**Experiment 10: Laser Tweezers**

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**Abstract**

Using a laser light source with wavelength of 651nm, diffraction patterns due to single slits, double slits, and hexagonal orientations were studied. Using equations derived from Huygen’s principle the single slit widths were verified to within about 20%. Measured data from double slit patterns indicates fringe spacing is consistent when slit width is, and that slit separation only serves to affect the less prominent fringes. Components of white light are diffracted at different angles using a grating, separation of colors like blue, red, and green were observed. Other shapes only diffract constructively in planes perpendicular to flat edges of the mask shape.

**Introduction**

Our laser tweezer setup was arranged using an optical breadboard for securing each element in place. Red laser light was reflected off an Al mirror at 45 degrees, passed through an adjustable polarizer used later for adjusting intensity, focused by a lens with a 200mm focal length, reflected off a Dichroic Mirror at 45 degrees, then put through a 100x objective for focusing at the position we place our slide sample. The lens between the polarizer and Dichroic Mirror is positioned on the breadboard with a rail allowing for pre-focusing of the laser before it enters the 100x objective. A lamp is used to shine white light into the slide in the opposite direction as the laser. The white light passes through the sample, the 100x objective lens, allowed to pass straight through the Dichroic mirror to illuminate our sample in the eye of a camera we used to measure the effects of our tweezer.

A Dichroic Mirror is a mirror which reflects and/or transmits light in different amounts based on the light’s wavelength.

**Analysis & Discussion**

Samples with a concentration of 1.2 micrometer sized beads were made. A few drops of more highly concentrated solution was added to a vile of de-ionized water and mixed—a diluted concentration was made, and a few drops of it was transferred to a small glass slide typical in microscopic setups. An even smaller, thinner slide is placed on top, sandwiching our sample between the two pieces of glass. Once made, the slide sample was put into a slide holder—right up against the business end of the objective lens so that the coverslip faced the lens. The slide holder allowed us to adjust the position and orientation of the sample along x, y, and z directions. Once oriented and close enough to the objective, a small amount of immersion oil was carefully placed between the two. As the oil was held in place by surface tension experienced in its close quarters, care had to be taken not to allow much space between the two.

**Q1** Immersion Oil is helpful to reduce the degree of refraction that happens as light travels from one media to the next. In our case, it helps keep the light from becoming obscured as it travels from the objective lens to the sample slide.

The white light lamp was then turned on to illuminate our set up for viewing with the camera. An aperture immediately after the lamp was closed slightly to decrease its intensity for optimal intensity resolution of the cameras digital image. The stage holding our slide is then adjusted so that the 1.2 micrometer beads came into focus on the camera as they traveled across the viewing area. **Q2** Beads were observed to be traveling with gravity in the downward direction.

Although all optical elements of this setup were already in place when we began, their positions and orientations were adjusted to verify its optimization and to get a feel for the setup. The 200mm lens wanted to be placed closer towards the Dichroic Mirror, increasing the lasers focus at the position of our slide—decreasing the beam size at the slide and increasing the lasers effective power there. Some adjustment was also needed for each of the two mirrors, and more-so after having shifted the central lens. Changes to these mirrors was done based on the quality of the hourglass shaped diffraction pattern made with the laser light. At this point we had expected to be able to observe the beads within our sample get trapped by our tightly focused laser light. However, after much effort, we were not able to achieve this on our setup within the allotted time.

*The rest of this lab was done based on work on an analogous setup prepared by a neighboring group. Though we made independent observations, ultimately our data was also given to us by a member of this other group, S. Fromm.*

*Items that likely contributed to our difficulty in optimizing our set up are taking for granted both the beam trajectory into the objective lens and the beam collimation throughout. Wording from here on out will be as if we had gotten the data ourselves.*

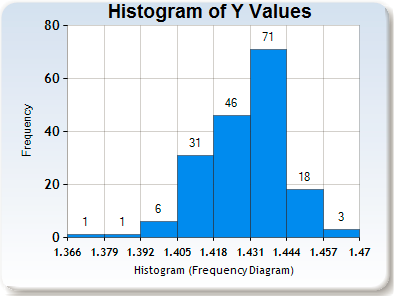
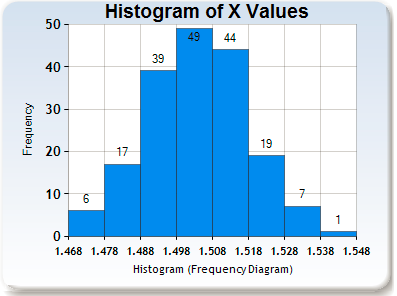
Trapping of 1.2 micrometer beads was observed. Adjusting the orientation of the polarizer, located in the beams path upstream, the laser’s intensity and effective power was decreased to minimize the chances of trapping a distracting number of beads. When moving the slide’s position, the already trapped bead did dislodged from the potential well generated by the focused beam. A red-light filter was added before the camera to keep from saturating our image with red light from the laser, having a spot of concentrated red light in our camera images was thought to be a potential issue later.

Image data from the camera was taken with a computer at a rate of 50ms for 100 image bursts, or over a time span of 5 seconds. Three sets of images were taken, one with the polarizer oriented to transmit 100% of the laser intensity, one which transmitted 75%, and one for 25%.

A software utility ImageJ was used to perform an offline analysis of each images x-y profile. These profiles were found after having chosen a static region of interest to be used in all images of a given image set. The position values for x and y that we ultimately ended up analyzing were defined internally by ImageJ from its x-y profiles.

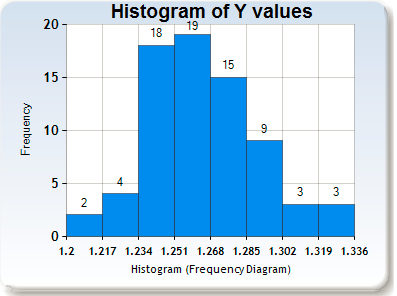
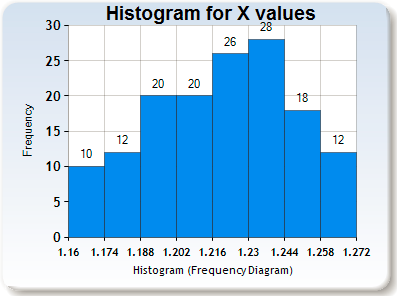
The X and Y data for each image set was plotted in separate histograms.

Power Value 1



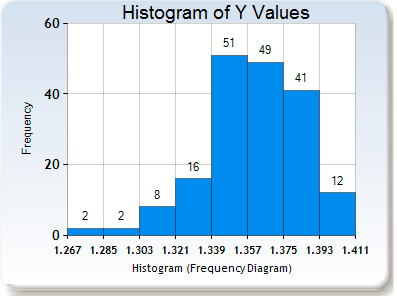
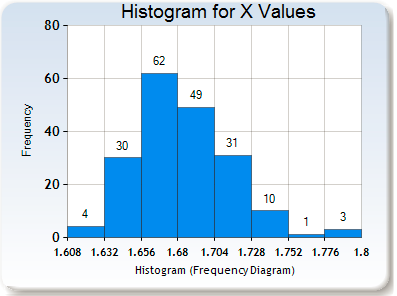
|  |  |
| --- | --- |
| **X Variance** | **Y Variance** |
| 0.000199 | 0.056268 |

Power Value 2



|  |  |
| --- | --- |
| **X Variance** | **Y Variance** |
| 0.000695 | 0.000622 |

Power Value 3



|  |  |
| --- | --- |
| **X Variance** | **Y Variance** |
| 0.000976 | 0.000586 |

Variance of the data from its mean was plotted verses 1/P.

**Conclusion**

It was found that for producing diffraction patterns, the slit widths affect what is the single slit diffraction pattern, and that adding multiple slits does not affect this envelope in the resulting pattern. However, adding slits does affect the characteristics of the micro-fringes in the resulting pattern.

Also, though there may be light coming out in different planes, the only ones which add up to something visible are those which are alongside many others with nearly identical patterns, a conclusion derived from seeing the patterns from square aperture gratings.

By viewing a diffraction grating with very dense lines, the single slit envelope seems to disappear from the pattern and a very fine, consistently bright pattern emerges.

These fine gratings diffract light at different wavelengths.