Looking Clearly Through the Clouds

Raneen Assy, Jonah Forman and Ethan Swagel

Mentor: Gal Gumpel, M.Sc PI: Dr. Erez Ribak

Physics Faculty, Technion – Israel Institute of Technology, Haifa, Israel

Introduction

A telescope condenses light beams to make an image more visible (Figure 1). The bigger the aperture, the better the resolution of the image. Greatly enlarging an aperture, however, is expensive.

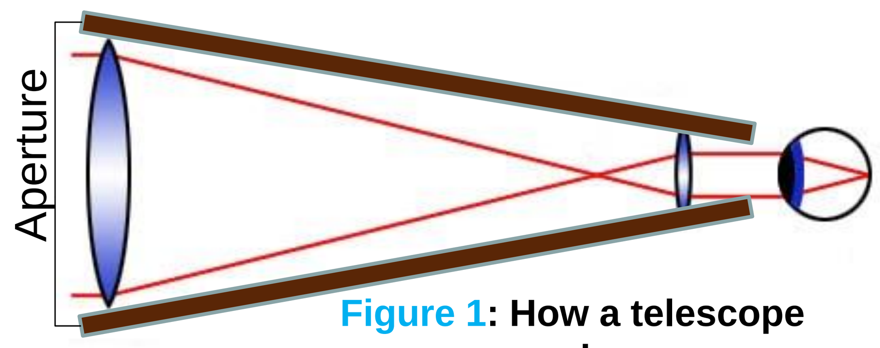

Figure 1: How a telescope works.

Our project addresses this issue through an optical phenomenon known as a corona.

When the light from the distant object passes through a high, thin cloud, it diffracts from the tiny water droplets and causes the halo effect of the corona (Figure 2).

The corona can be as much as eight times larger than the central aureole, the brightest spot in the middle. The cloud act as a natural thin lens, effectively enlarging the aperture size.

Figure 2: A natural corona around the moon (Cowley, Laven, & Vollmer, 2004).

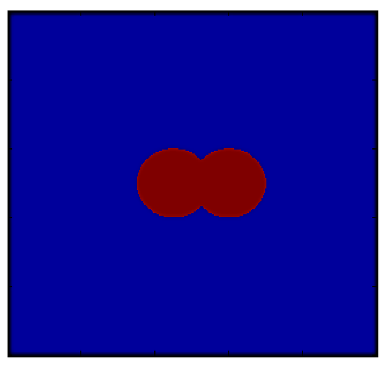

Figure 3a: Two overlapping circular light sources drawn in Matlab.

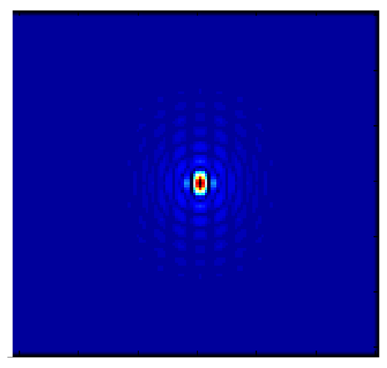

Figure 3b: The inverse Fourier Transformation of Figure 3a. Notice the alternating dark and light columns.

When light passes through a lens as it does in a telescope, it naturally undergoes an operation called a ***Fourier Transformation.***

To see the image that entered the telescope, one must perform an Inverse Fourier Transformation on the detected image (Figure 3).

Experimental Setup

Goal: Create two parallel laser beams with an adjustable distance between them

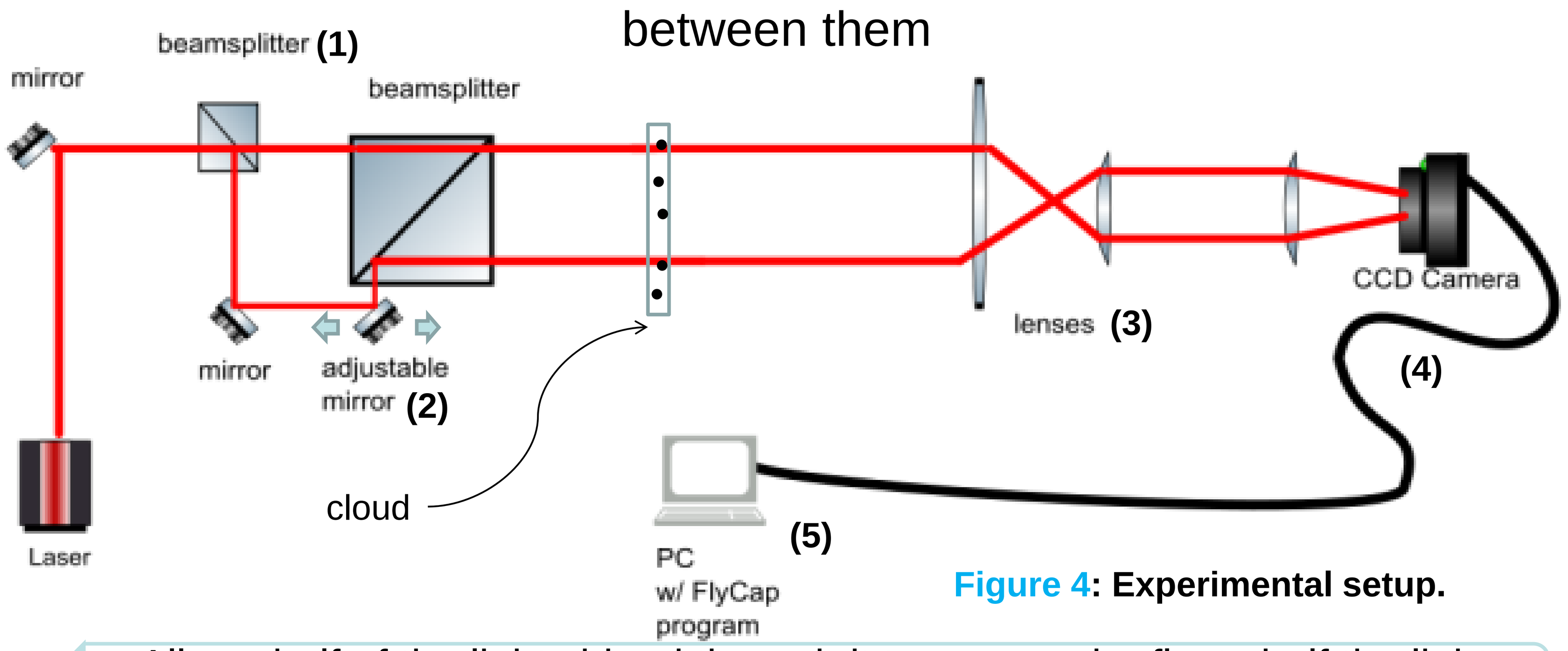

Figure 4: Experimental setup.

1. Allows half of the light shined through it to pass and reflects half the light at a 90 degree angle.
2. Moving the adjustable mirror along the direction indicated by the arrows changes the distance between the beams.
3. "Telescope" – condenses the laser beams.
4. The camera is linked to a computer program called FlyCap, which records the intensity of light at each pixel.
5. Transferring the image created by FlyCap to Matlab, we perform an inverse Fourier Transformation on the image as seen in Figure 5.

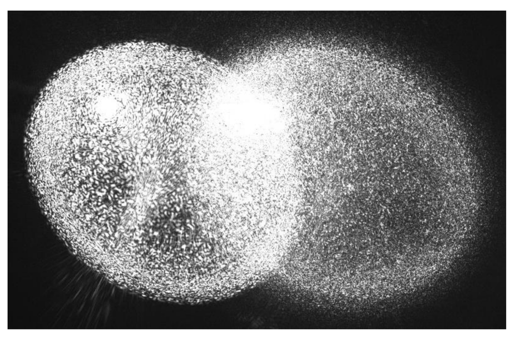

Figure 5a: Detected beams of parallel lasers in FlyCap. Real-world trial of Figure 3a.

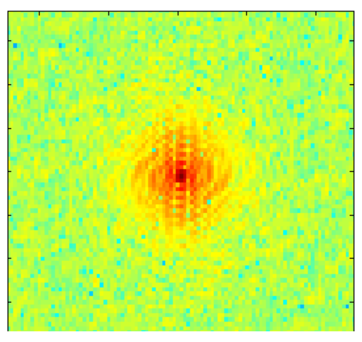

Figure 5b: Inverse Fourier Transformation of Figure 5a.

Results

We took images of the laser beams at different distances, first without the cloud then inserting the "cloud," a glass slide lightly coated with alumina particles, after the second beamsplitter (Figure 6).

The clearly higher resolution of the image with the cloud and the diffraction pattern in the inverse Fourier Transformation demonstrate the viability of our methods.

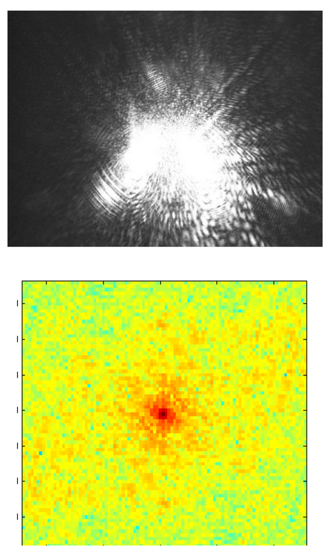

Figure 6a: Image and inverse Fourier Transformation of lasers separated by 8.5mm

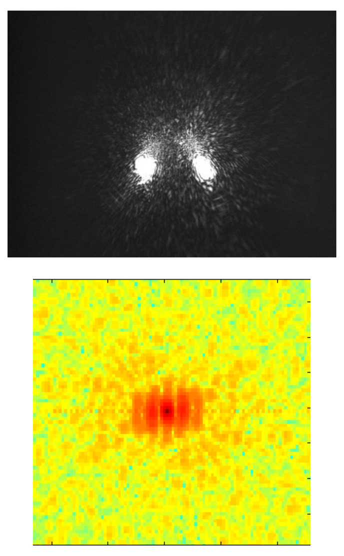

Figure 6b: Image and inverse Fourier Transformation of lasers separated by 8.5mm passed through the "cloud"

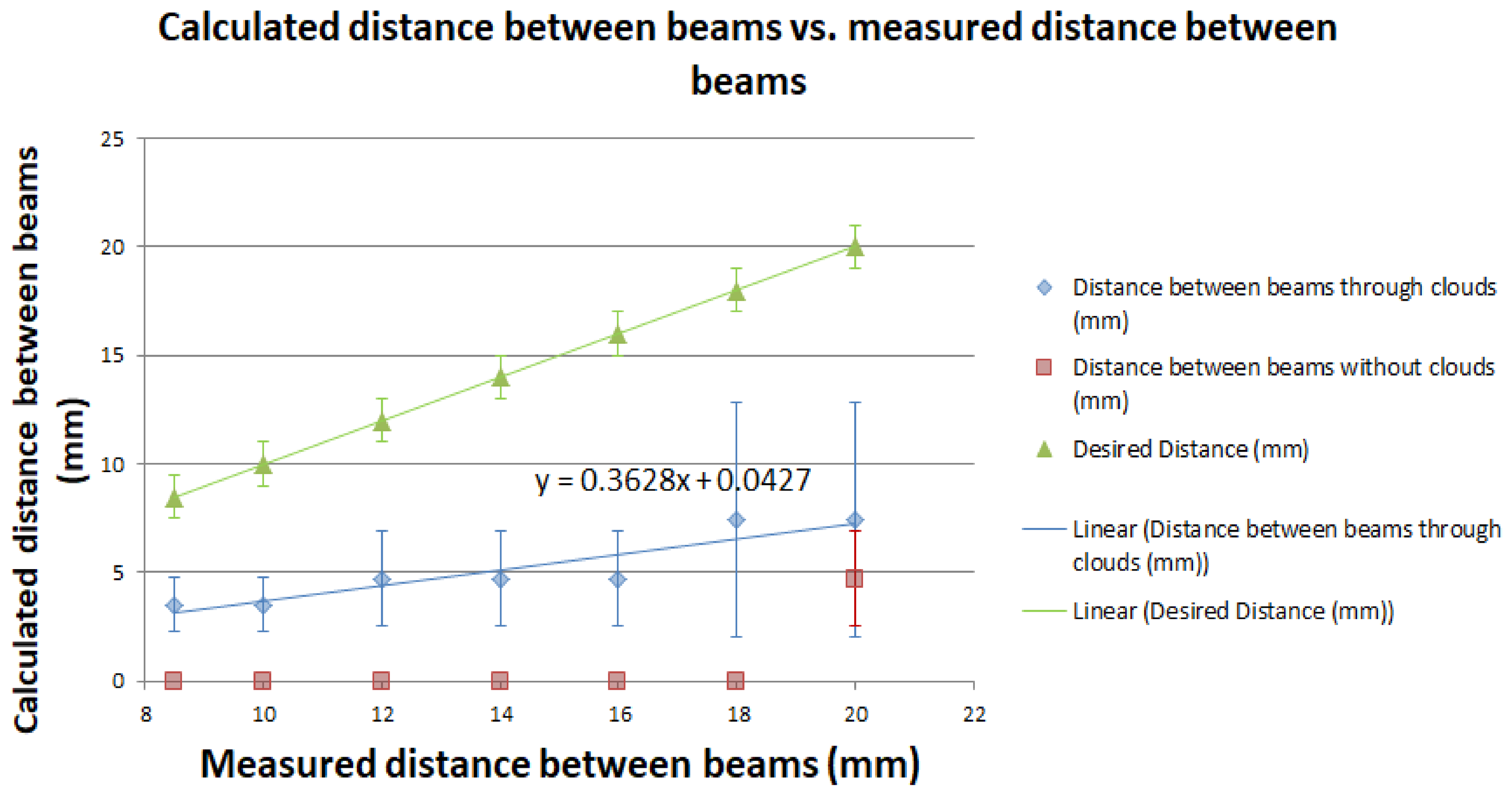

Figure 7: Results of the experiment with parallel laser beams. Until 20mm separation, the images without the clouds had no distinguishable diffraction pattern to accurately measure the distance between fringes.

White Light

Most galactic objects transmit white light, light made up of all visible wavelengths, so to more realistically test the diffraction we set up a similar experiment, passing white light through two slits (Figure 8).

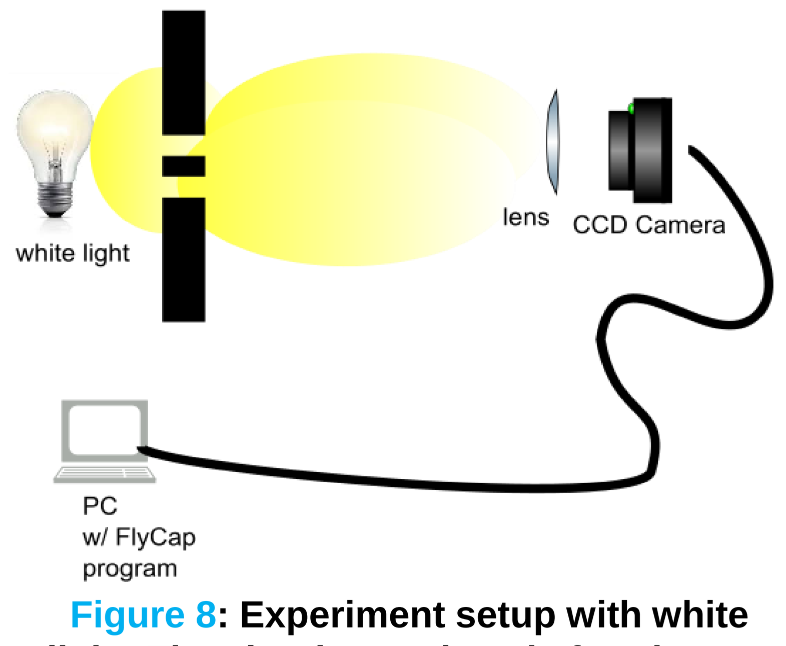

Figure 8: Experiment setup with white light. The cloud was placed after the two slits.

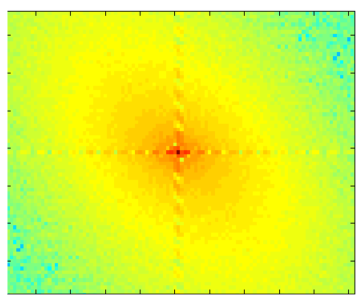

Figure 9a: Diffraction pattern of the white light through two slits without the cloud

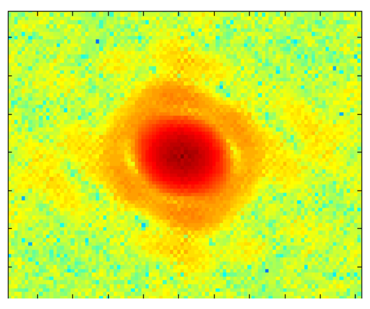

Figure 9b: Diffraction pattern of the white light through two slits with the cloud

Figure 9b has a clear ring around the aureole, although the ring is not uniform. This indicates that the slits were not perfect circles, a detail not visible in Figure 9a.

Conclusions

The better resolution of the images through the cloud, as well as the more distinctive diffraction patterns, demonstrate the efficacy of a layer of thin cloud to improve telescopic imaging. However, further experimentation should use a camera with better resolution to capture the diffraction pattern more precisely. Despite the resolution of the camera, our experiment is a proof of concept, as the superiority of both the images from the camera and the inverse Fourier transformed images was visible to the naked eye.

Acknowledgements

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Reference

Cowley, L., Laven, P., & Vollmer, M. (2004). Rings around the sun and moon: Coronae and diffraction. *Physics Education,40*(1), 51-59. doi:10.1088/0031-9120/40/1/004