Using a Spatial Filter to Reduce Noise in Optical Diffraction

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Introduction

We use optical diffraction to analyze the locomotion of the *C. elegans*, a microscopic worm the diameter of a human hair, which is commonly used as a simplified model for more complex organisms. A laser is directed at the live worm, producing a dynamic diffraction pattern, captured by a high resolution CCD camera. However, a raw, unfiltered laser beam does not produce a clear, symmetrical pattern, as shown in Figure 1. We modified and updated our original optical setup [1] by using a spatial filter and an assortment of lenses to prepare the beam so that a clear diffraction pattern could be produced, using a hair to model the worm.

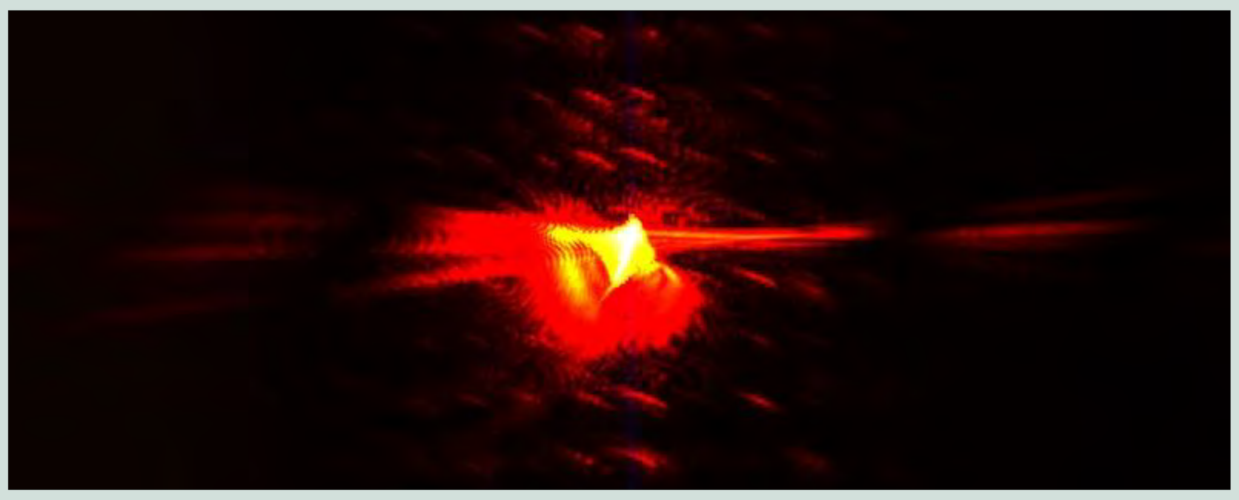

Figure 1: Rudimentary, asymmetrical diffraction pattern of a hair produced by the original optical setup.

Spatial Filter

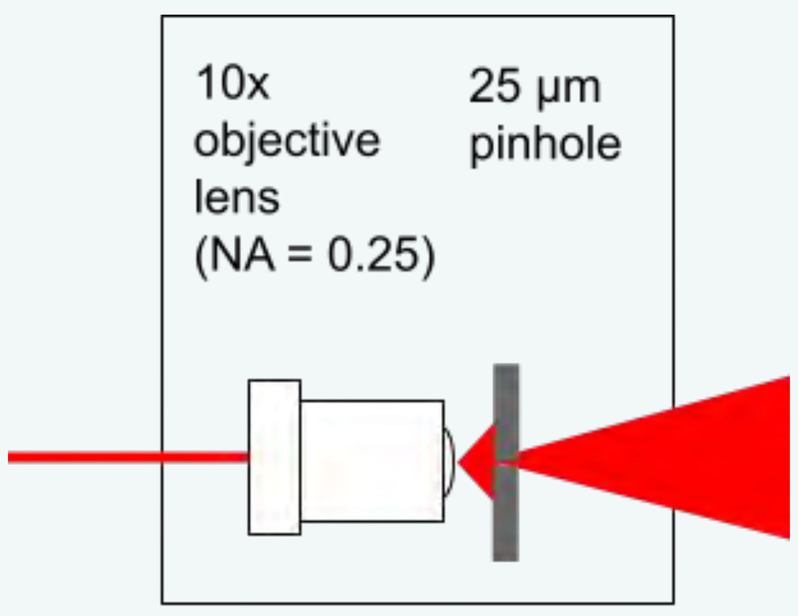

Figure 2: The spatial filter cleans the beam by shaping it into a consistent plane wave. First, an objective lens focuses the light of the non-uniform beam into a concentric pattern of rings, around a central circular beam. Next, a pinhole allows only the desired central beam to pass, improving the overall quality of the beam, which exits the pinhole and expands rapidly [2].

Collimation Lenses

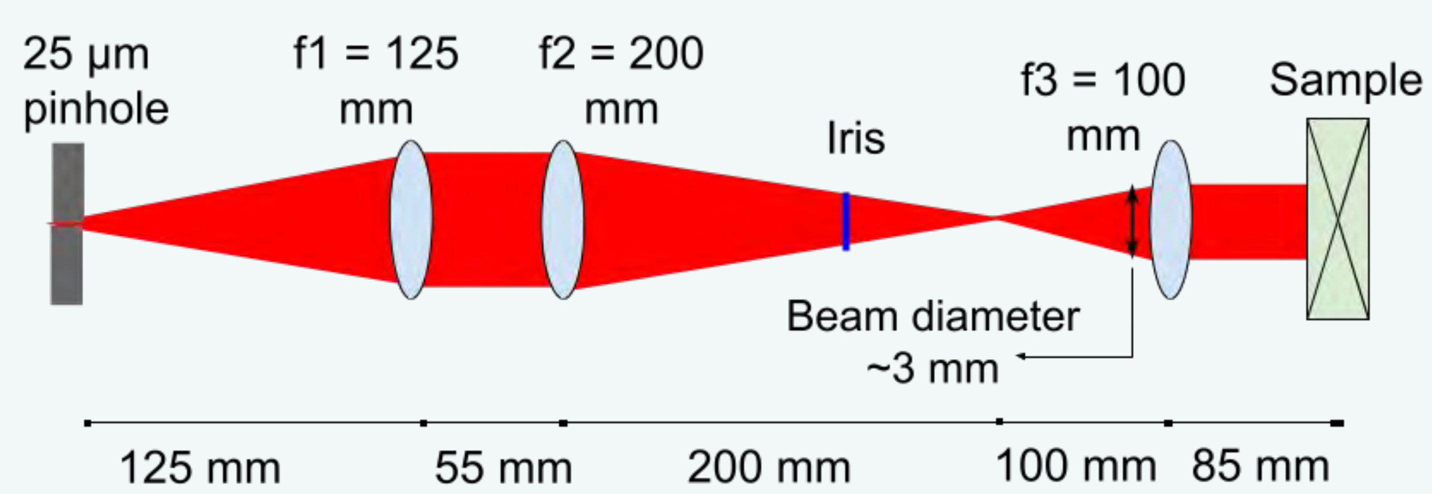

Figure 3: Because the light exiting the pinhole is rapidly expanding, we must collimate the beam, or make it parallel. However, one lens does not allow the beam to be collimated at a small enough diameter. We used a setup consisting of 3 convex lenses in order to collimate the beam at the desired diameter, so that the light is collimated as it hits the sample and produces the diffraction pattern.

Conclusion

Our final optical configuration is depicted in Fig. 4. By implementing the spatial filter and system of lenses, the laser produced a much more symmetrical diffraction pattern, as seen in Fig. 5. Variations in light intensity at just one point in the pattern contain information about the entire pattern, and therefore the object's overall movement. Going forward, we will record and analyze diffraction patterns of the actual *C. elegans*, utilizing computer programming to obtain information about the neuronal dynamics of its motion. We will also work on eliminating the background scattering produced by the camera [3].

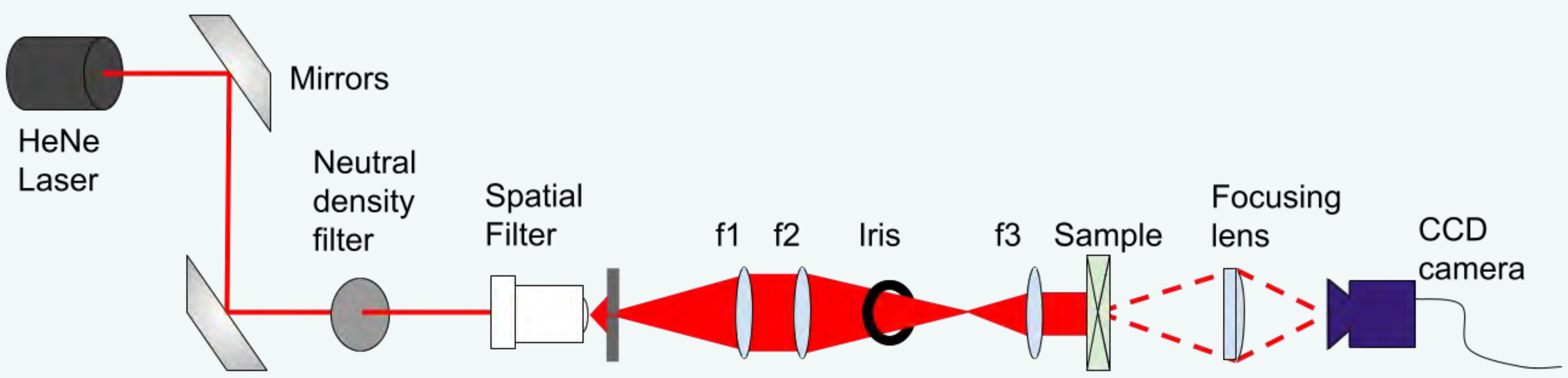

Figure 4: Completed optical setup

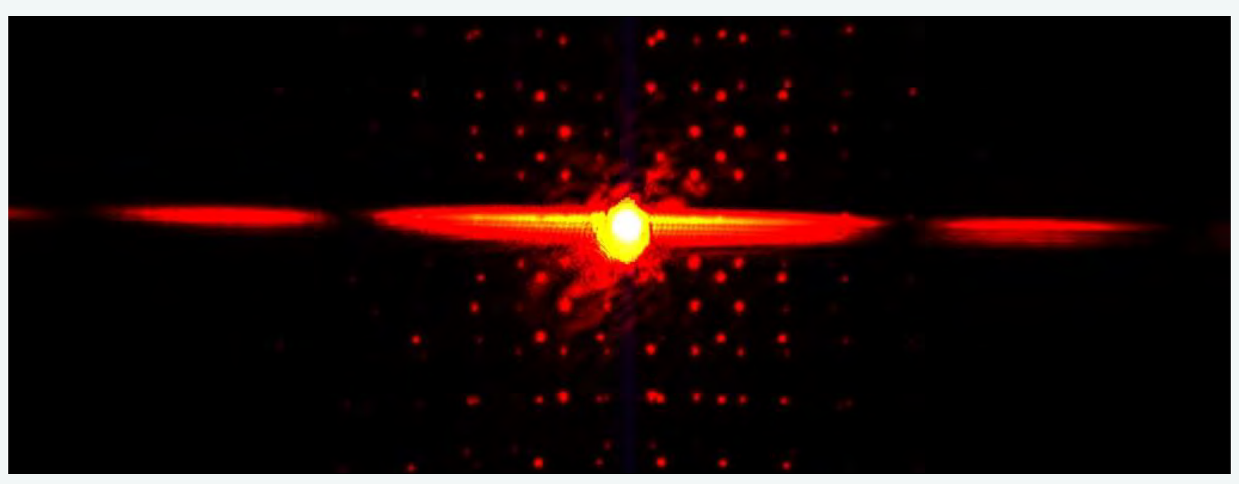

Figure 5: Clean diffraction pattern of a hair produced by the final optical setup, which is very symmetrical and ready for analysis

References

[1] P. Thibault, and I. C. Rankenburg, American Journal of Physics **75**, 827 (2007). doi: 10.1119/1.2750378.
[2] P. Beyersdorf, *Laboratory Optics: A practical guide to working in an optics lab*, printed by the author, (2014).
[3] J. J. Barreiro, A. Pons, J. C. Barreiro, J. C. Castro-Palacio, and J. A. Monsoriu, American Journal of Physics **82**, 257-261 (2014). doi: 10.1119/1.4830043.

Acknowledgements

We would like to thank Jenny Magnes, Susannah Zhang, Harold Hastings, Juan Merlo, Sam Gonzales, and the Lucy Maynard Salmon Research Fund for their patience and vital contributions to this project.

Questions?

For more information, scan the QR code or send an email to **kcanavan@vassar.edu**.