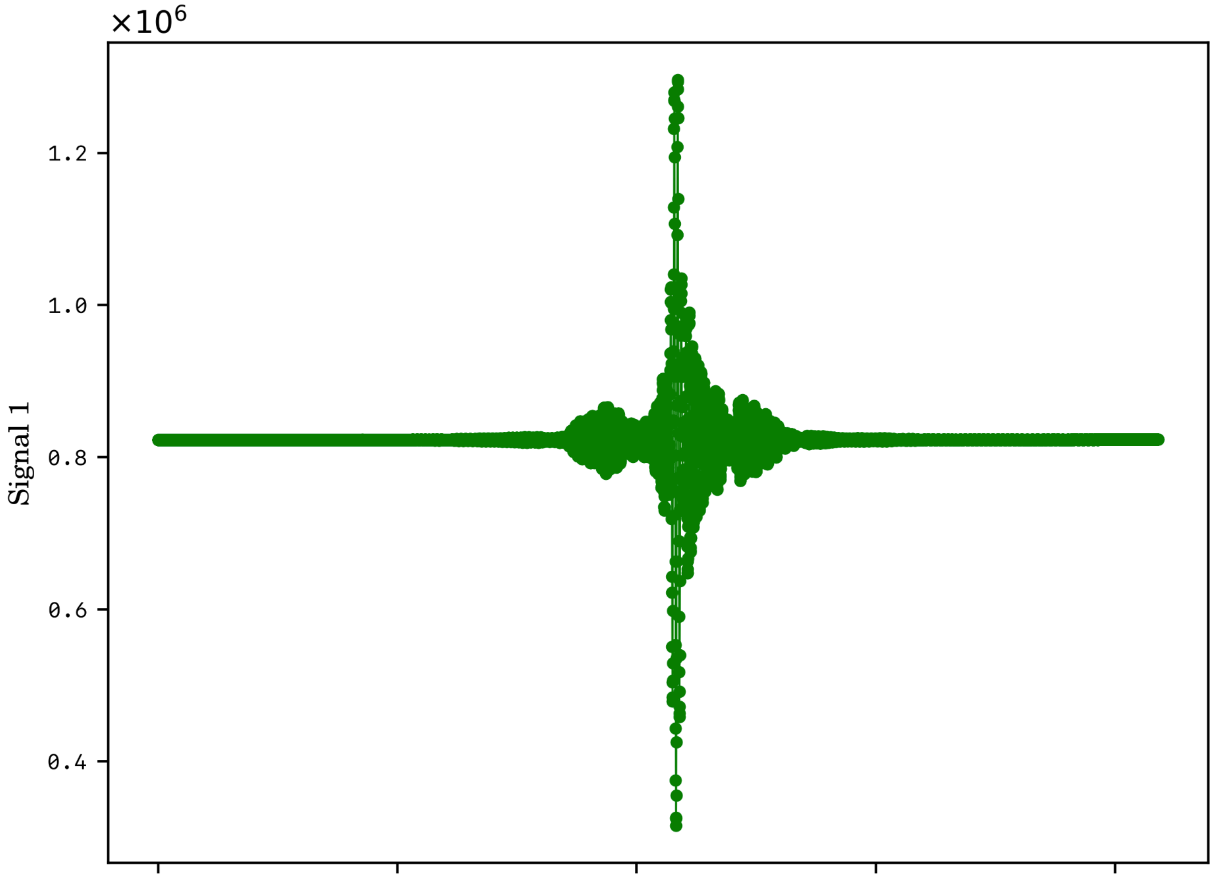


Fig 33. plot of signal (intensity) against position for the blue LED, can clearly see that the interferogram is asymmetrical.



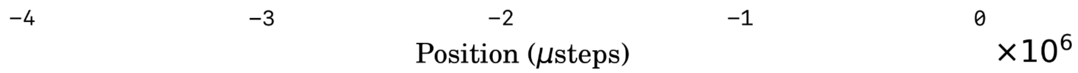


Fig 34. plot of signal (intensity) against position for the white LED, can see it's asymmetrical unlike the earlier simulation we ran.

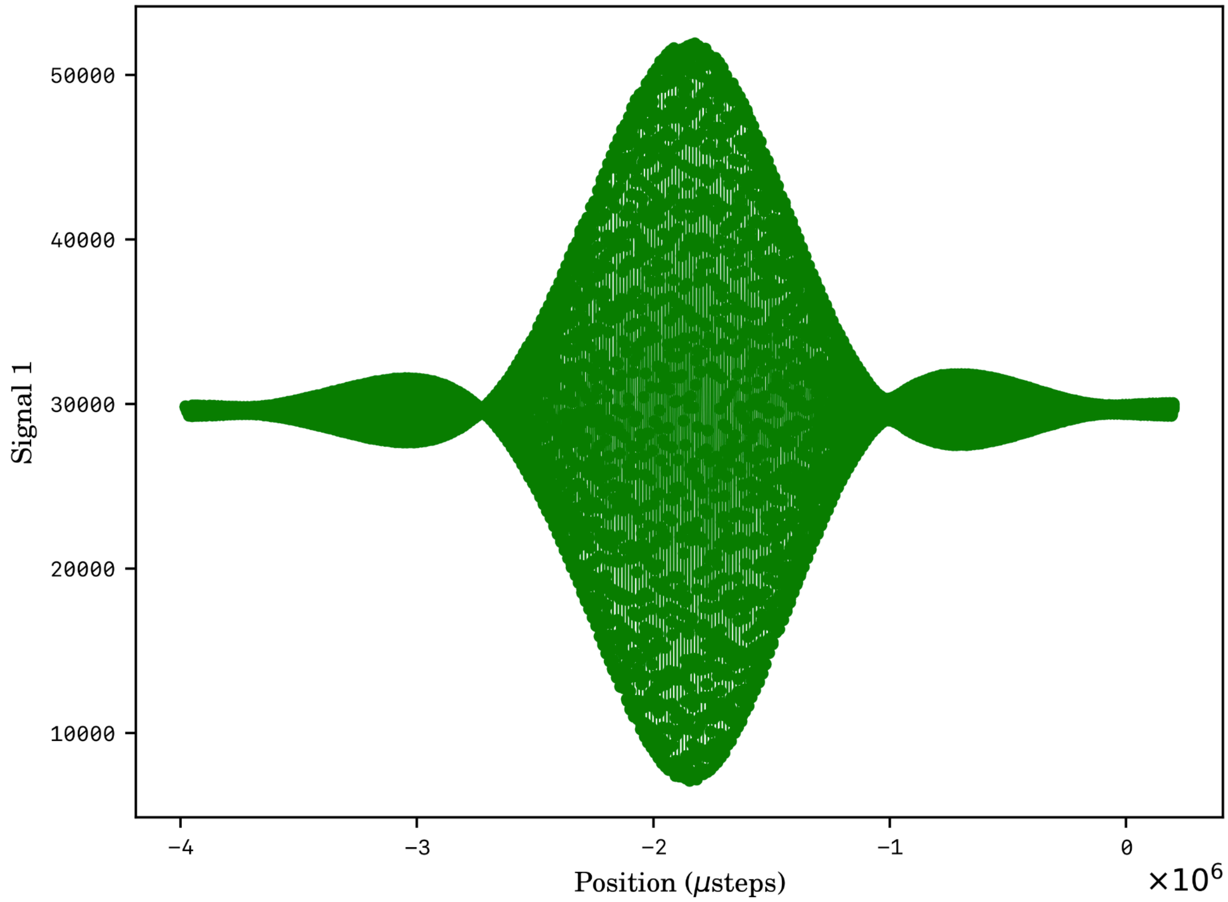


Fig 35. plot of signals (intensity) against position for the white LED with a green filter applied to it. Can see that this is the only interferogram that looks perfectly symmetrical

In order to analyse these interferograms we are going to first use the code provided in calibration to find the mean difference between crossing points as doubling this will yield the wavelength of the source.

In order to do this we will be using the scale factor calculated in task 6 to transform the mean difference between crossing points into nm so that we can calculate the wavelengths of the source.

These wavelengths are summarised in **table 3.**

Source	**Mean difference Crossing points nm**	**Wavelength of Source nm**	**Associated error Of wavelength nm**

Blue LED	232.07031873147287	464.14063746294573	5.8434021171952155
White LED	289.16326724394133	578.3265344878827	8.791273907930908
White LED w/ green filter	270.29697527415607	540.5939505483121	5.523548422647406

Table 3. summarising the wavelengths of the respective sources and their associated errors

From **table 3.** we can see that we have wavelengths we would expect for blue and the green filter as blue light is typically 450 nm and green 550 nm from

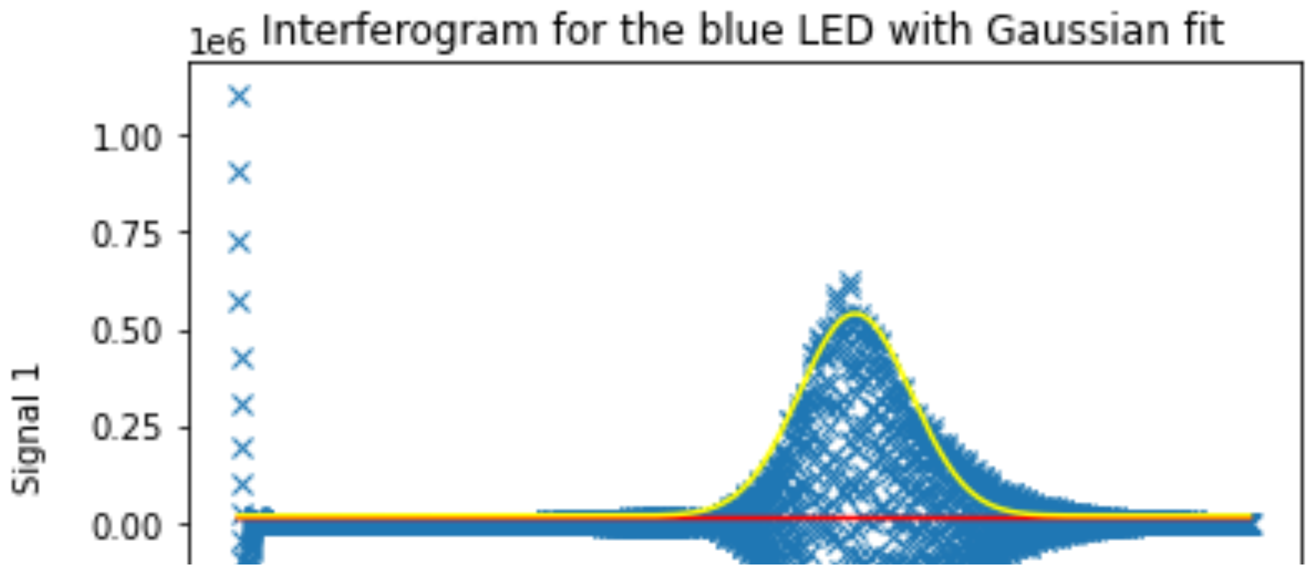
https://www.britannica.com/science/color/The-visible-spectrum

The white light is also unsurprising as we know it's made of a range of wavelengths. Typically from 400 - 700 nm of which the experimental value is roughly central.

To find the coherence length of each source we must first fit a Gaussian to each interferogram. This is achieved by only looking at the data points above the mean amplitude and using scipy.optimise curvefit.

Once the Gaussians are fitted we can find the coherence length by finding the full width half maximum which is the equivalent of the coherence length.

The fwhm is equal to 2.35 times the standard deviation of the gaussian. Therefore, we obtain the coherence length using the optimised standard deviation from our curve fits and again scaling into nm. The error for which is the square root of the diagonal of the covariance matrix. This is then propagated to get the error for the coherence length.



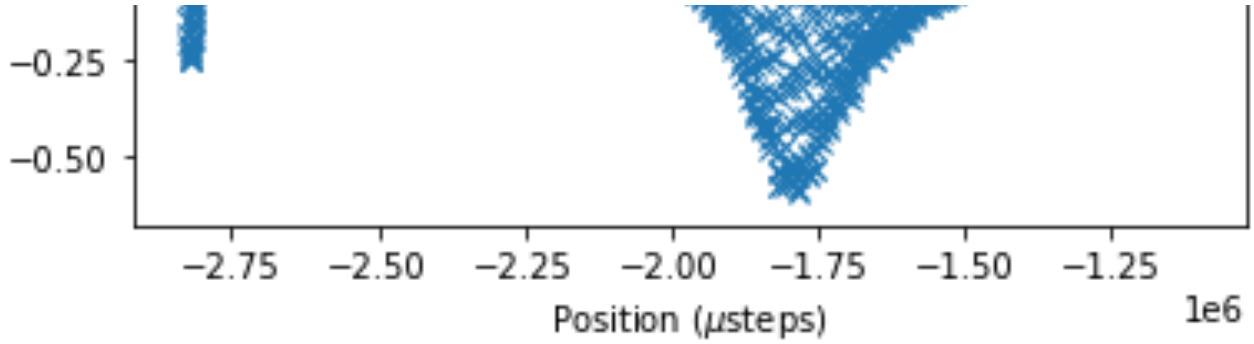


Fig 36, plot of signal (intensity) against position for the blue led. note the data has been passed through the butterworth filter provided in the calibration code. A Gaussian has been fitted to this plot to obtain the coherence length

From ***fig 36.*** we find the coherence length of the blue LED to be **8197.737794391534 +/- 1197.0615600124786 nm**

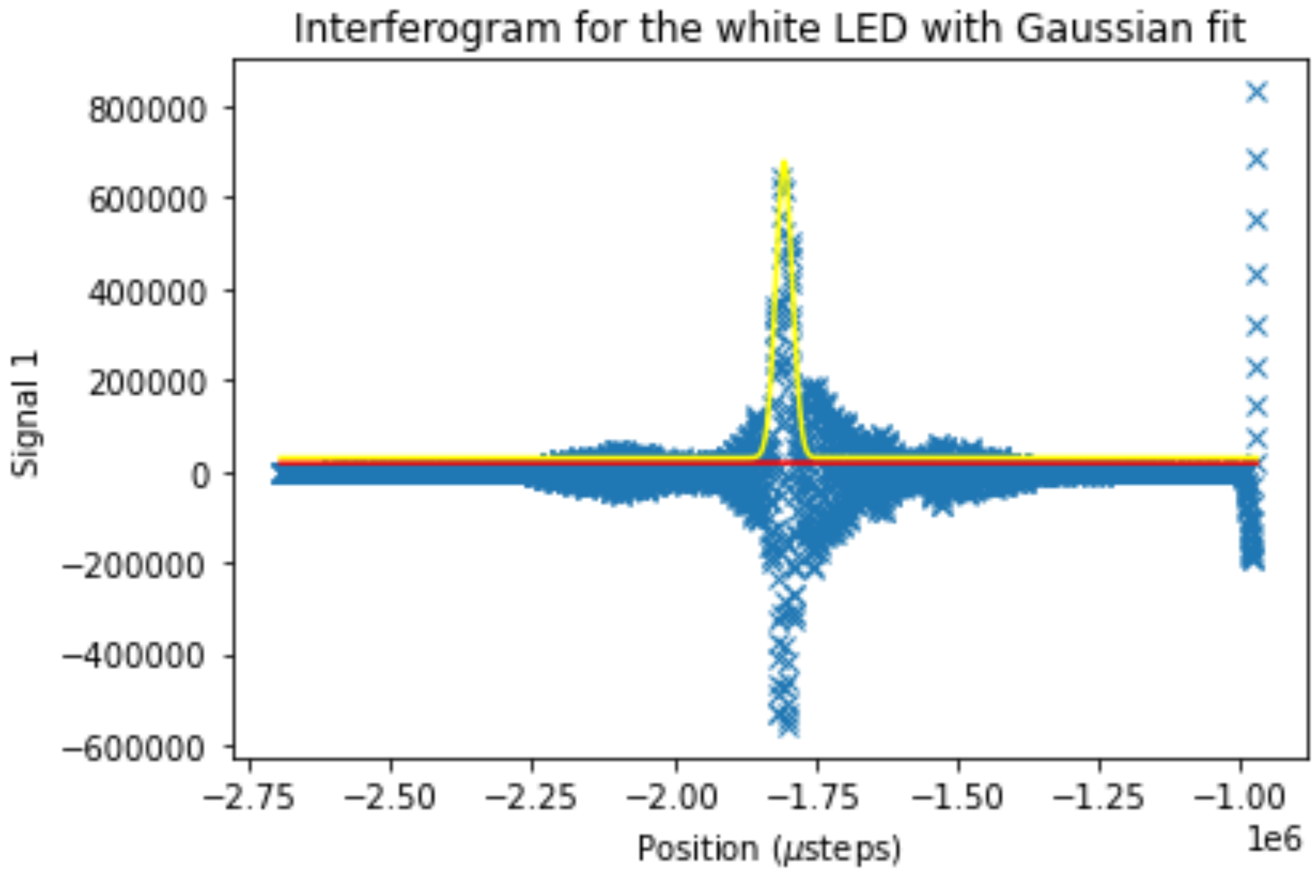


Fig 37. plot of signal (intensity) against position for the white LED. note the data has been passed through the butterworth filter provided in the calibration code. A Gaussian has been fitted to this plot to obtain the coherence length

We decided to curve fit the gaussian to the significantly taller peak in the interferogram in ***fig 37.*** this yielded a coherence length of **1244.4448373187054 +/- 230.27611596941236 nm**

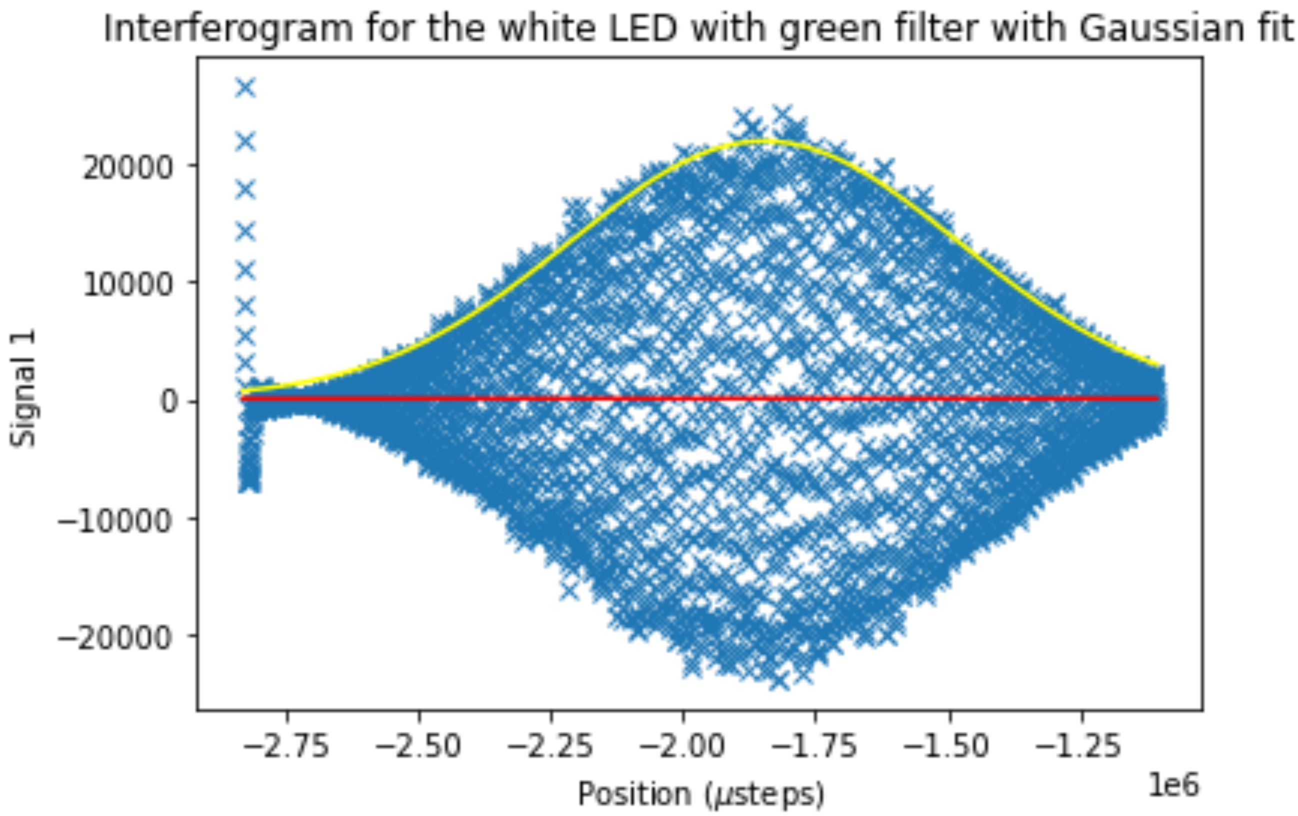


Fig 38. plot of signal (intensity) against position for the white LED. note the data has been passed through the butterworth filter provided in the calibration code. A Gaussian has been fitted to this plot to obtain the coherence length

From **fig 38.** we find the coherence length to be **31556.411458054732 +/- 7247.3885421112445 nm**

To find the spectral width we use formulas (3) and (4) in the lab script and combine them to get:

$$\Delta\nu \times L = \frac{c}{2\pi} \qquad \Delta\nu = \frac{c}{\lambda^2}\Delta\lambda$$

$$\Rightarrow \quad \Delta\lambda \frac{\cancel{c}L}{\lambda^2} = \frac{\cancel{c}}{2\pi}$$

$$\Rightarrow \quad \Delta\lambda = \frac{\lambda^2}{2\pi L}$$

$\Delta\lambda$ = spectral width
L = coherence length
λ = wavelength.

To calculate the error associated with the spectral width. We propagated the error of the coherence lengths and wavelengths found experimentally using

$$\sigma = \sqrt{\left(\frac{\partial(\Delta\lambda)}{} \sigma_\lambda\right)^2 + \left(\frac{\partial(\Delta\lambda)}{} \sigma_L\right)^2}$$

$$= \sqrt{\left(\frac{\lambda}{\pi L}\sigma_\lambda\right)^2 + \left(\frac{-\lambda^2}{2\pi L^2}\sigma_L\right)^2}$$

The calculated spectral widths and errors are supplied in **table 4.**

Source	Spectral Width (nm)	Error associated (nm)
Blue LED	4.182397412134439	0.6197409590617836
White LED	42.77506902149541	8.021359212527988
White LED With Green filter	1.4739233005830796	0.339845267015582

Table 4. summarising the spectral widths of the sources used and their associated errors

From **table 4.** we can see that the white LED has a significantly larger spectral width. This is unsurprising as we know it should include a range of different wavelengths unlike the other two sources. However, we would have expected the width to be larger - closer to 300 nm as we expect it to cover most of the visible light spectrum.

To better interpret our results, we now take a fourier transform of the data we have taken for each source. We do this by setting the nsamp to be the size of the x array. We then find the mean distance (in nm) between each data point (a data point is equivalent to a sample).

We then use the fourier transform code given to us in inter.py to fourier transform our data. We also decided it would be worthwhile to fit a Gaussian to each plot as we can use this fit to obtain key results to compare to those we have already calculated.

The errors associated with any values found from the fourier plots were calculated from the square root of the diagonal of the Gaussian fit.

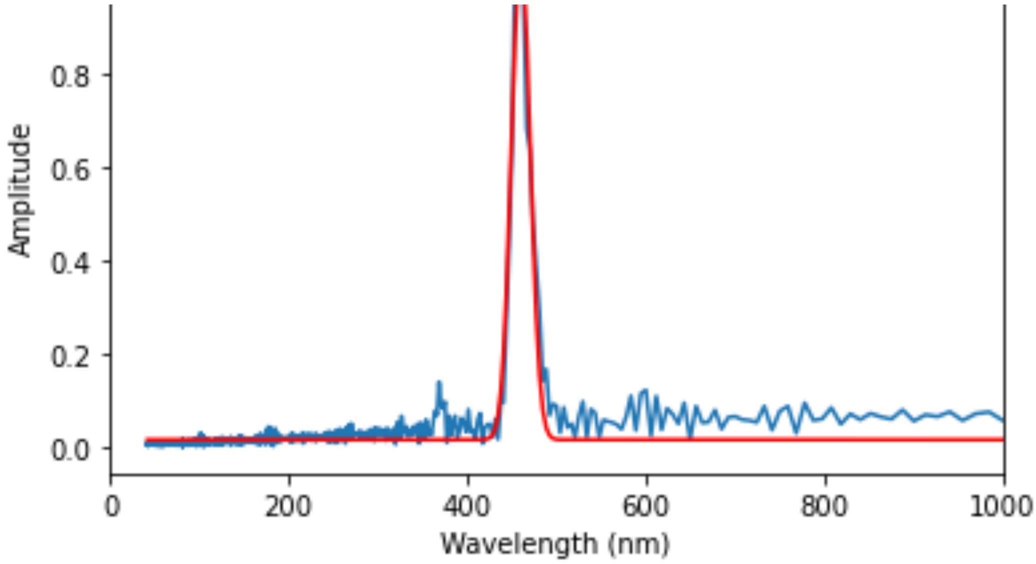


fig 39. plot of amplitude (intensity) against wavelength. Is the fourier transformed data for the blue LED representing its spectrum.

Using the curve fit parameters for **fig 39.** we find that the blue LED has a wavelength of **459.911236840675 +/- 11.986232748022125** which overlaps with the wavelength calculated in **table 3.** We also note that there is a lot of noise around the base of the peak.

Fig 39. looks much as we expected from our earlier simulations.

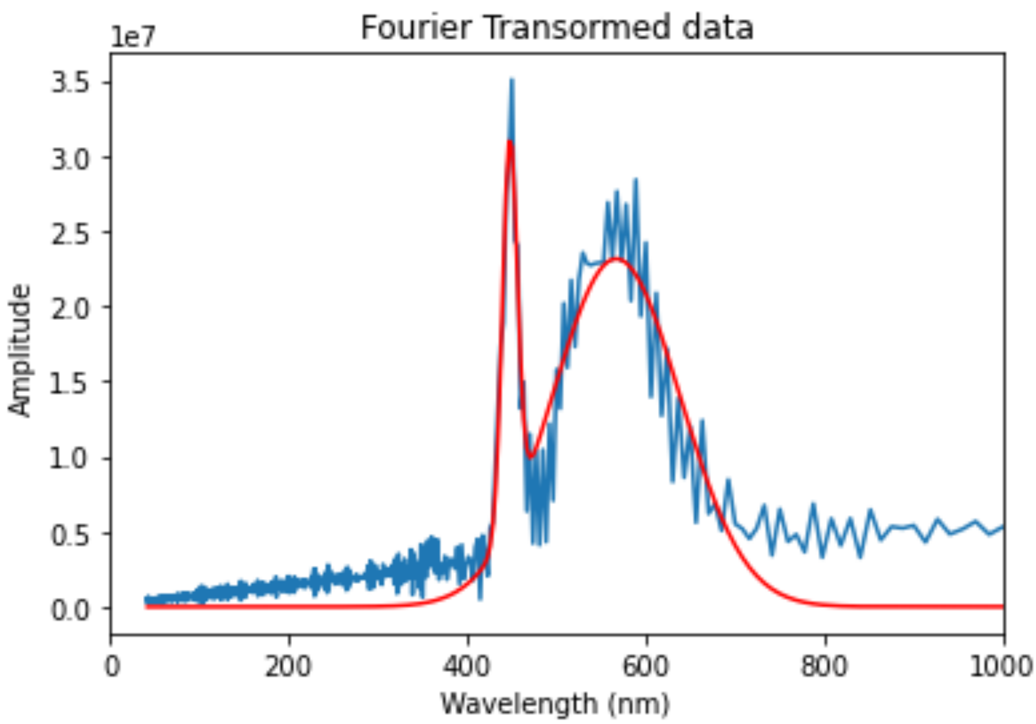


fig 40. plot of amplitude (intensity) against wavelength. Is the fourier transformed data for the white LED representing its spectrum.

Fig 40. is significantly different to what we were expecting. From our simulation in task

Fig 40. is significantly different to what we were expecting. From our simulation in task 7 we expected the Fourier transform to be a wide gaussian with steep sides. However, here we have two distinct peaks at **447.6485244468492 +/- 32.56240089236242 nm** and **566.782307821406 +/- 14.192358529645482 nm.**

The second of these peaks does overlap with the wavelength calculated in **table 3.** Interestingly, the first peak seems to correspond perfectly with the blue LED peak in **fig 39.** We also observe an awful lot of noise from the higher wavelengths in the 800 - 1000 nm range.

The distinct two peak nature of **fig 40.** is because white LEDs do not produce the entire visible light spectrum evenly. Instead of being produced by mixing multiple monochromatic LEDs together, most of the time, white LEDs are produced by Phosphor down conversion.

This is the process in which a single low wavelength LED (typically blue which explains why the first peak matches that in **fig 39.)** is emitted. Surrounding the LED are some phosphor particles which take the short wavelength and convert them to longer wavelengths. This is the second peak shown in **fig 40.** and also explains why there is still a lot of noise around the higher wavelengths since some of these are being produced in this process too.

This also explains the asymmetry of the original interferogram as instead of a single peak we have two peaks with one being significantly wider than the other peak.

https://www.sciencedirect.com/science/article/pii/S163107051830029X

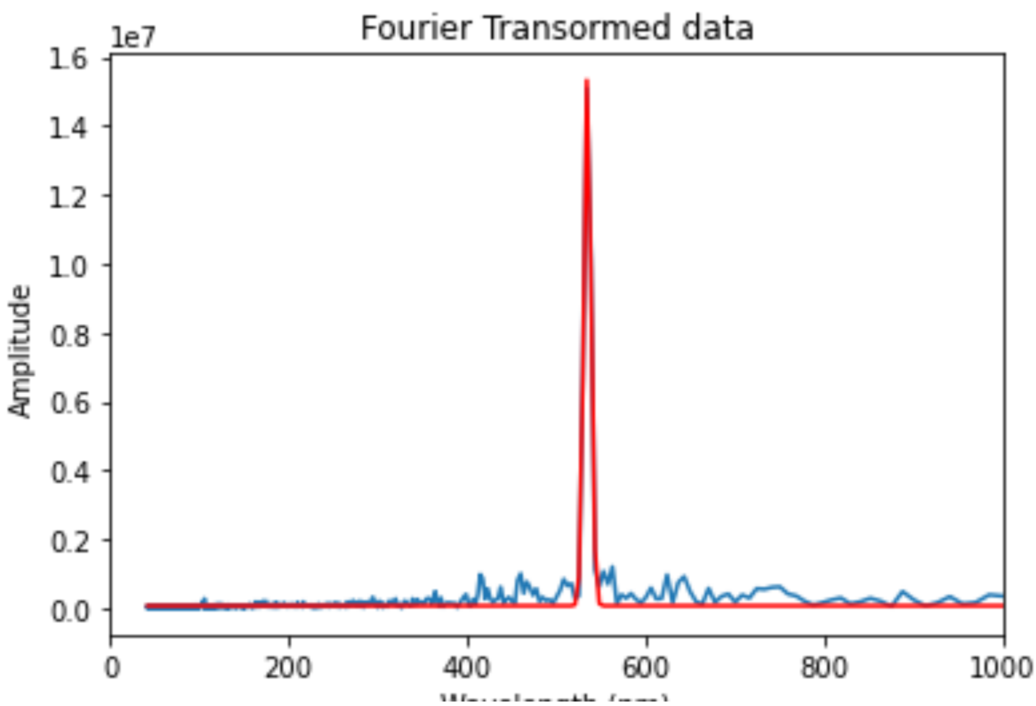


fig 41. plot of amplitude (intensity) against wavelength. Is the fourier transformed data for the white LED with the green filter representing its spectrum.

Using the curve fit parameter we find the wavelength to be **534.5569296533005 +/- 3.372782818187571 nm** for the white light with the green filter on. This is also very close to the value calculated in **table 3** with it being just outside the error of the value from **table 3.**

Fig 41. looks as expected from our knowledge from the earlier simulations.