Lateral Color in Mobile Imaging Lenses

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1. Background

Chromatic aberration (CA) is one of several aberrations that degrade lens performance. Other common aberrations include coma, astigmatism, and curvature of field. Chromatic aberration occurs because the index of refraction of the lens material varies with the wavelength of light, i.e. it bends different colors by different amounts as shown in Figure 1. This phenomenon is called ***dispersion***. Minimizing chromatic aberration is one the goals of lens design and it is accomplished by combining glass elements with different dispersion properties. Three element lenses (3P or 1G2P) are popular for mobile imaging applications. However, the optical performance of all 3-element lenses is limited by lateral chromatic aberration, also known as lateral color. This aberration can only be eliminated using a 4-element design with a 2P2G configuration. This paper compares the lateral color of a 1G2P lens with a 2G2P lens.

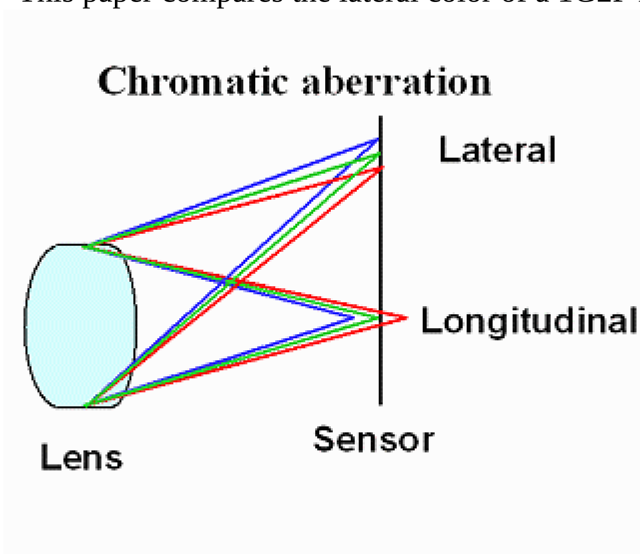


Figure 1. Chromatic aberration in lenses

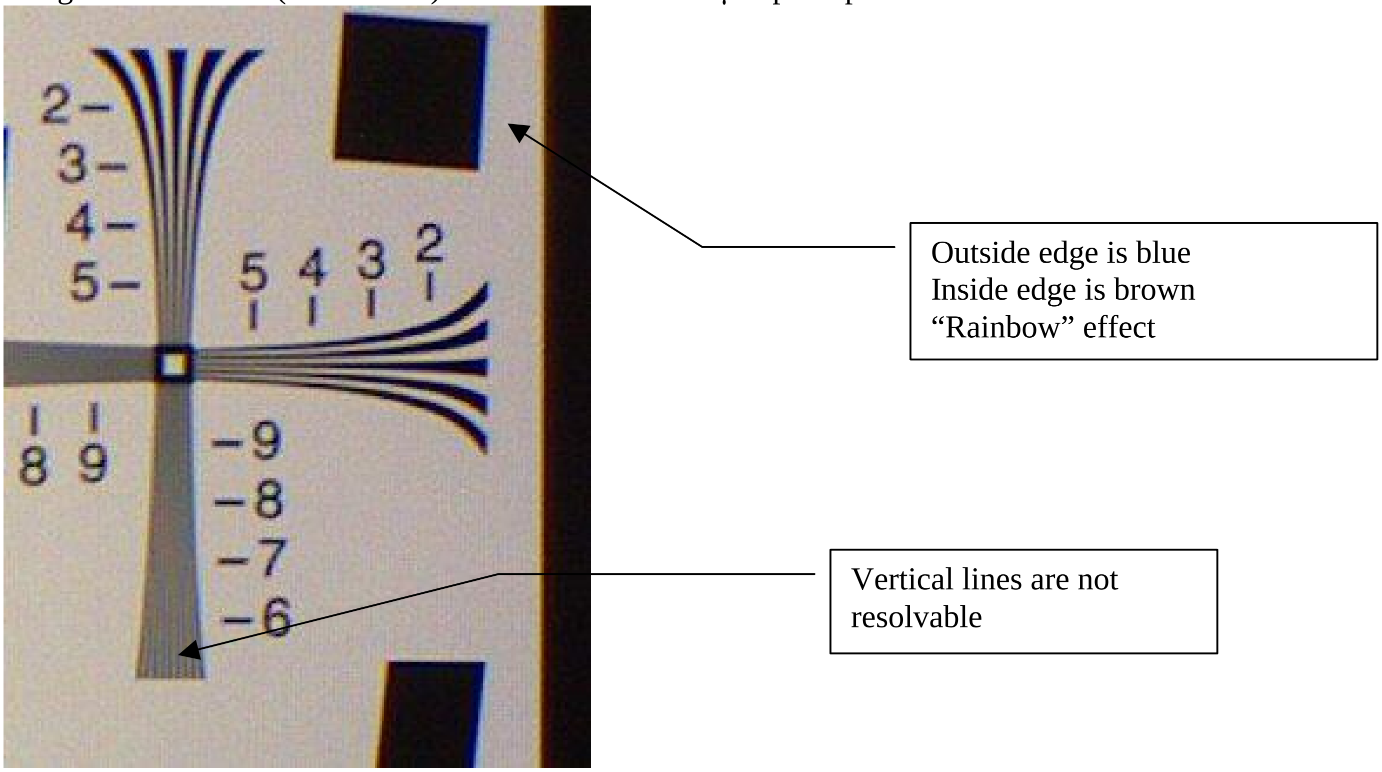
2. How to detect lateral color

The two types of chromatic aberration are illustrated in Figure 1.

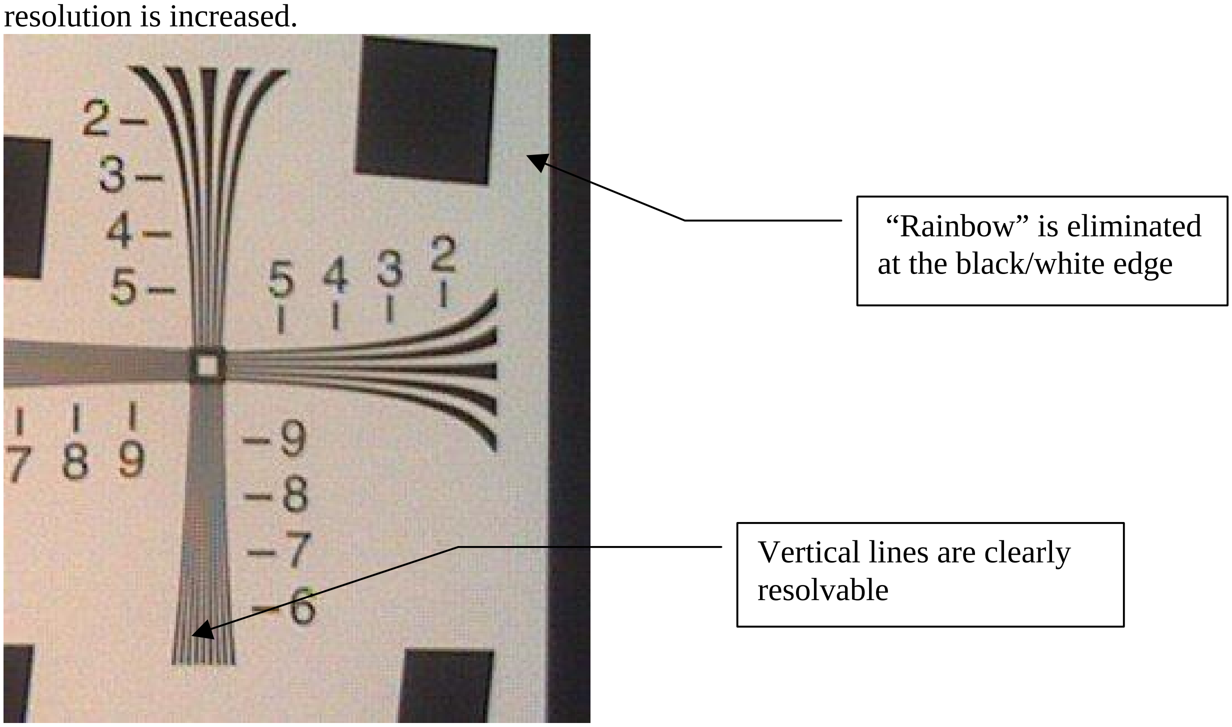
- **Longitudinal chromatic aberration** causes different wavelengths to focus on different image planes. It causes degradation of MTF response – with different amounts for different colors.

- **Lateral chromatic aberration** is the color fringing that occurs because the magnification of the image differs with wavelength. It tends to be far more visible than longitudinal CA. For a given amount of lens CA, the smaller the pixel size the more visible the lateral CA in the captured image. The lateral CA can measured in terms of number of pixels. In a good imaging system the lateral CA should be <1x pixel.

The lateral color is most visible if one examines a black/white edge at an off-axis viewing angle. The black/white edge should be oriented almost perpendicular to the radius. For example, following is the left side of a picture taken with a 1G2P lens (Sunex PN DSL746). All images and analysis were done using a Micron 2MP (1600x1200) demo board with 2.8 μm pixel pitch.

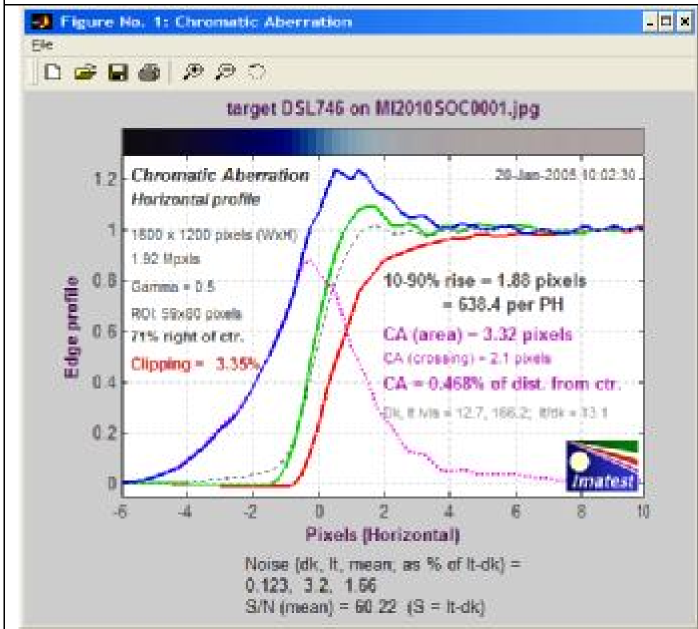
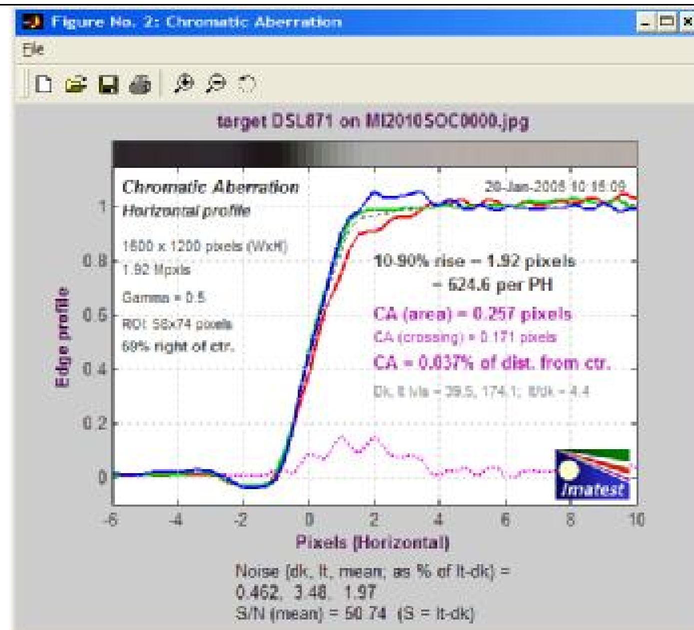


With a 2P2G design (Sunex PN DSL871/872) the lateral color is eliminated. As a result, the optical resolution is increased.



3. Measurement of Lateral Color

The amount of lateral color can be measured using commercially available software (ImaTest at http://www.imatest.com/). This program examines the transition from black to white at an off-axis edge for each primary color, and then calculates the amount of chromatic aberration at that edge.

<table>
<tr><td>1G2P lens</td><td>2G2P lens</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>The blue channel transition (the blue color curve) occurs before the red channel (red color curve). The distance between the two curves at 50% edge response is 2.1 pixels. This represents 0.468% of the distance to the center of the picture. This implies that there is 0.468% difference in magnification between the blue and red channel in this lens.</td><td>The blue channel transition occurs at nearly the same location as the red and green channels. This results in very little chromatic aberration. The separation between the blue and red is insignificant (0.171 pixel) in comparison to the size of the pixel.</td></tr>
</table>

4. Conclusion

With the industry trend towards higher pixel count image sensors with smaller pixel sizes the lateral chromatic aberration of a 3-element lens will become a major problem. For the Micron 2M imager (MI2010) with a 3-element lens, the lateral color can be 2 or more pixels. Aberration on this order significantly reduces the optical resolution and MTF at off-axis viewing angles resulting in an apparent decrease in image detail.

For next generation mobile imagers with higher resolution and smaller pixel spacing more sophisticated lens designs, such as the Sunex DSL871 and DSL872 with a 2G2P structure, are required to eliminate the lateral color. These 4-element lens designs allow the end-user to take full advantage of the increased imager resolution.