Recording the Laser Light: Still Image

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Introduction

An image of the laser beam allows the beam to be studied more analytically than simply studying the beam by eye. With the aid of camera software and Matlab, the beam intensity distribution and beam size are accurately measureable. To prepare for this lab, we studied basic optics in class and became familiar with the camera's settings and other basic camera properties. Objectives of this lab included familiarization with the camera and its different lenses, camera setup, and camera software that captures the image.

Setup

Capturing an image of the beam involved the setup from the previous lab, consisting of an expanded and unexpanded ThorLabs 2 mW He-Ne laser source, with the addition of the ThorLabs 340M-GE camera and a lab computer with the ThorLabs camera software. The software allows image viewing, some basic image analysis, and image capturing. The camera was mounted on a tripod approximately one meter from a white board that was also mounted on a tripod. The image the camera captured was the beam as it projected on the board, which was approximately ten meters from the sources. Using a laboratory computer, we connected the camera and opened the camera software to view the image.

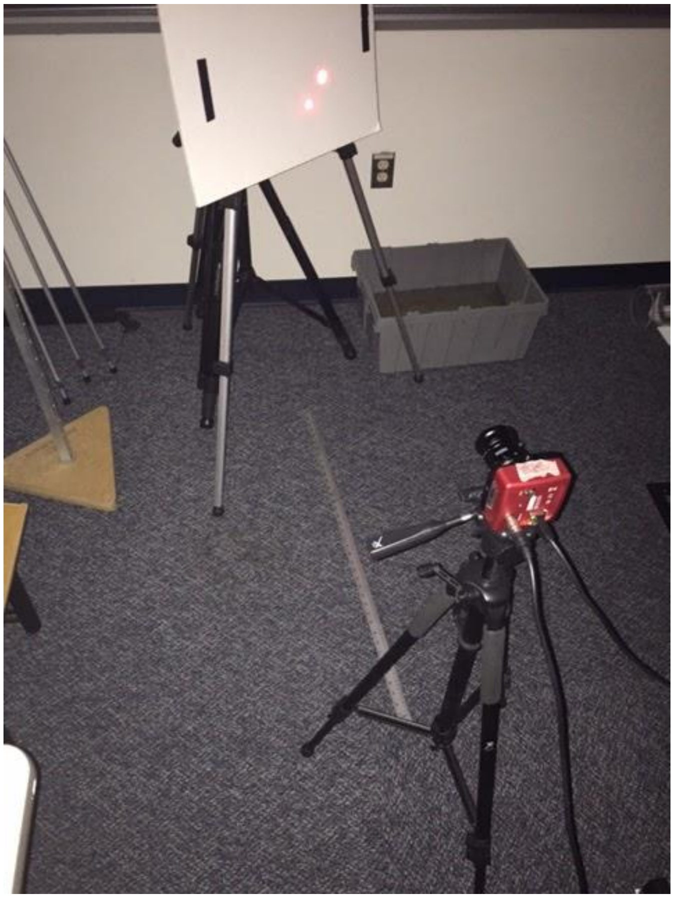

Figure 1 Lab setup of camera and beams on white board

Results

The results presented in this report are images of the 2 mW He-Ne laser beam on a white board at a distance of 10 meters. These pictures were taken with the same lab setup and conditions as Lab 1, such that we are able to compare the measurements of the beam we took with a ruler to the measurements we calculated from the images. We experimented with several lenses to get the best image, testing 12, 17, and 75 mm lenses; ultimately using the 75 mm lense. In hindsight, using the 17 mm lense would have allowed us to set the camera closer to the white board. To calculate the widths, we approximated the range of horizontal pixel values that the beam images covered, and converted that number to millimeters. For the first lab, we measured the width of the beam with a ruler in millimeters, so the measurements are comparable; though the images allowed more precision in measurement.

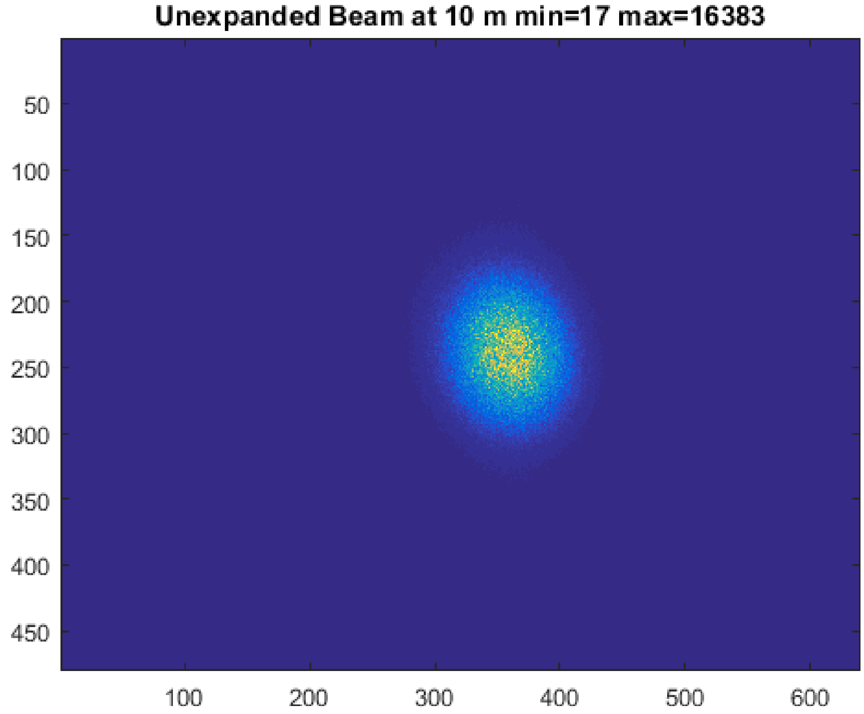

Figure 2 Unexpanded beam image based on intensity. Lighter color denotes higher intensity

The ThorLabs camera that we used measured has 16384 levels of light intensity that it can measure per pixel. With this, we can clearly define the intensity levels of the beam using the 256 color levels the computer uses. In this image, the unexpanded beam has a clearly Gaussian intensity distribution; the intensity peaks at the middle of the beam and levels out towards the outer edges of the beam. In three-dimensional space, the intensity graph would look like a bell. One can also see the distortion of the beam from what many imagine as spherical to more elliptical, owing to beam spreading and scattering and possibly a misshapen board.

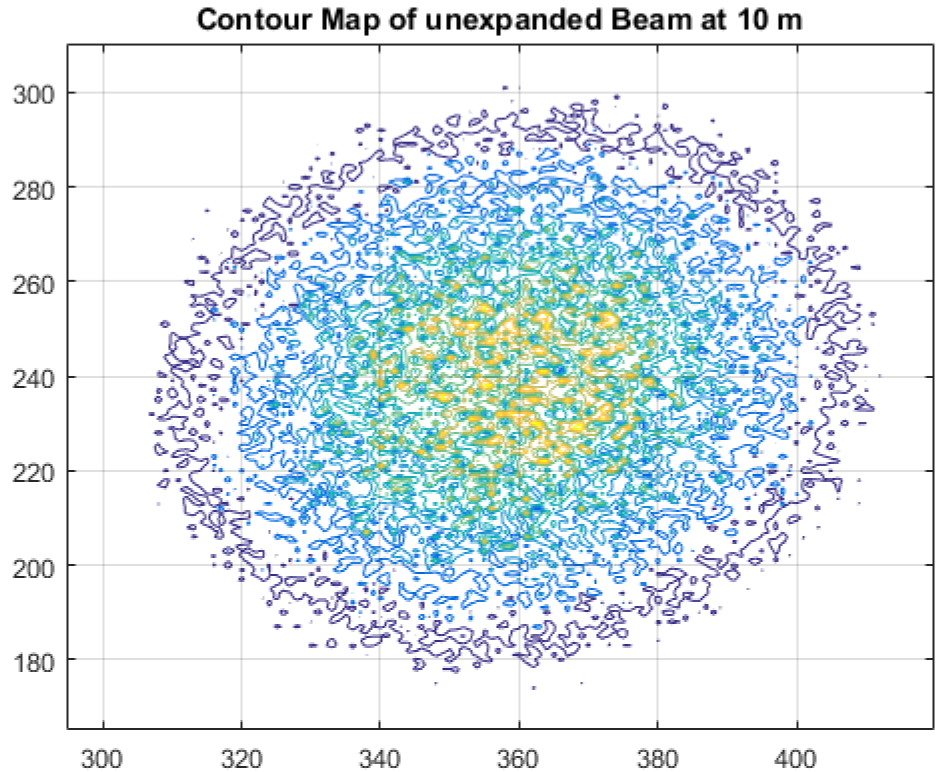

Figure 3 Zoomed four contour image of the beam based on intensity. This image was used to measure beam size.

The contour map of the unexpanded beam appears similar to Figure 2. This is in part due to the fact that the white board that we projected the beam on for imaging is not perfectly flat, so there exists scattering at the surface. A Gaussian projection remains apparent in this image, however. The shape of the beam is lost due to zooming of the figure for more clear contour lines. Measuring the beam size using the camera, we obtained 16.7 mm, which is within 1 mm of our previous ruler measurement of 16.0 mm.

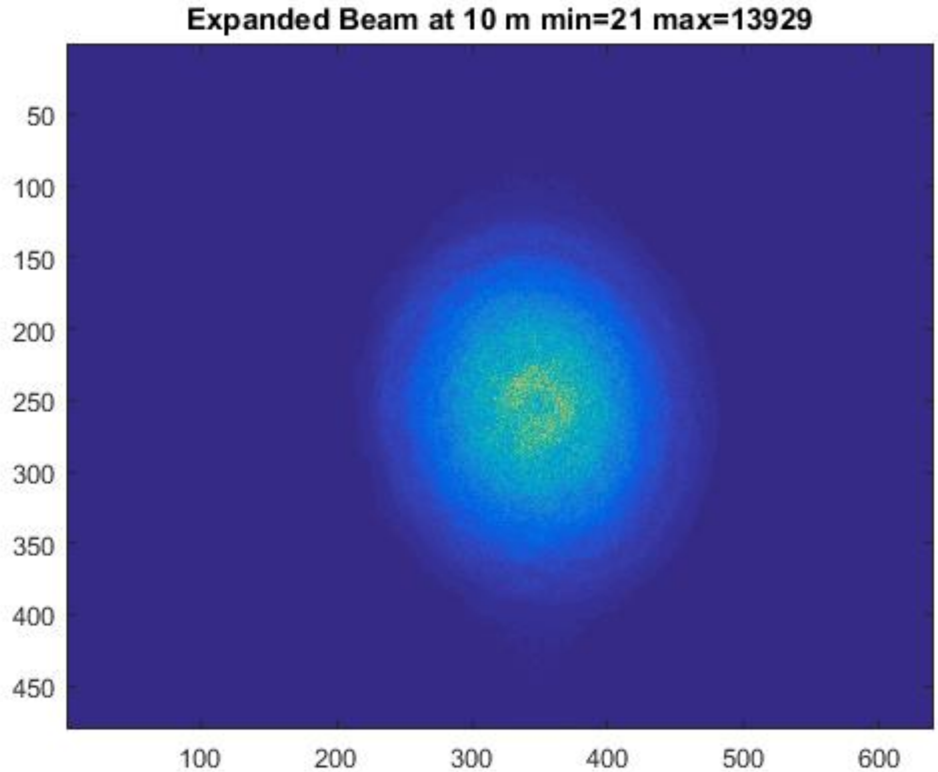

Figure 4 Expanded beam image based on intensity. Lighter color denotes higher intensity.

The differences between the unexpanded beam and the expanded beam are apparent between Figures 2 and 4. In Figure 4, the expanded beam has a more evenly distributed intensity spread over the area of the beam, compared to the Gaussian structure of the unexpanded beam. Also worth noting is the measured peak intensity on the camera sensor, shown in the titles of Figures 2 and 4.

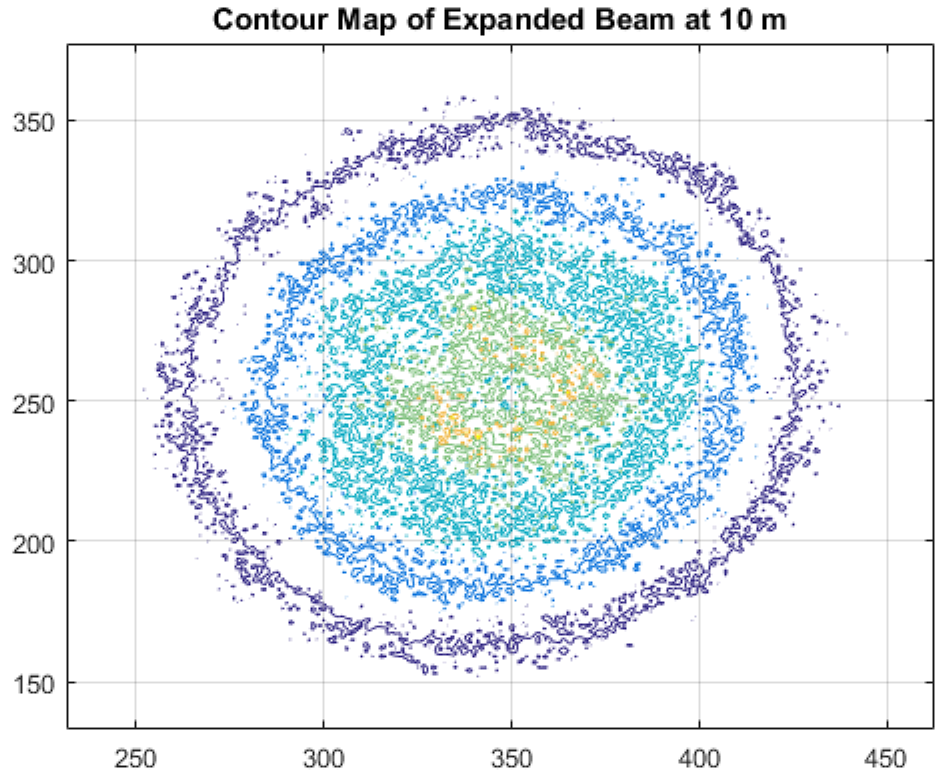

Figure 5 Four contour image of expanded beam based on intensity. This image was used to measure beam size.

Again, the contour image of the expanded beam does not accurately represent the shape of the beam due to zooming, but it emphasizes the more even distribution of light intensity across the beam. The contours are more well-defined in Figure 5 compared to Figure 3, the contour image of the unexpanded beam. Had we used a board constructed of a smoother material, the contours would have been smoother and the image would more accurately represent the actual beam. The size of this beam measured using the camera is 26.4 mm, which is close to our previous measurement with the ruler of 26.5 mm.

Lessons Learned

After learning about what the settings of the camera meant and how they manipulated the image, we tested different lenses on the camera to learn the implementation of the settings. Perhaps the most important trick we learned is that the lenses have to be unscrewed in their mount on the camera to best focus the image on the sensor. Using a ruler on the target surface where the beam was reflected, we could adjust the lense until the the millimeter markings on the ruler were well defined in the image. From that base setting, we would carefully adjust the aperture on the lenses such that the sensor was not saturated.

Concerning the analog settings on the lense and the camera software settings, we discovered several qualities about beam imaging. When the sensor saturates from the beam image, either the aperture on the lense can be closed or the exposure time in the software can be reduced. An exposure time of one millisecond worked well. If the sensor remains saturated, filters can be mounted on the lense as a remedy. If the image is not focused, the aperture will not help focus it. We left the software's gain setting and black level at the manufacturer's default. When the beam takes up the majority of the area of the image, the image is focused based on metrics mentioned earlier, and the sensor is not saturated; we consider the image "good" and capture it.

Lastly, the image produced by the camera and the image produced by the naked eye are different. For example, to the naked eye, rings of light are apparently visible around the unexpanded beam on the board. The camera image shows the rings only if the aperture is opened and the exposure time is increased. This has the effect of saturating the sensor for the majority of the beam image, which does not allow for accurate beam analysis. At the same time, the eye does not have the ability to quantify the difference in intensity across the beam as the camera does, once properly filtered. Trying to rectify the two views of the beam should be surmounted by accomplishing the objectives for imaging the beam.

Conclusion

Without a doubt, this was a learning experience. With regard to the camera and imaging software, we developed an understanding of how to focus the beam, lense characteristics, manipulating the image in the software, and capturing the beam image. Countless other tricks were learned about the equipment and set up became faster every time we attempted to capture an image of the beams. These will prove their worth as we move forward in the class.