Application Note

AN003: Image Quality Improvement

Introduction

A simple approach to improving image quality is by improving the image sharpness. The image sharpness can be detected and then used to improve image quality by removing undesirable optical system artifacts from poor quality optics, atmospheric aberrations, and environmental distortions. Image sharpening is the approach used in most auto focusing camera and video systems. Other examples of such systems are surveillance, telescopes, still photography, and machine vision. For systems imaging through the atmosphere, the majority of wavefront aberrations can be corrected by removing defocus and tilt when atmospheric conditions with $D/r_0 < 5$ exist, where D is the optical system entrance aperture diameter and r_0 is Fried's parameter.

An AgilOptics 25/37 Multi™, shown in **Figure 1**, and Clarifi™ were used or this experiment. Clarifi™ is a Windows® based, closed-loop application developed by AgilOptics to control deformable mirrors (DM). A portion of a bar pattern was imaged into a CCD video camera through an optical system that included a DM. The *Image Sharpness* metric, included within Clarifi™, was used to improve the picture quality.

Figure 1 25mm Multi™

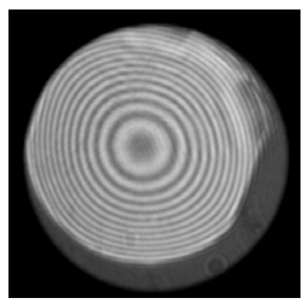

Figure 2 25mm Multi™ active at 90V

Image Sharpening Results

This experiment shows an increase in an image sharpness metric used by Clarifi™. **Figure 4** shows an image at best manual focus with an image sharpness metric of 4.56. **Figure 5** shows an image after defocus aberration is introduced into the system; thus, reducing the sharpness to 4.32. **Figure 6** shows an image with sharpness at 4.6 corrected with stochastic parallel gradient descent; one algorithm available in Clarifi™. **Figure 7** is the image corrected with Clarifi's focus dithering optimization, increasing sharpness to 4.55. **Figure 8** was corrected using Clarifi's Zernike dithering that resulted in a sharpness of 4.58.

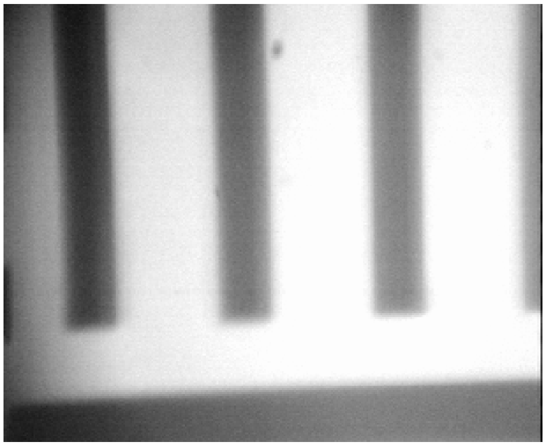

Figure 3 Best manual focus; sharpness =4.56.

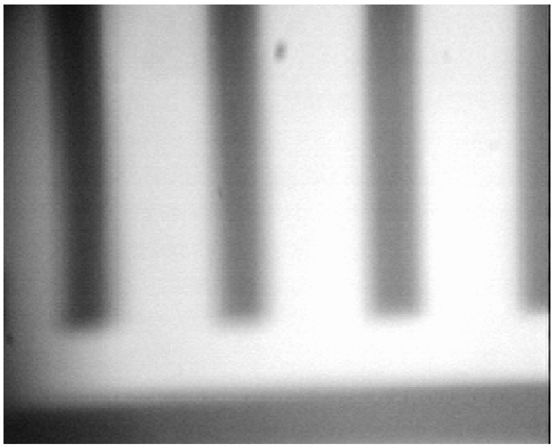

Figure 4 Defocus aberration introduced; sharpness = 4.32.

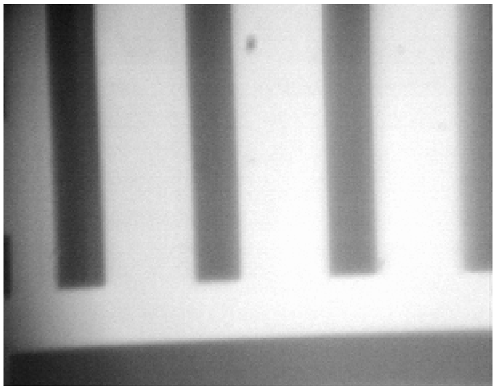

Figure 5 Defocus aberration removed with Clarifi™, sharpness = 4.60

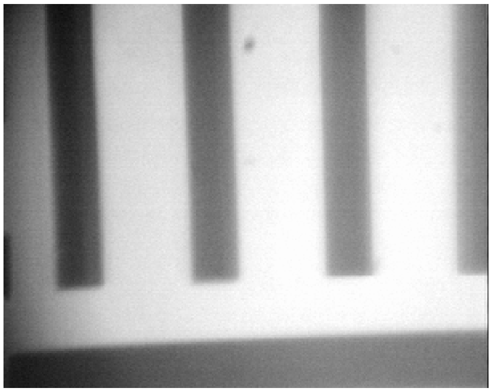

Figure 6 Defocus removed with Clarifi™; sharpness = 4.55.

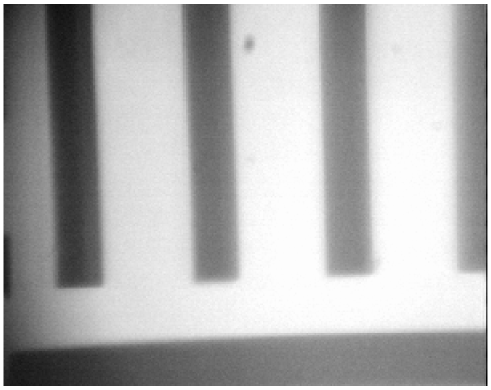

Figure 7 Defocus removed with Clarifi™; sharpness = 4.58.

These results show that Clarifi™ and a AgilOptics deformable mirror will sharpness beyond the best manual focus in an imaging system.

Experimental Configuration

The following is a list of the optical components used for this experiment.

- incoherent light source
- chrome etched glass plate for the target
- 4 m focal length lens for defocus
- Genwac CCD video camera
- 175 mm focus lens
- 330 mm focus lens
- an adjustable iris
- a flat mirror
- a beam splitter
- 25 mm Multi™ DM

The optical configuration is shown in **Figure 8**. The Multi™ DM uses 37 electro-static actuators and has a 1 µm thick membrane.

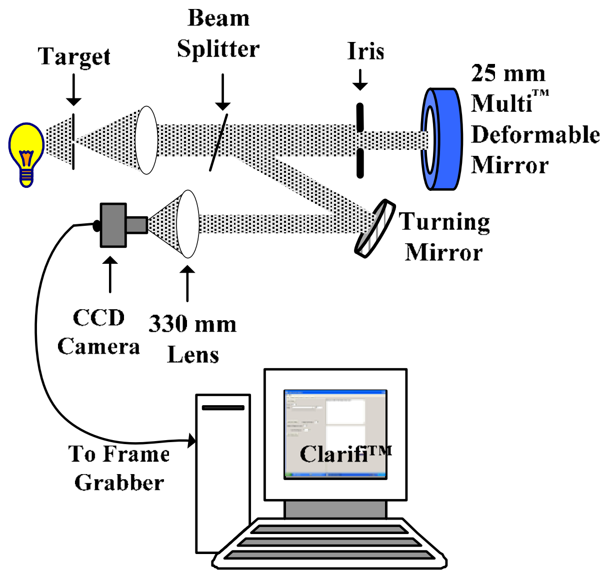

Figure 8 Optical setup used for experiment

The incoherent white light source illuminates the chrome etched target. The 175 mm focal length lens images the target into collimated space. The collimated light passes through the beam splitter and is stopped down to 67% of the DM active area by the adjustable iris. The DM directs the collimated light back into the original direction and is redirected to a turn mirror with the beam splitter. The 330 mm focal length lens images the target at its focal distance. The camera then images the target onto its detector array.

The camera image is digitized by a frame grabber. Clarifi™ calculates the image sharpness from the digitized image. An optimization algorithm is used to determine the DM shape that will improve the image sharpness metric. **Figure 9** is a picture of the test setup.

Figure 9 Photograph of setup for testing Image Sharpness

Dedicated hardware that produces single image sharpness metrics, such as an image sharpness detector array, may be integrated with Clarifi™ for improved optimization.

Conclusions

Removing undesired aberrations in either coherent or incoherent light will result in a clearer focus. These aberrations are caused by the optics, the laser itself, and by the surrounding environment. A wavefront beam corrector will remove these aberrations and provide a sharper focus. Image sharpness can be used in auto focusing systems as well as wavefront correcting systems. This experiment shows that the AgilOptics' Clarifi™ system can improve the image quality through image sharpness techniques using a deformable mirror in a closed loop system.

What Can Deformable Mirrors Do?

- Correct Optical Aberrations
- Laser Beam Shaping
- Optical Image Enhancement

Deformable mirrors are revolutionizing laser and optical systems by replacing static components with dynamic optics. Deformable mirrors (DM) are adaptive optics with dynamic faces able to optimize or change the characteristics of reflected light for a specific application. With time-varying control, a DM can focus a beam at several different points at different times or it can replace a lens in an optical system. Deformable Mirrors can improve optical images in telescopes, cameras, and other imaging systems.

For further information and discussion about how deformable mirrors work and how they will solve your optical problems see the manuals for HVDD, Clarifi™, and the application notes available on the Web.

http://www.agiloptics.com/AppNotes.htm

http://www.agiloptics.com/downloads.htm