Determining the Widths of a Ronchi Ruling

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In this report I will be discussing how we determined the values of a and b, which are the values of the slit width and centre-to-centre separation respectively, of a Ronchi ruling with N slits. While there is a more analytic way to find these values by curve fitting the fourier plane image of the Ronchi ruling, I have decided to use the real image of the ruling to determine the specified values.

The setup we used to calculate these values consisted of three lenses, a vertical slit, a Ronchi ruling, a CCD camera and an LED light. Two of the mentioned lenses are plano-convex while the third is a biconvex lens. This equipment allowed us to create a setup where we directed a collimated beam of light originating from the LED light towards the Ronchi ruling, which then allowed us to receive a real image of the Ronchi ruling. We used the thin lens equation,

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \tag{1}$$

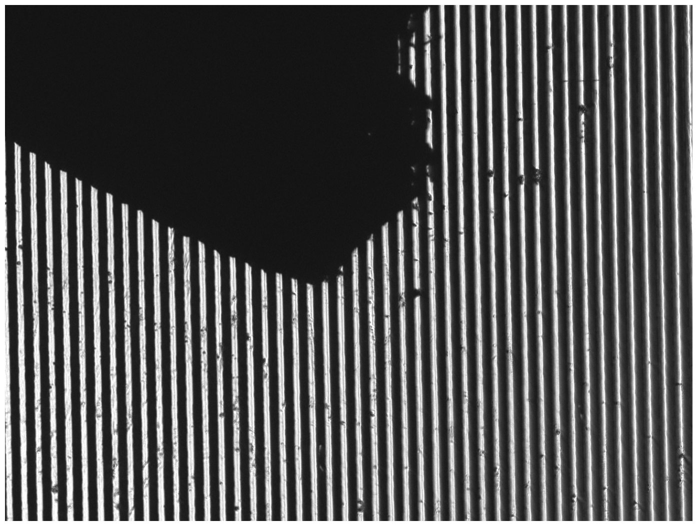
where i is the distance of the image to the lens, o is the distance of the object to the lens and f is the focal length of the lens, to find the appropriate distances between the Ronchi ruling, a plano-convex lens with a focal length of 180mm, and the CCD camera to receive a real image of the Ronchi ruling as seen in Fig.1a. Once we had the image we used the magnification formula,

$$M = \frac{-i}{o} \tag{2}$$

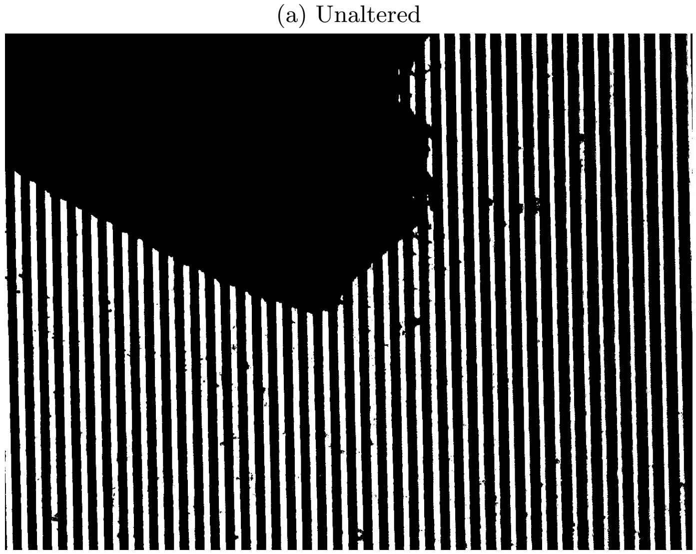
where M is the factor of magnification of the real image compared to the actual object, to find that the our magnification factor was M = -0.652 $\pm$ 0.001. We then took an intensity profile of the real image using a line profile and running it perpendicular to the vertical lines of the image. This profile does not give us a square wave as we need as seen in Fig,2a. As we did not record any preliminary noise, we decided to filter out any medium intensity values with ImageJ to eliminate the bleeding intensity values that may come from the strength of the light, which results in an image with only the extremum of white and black as seen in Fig.1b.

To analyze the data I used the measured the distances between extremum on the intensity profile and converted it to real measurements by using Eq.2 and converting from pixels to μm. The width of one pixel according the the manufacturer's website of the CCD camera is 3.45μm. I then measured the width of each high intensity square wave and the width between the square waves at multiple locations on Fig.2b by changing the selection to the "To Bounding Box" selection and finding the width of that box in pixels as it automatically outlines the needed widths. Then I averaged them to find that a = 108$\pm$6μm and the width between slits, c, is 61$\pm$2μm. The value of b is simply the value of a + c so b = 170$\pm$7μm.

The accuracy of the results along with their uncertainties are unknown as the actual dimensions of the slits for the Ronchi ruling that we used were not given so there is no proven result to compare to. A source of an uncertainty in the measurements is derived from the measurement uncertainty from physically measuring the distance between the different components of the setup. As we measured with a ruler, the measurement not only has a innate uncertainty of ± 0.05cm but there is also an unmeasurable uncertainty due to the pieces of equipment not having solid marks of references to measure with. Due to this we only roughly measured from the center of one lens to the center of another component. Another unmeasurable source of uncertainties is from filtering out the intensities that weren't on either side of the extremum as it may have adjusted the widths of each of the slits that I measured. To control the intensity we put a ppiece of clear tape of the LED to lower the intensity as the CCD has a max value of 255. Given our intensity plot of the real unfiltered image we should have changed some computer settings to reduce the bleeding light but unfortunately we did not. There are more methods to confirm my conclusions with the first being to get the fourier plane image of the real image and then fit a plot to the intensity plot of that fourier plane image and examine the coefficients used in the fit. Another method would be to use the MonteCarlo method to simulate the function for the fourier plane fit several times to get an approximate of the values. A physical method that is similar to the method that I used would be to use a strand of human hair and measure it with a micrometer and then put it on the Ronchi ruling to display it on the image so that there is a reference to compare the values of a and b to. Unfortunately I was unable to get the analytic methods to work so I instead used my brute force method to obtain my results. For any future attempts at the measuring the values of a and b, there a few key things to do to reduce the uncertainty and obtain better values in general. The unmeasurable uncertainties could be decreased by setting discrete measuring points between components of the setup and by adjusting the camera settings to lower the peak intensities. The measurable uncertainties could be reduced by using a more accurate measurement device. By fitting the data with relevant equations or by generating data using the Monte Carlo method, the uncertainties of the parameters can also be strengthened.

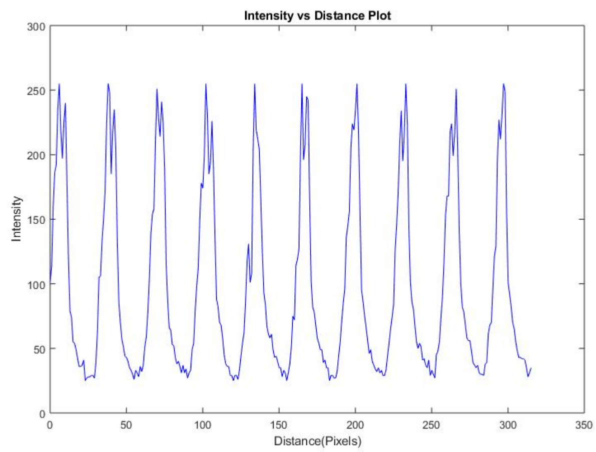


(a) Unaltered

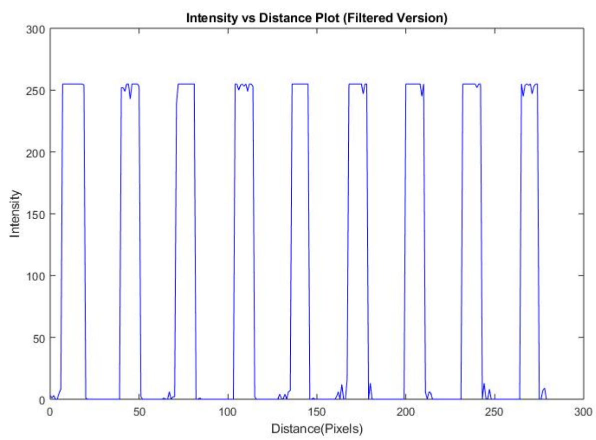


(b) Altered

Figure 1: These are two figures of the real image of the Ronchi ruling captured by the CCD camera. a) is the raw unfiltered real image that was obtained while b) is the raw image that is filtered by an automatic threshold by using ImageJ.



(a) Unaltered Intensity



(b) Altered Intensity

Figure 2: These two figures are the result of analyzing the intensity profile across a small portion of the images in Fig.1, which results in the given Intensity vs Distance(Pixels) plots. a) is the intensity profile of Fig.1a where a square wave is expected but instead, a plot of sharp peaks is obtained. b) is the intensity profile of Fig.1b where the noise is filtered out and a square wave is obtained.