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Spatial Coherence Module Writeup

1. Prompt

Original - Measure the center wavelength of the light from the diode by observing characteristics of the fringe pattern produced by a light emitting diode. What is the minimum coherence area the beam must possess to produce the observed fringe pattern?

Modified – Generate an interference pattern with a stable HeNe laser propagated through two pinholes onto a sensor. Analyze the fringe pattern created and devise a model using system parameters that can measure the wavelength of a new laser with an unknown wavelength.

2. Data Gathering

Data was gathered for this experiment using a HeNe laser that produced a stable $632.8nm$ beam of coherent light. The laser was propagated though a piece of thin cardboard that had two small pinholes punched into it onto a Raspberry Pi camera module with a resolution of 2000 by 2000 pixels and pixel size of $2um$. After some testing, the image shown in Figure 1 was deemed to hold enough interference information to continue analysis.

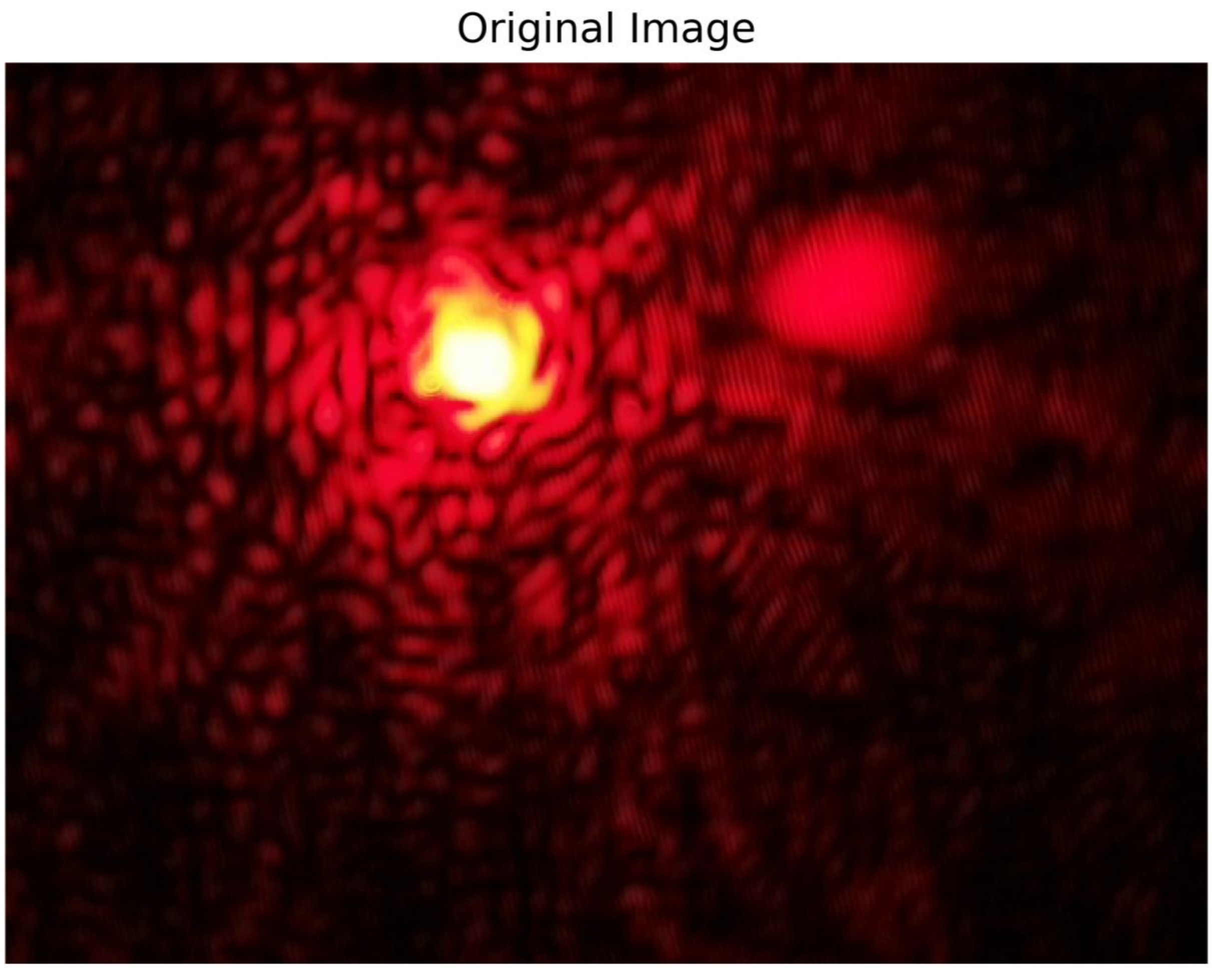

Figure 1. The original full size image captured by the camera module.

3. Isolating Interference Zone

In the original image, only a small portion of the total capture demonstrated an interference pattern. The zone containing the interference pattern was isolated and the data around it was truncated, resulting in the pattern seen in Figure 2.

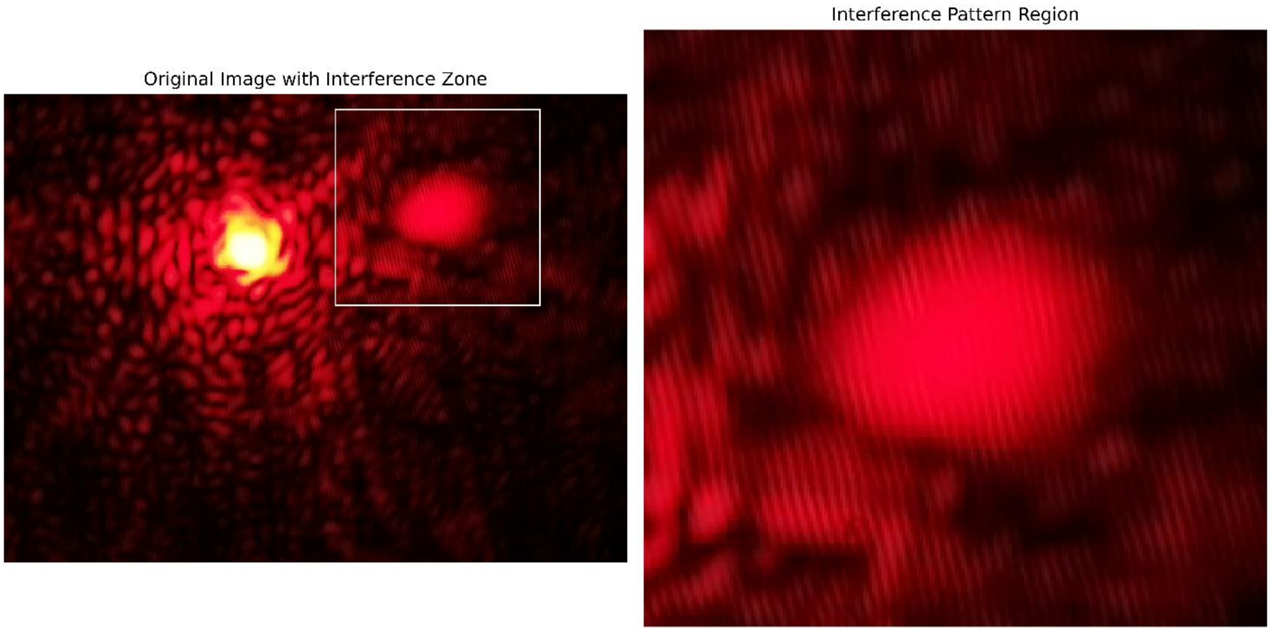

Figure 2. A visual representation of where in the original image the interference pattern was observed and the full size image of the interference region analyzed.

4. Fringe Pattern Analysis

From the interference region, a horizontal slice of pixels were extracted on a line just below the large dot of saturated data in the center to maximize the number of fringes captured. At this time the data was also converted to gray scale to combine the three colors originally captured with the camera module. The plot of this line is shown in Figure 3.

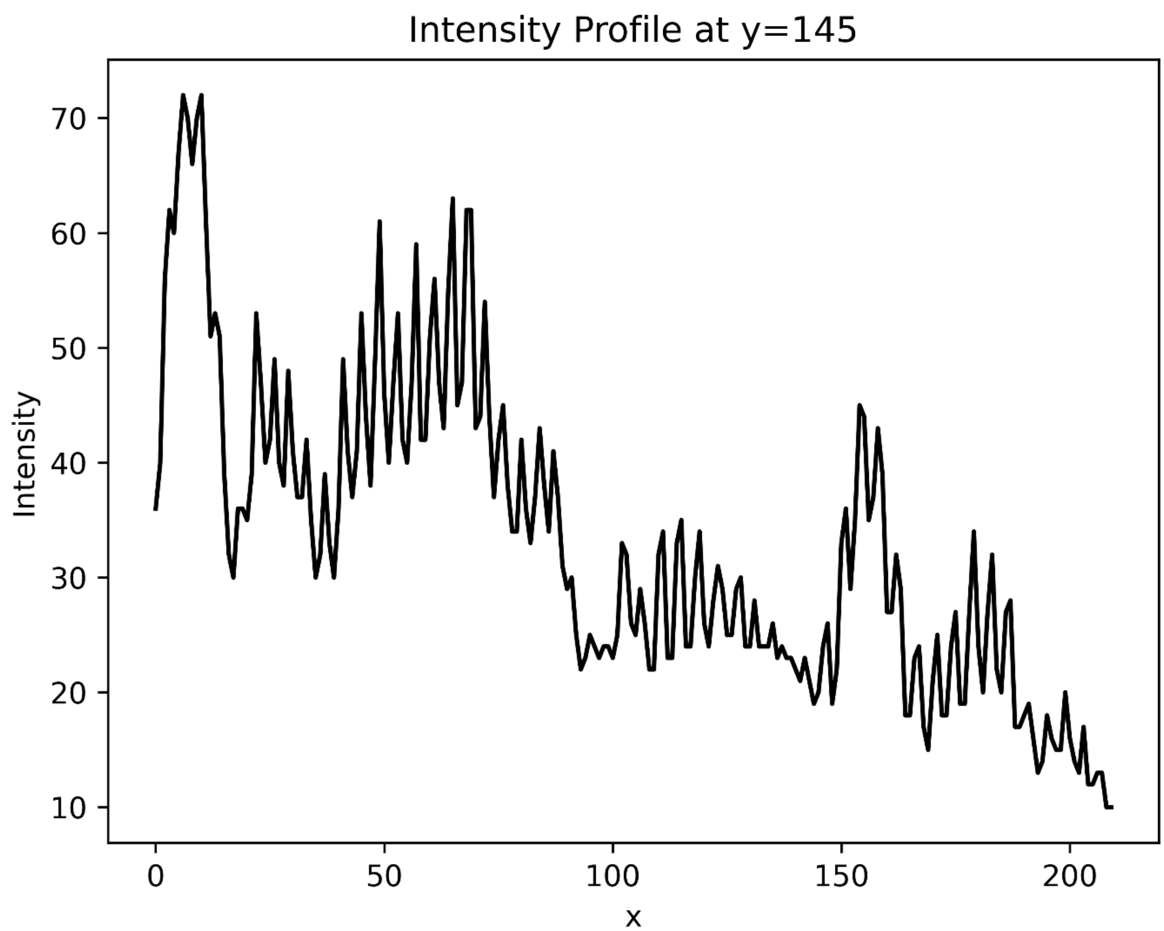

Figure 3. The plot of a horizontal line of data extracted from the interference region.

In this plot, strong indications of uniform peaks and troughs of the intensity were observed, even as the overall underlying intensity fluctuated. In order to better examine the distance in pixel space between the peaks, the plot was zoomed in and it was determined that the strongest peak period present was every four pixels. An example of this is shown in Figure 4, where a vertical line is placed a the index 45, 49, 53, and 57.

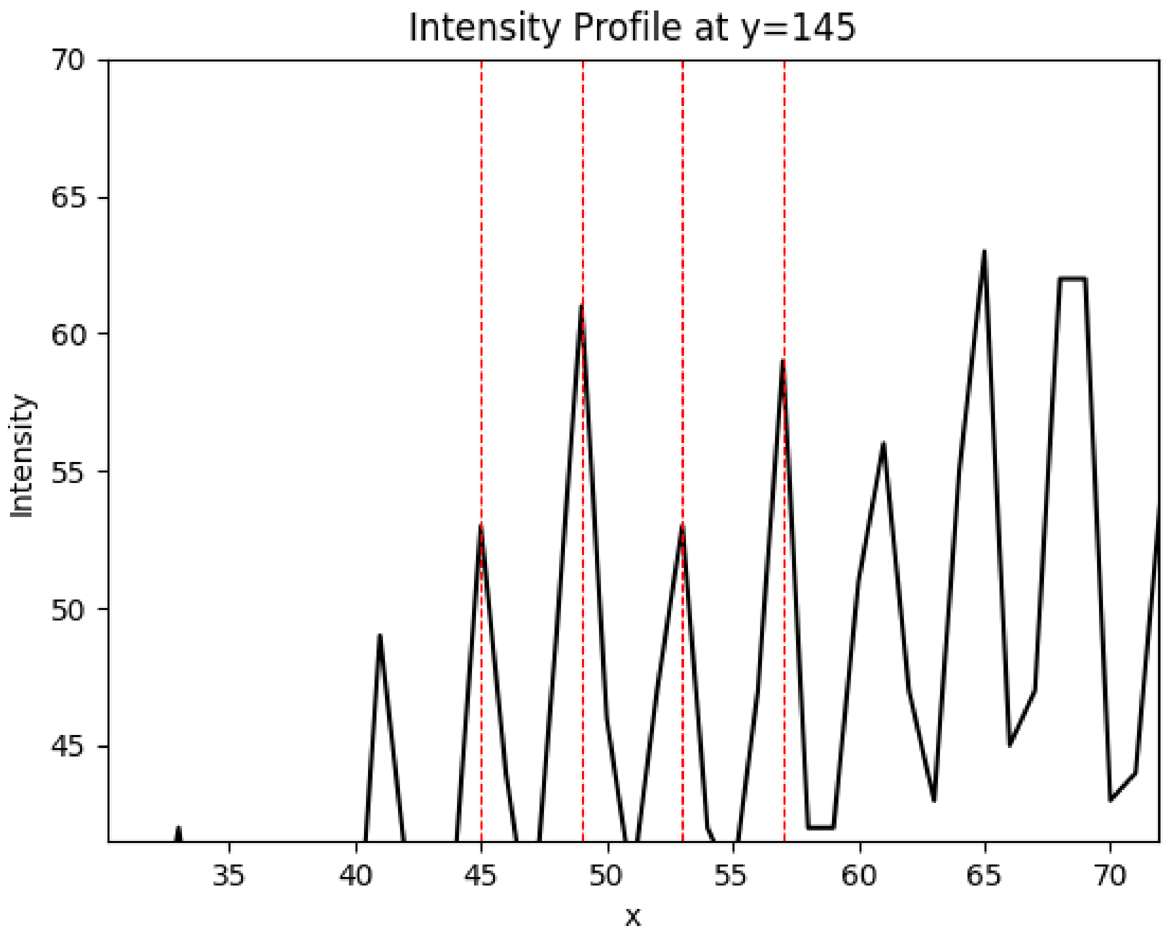

Figure 4. Zoomed in portion of Figure 3 with lines showing four-pixel periodicity

Considering the pixel size of $2um$, it was then determined that the fringe pattern observed exhibited a period of $8um$.

5. Application to a Laser of Unknown Wavelength

Given the information known about the laser used to generate the initial data and the hardware parameters of the camera, it then becomes possible to create a model that could be used to derive the wavelength of a new unknown laser, under certain conditions. The model starts with Equation (1.1), the spatial fringe period on the observational plane, found in Goodman's Statistical Optics equation 5.2-25.

$$L = \frac{\bar{\lambda} z}{d} \tag{1.1}$$

Where L is the spatial fringe period, $\bar{\lambda}$ is the center wavelength, z is the propagation distance from the pinholes to the detector plane, and d is the distance between the pinholes. In this equation, L can be converted to the value Δx, converting the pixel periodicity to a real spacing of $8cm$ on the sensor. Additionally, we can consider the center wavelength $\bar{\lambda}$ to be the wavelength of the HeNe laser used to generate the data, $632.8nm$. Rearranging the equations to consolidate the known and unknown values results in Equation (1.2), the ratio of z to d.

$$\frac{\Delta x}{\lambda} = \frac{z}{d} \tag{1.2}$$

Inserting in the known values results in a ratio of 12.64. One strong condition that arrives from this ratio is that any future calculation utilizing it must have the exact same values for z and d to maintain continuity. However, if this condition is satisfied and a laser of unknown wavelength is used to generate new interferences patterns, by performing the same analysis done previously and calculating a new spatial fringe periodicity distance, Δx_2, the wavelength of the unknown laser could be calculated using Equation (1.3).

$$\frac{\Delta x_2}{12.64} = \lambda_2 \tag{1.3}$$