Lab Write-Up Week 2

Introduction to Optical Imaging (II)

Andrew Emerson

14 February 2023

Resolution Test Images

A microscope system was set up with a 150mm focus achromatic tube lens and a 25mm focus PCX lens imaging with infinite conjugates. A chromium resolution test target was imaged with the orientation of the objected lens flipped, and a diffuser selectively inserted to examine the effects of these components on image quality. Figure 1, Figure 3, Figure 5 and Figure 7 show the resultant images of the varied optical setups. Each image has a corresponding line plot of the pixel intensity of the smallest resolvable element. A 3-bar element is considered resolvable if the contrast between the black bars of the element and the white spacing between the bars is at least 10% as calculated by Equation 1.

Equation 1. $$res = \left|\frac{I_{max}-I_{min}}{I_{max}+I_{min}}\right| * 100$$

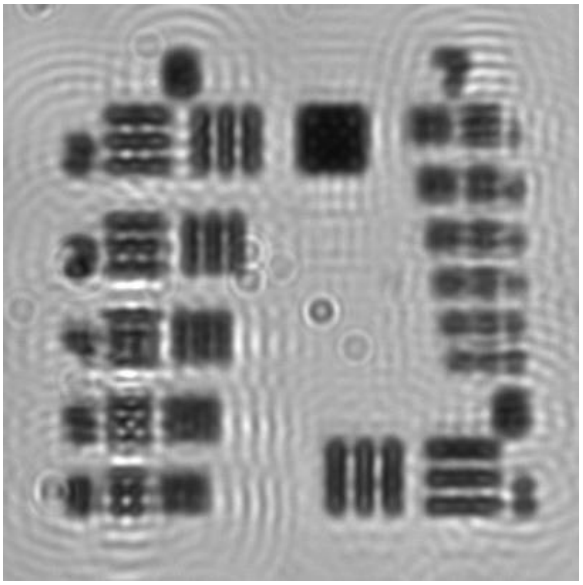

Figure 1. Resolution test target illuminated by halogen lamp (630nm). Exposure: 20ms. No gain. PCX lens orientated with planar surface facing camera. No Diffuser was used. Diffraction patterns can be seen around the chromium printings on the target.

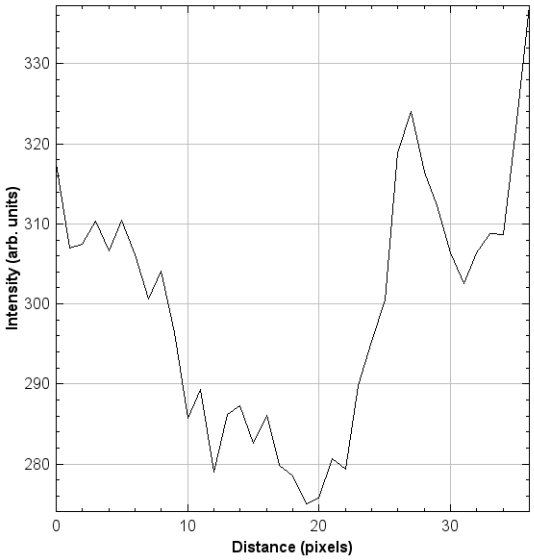

Figure 2. Line plot of Group 6, Element 5 of Figure 1. Maximum Intensity is 337, minimum is 275. Contrast is 10.2%

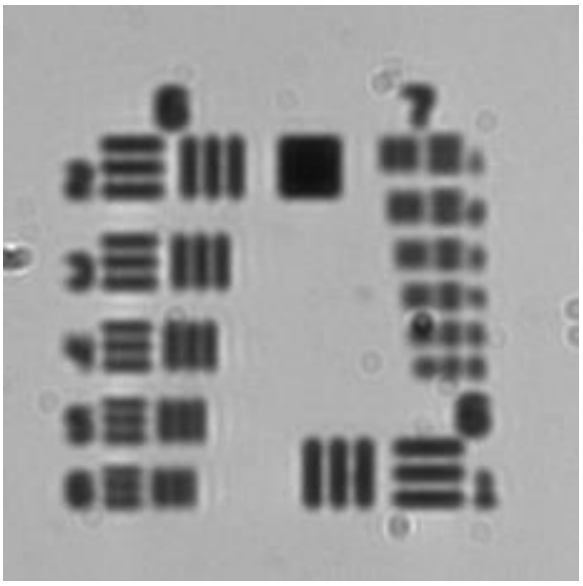

Figure 3. Resolution test target illuminated by halogen lamp (630nm). Exposure: 25ms. No gain. PCX lens orientated with planar surface facing camera. Diffuser was placed between lamp and resolution target. Diffraction patterns have been greatly reduced as compared to Figure 1.

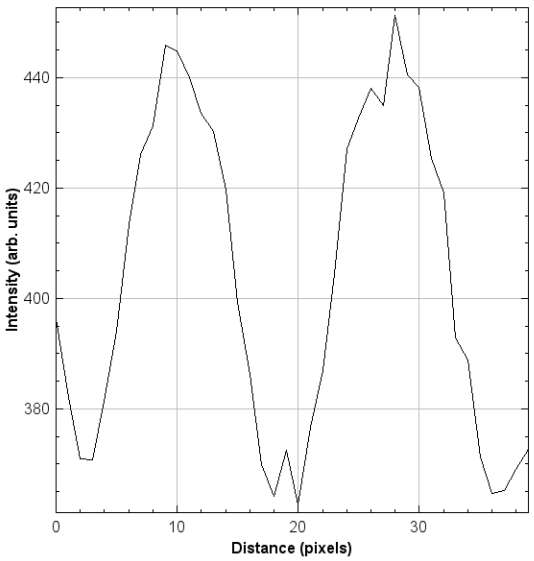

Figure 4. Line plot of Group 6, Element 5 of Figure 3. Maximum intensity is 451 minimum is 362. Contrast is 11%

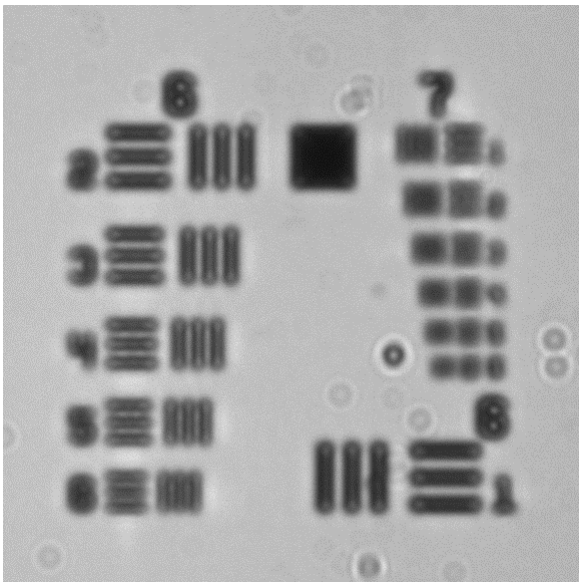

Figure 5. Resolution test target illuminated by halogen lamp (630nm). Exposure: 25ms. No gain. PCX lens orientated with planar surface facing resolution target. Diffuser was placed between lamp and resolution target. Sharper image quality compared to Figure 3.

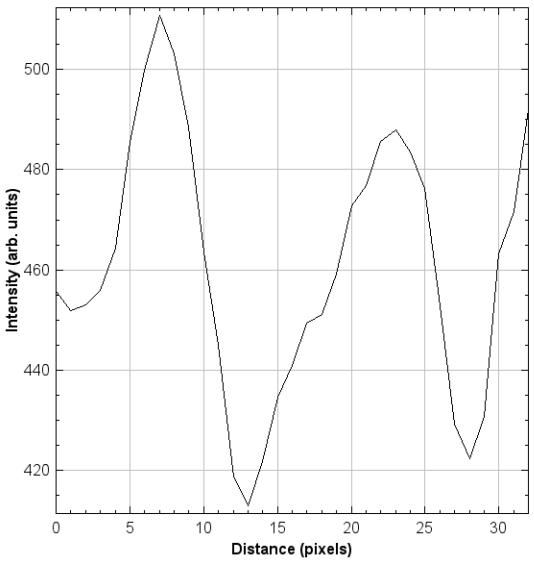

Figure 6. Line plot of Group 6, Element 6 of Figure 5. Maximum intensity is 510, minimum is 412. Contrast is 10.6%

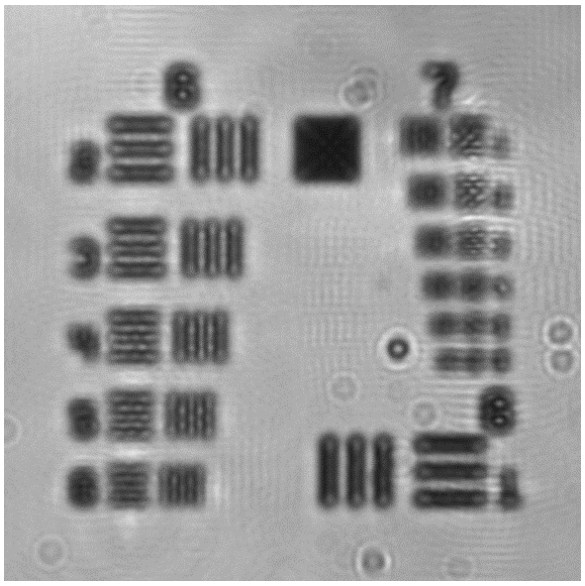

Figure 7. Resolution test target illuminated by halogen lamp (630nm). Exposure: 25ms. No gain. PCX lens orientated with planar surface facing resolution target. No diffuser was used. Diffraction pattern are apparent when compared with Figure 5.

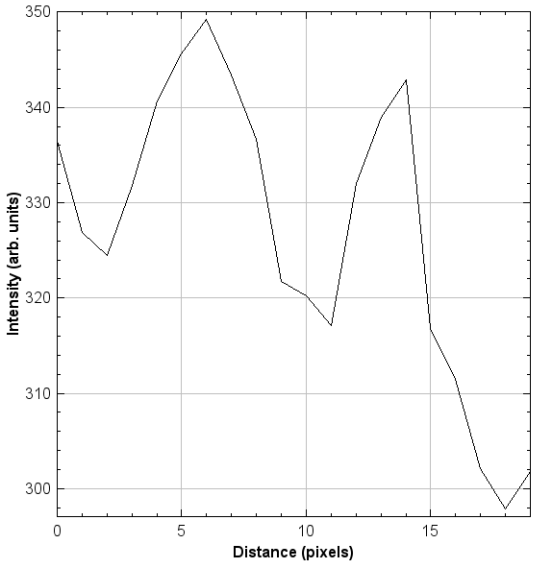

Figure 8. Line plot of Group 6, Element 6 of Figure 7. Maximum intensity is 433, minimum is 335. Contrast is 12%

Optical Resolution

Lamp Wavelength, nm	Lens NA	Resolution, PCX Lens Round Side Toward Resolution Target (nm)	Resolution, PCX Lens Flat Side Toward Resolution Target (nm)
630nm	0.5	9800	8800

Table 1 Using the diffuser had minimal effect on the resolution of the test images, with no change in the minimal resolvable test element between setups. Table entries are understood to be the same with or without diffuser element.

Calculations

The Numerical Aperture is calculated in Equation 2 and the Rayleigh resolution is calculated in Equation 3 for the objective lens used with a diameter of 25mm and a focus of 25mm. The wavelength of light used has a peak of 630nm.

Equation 2. $$NA \cong \frac{r}{f} = \frac{25mm/2}{25mm} = 1/2$$

Equation 3. $$\delta = \frac{0.61\lambda}{NA} = \frac{0.61\,(630nm)}{1/2} = 770nm$$

The best resolution measured, 8800nm is worse than the theoretical Rayleigh resolution of 770nm calculated in Equation 3 by an order of magnitude. The measured resolution was expected to be worse than the Rayleigh resolution, as Rayleigh is the theoretical minimum of a system limited by diffraction.

The resolution of the physical optical system is limited by geometric aberration including spherical and chromatic aberrations.

Orientating the objective lens such that the flat side was towards the resolution target improved the resolution by 11% over when the PCX lens had the convex side facing the target. This is due to the thin lens approximation used when forming the lens. The equation holds when the angle of incidence is close to zero. With the round side of the lens facing the target, light is only bent on the round surface, as the light rays will be normal to the flat side and cross through unaltered. One surface performing all the bending will increase aberrations. When the lens is flipped so that the flat side is facing the target, the light rays from any specific point will not be collimated normal to either side of the lens, with the light being bent twice. Roughly, this half the error caused by spherical aberration.