Allied Vision

WHITE PAPER

Lens Testing at Allied Vision

V1.0.1
2020-Jun-09

Scope of this document

To deliver high quality images from your vision system you need a reliable and well-proven lens solution that suits your application. We perform comprehensive tests in our own optical laboratory for various camera-lens combinations. Ask our team for recommendations for your camera application.

Even if a lens fails in one test, it may be the perfect match because it fulfills the essential requirements of your application. Our task is to find the right lens for your specific needs.

- This document shows typical aberrations, followed by basic explanations.
- To illustrate the effects of aberrations, low-quality lenses or defective lenses were used.

Contents

Aberrations: Six most common optical aberrations are described. The impact of an aberration on applications is explained. Depending on the application, an aberration can be unacceptable; sometimes, it does not even have to be considered.

Test equipment: Components of a test setup are listed.

Tests for modulation transfer function (MTF) and lateral chromatic aberration (CA) show how aberration measurements are interpreted.

Aberrations

Spherical aberration

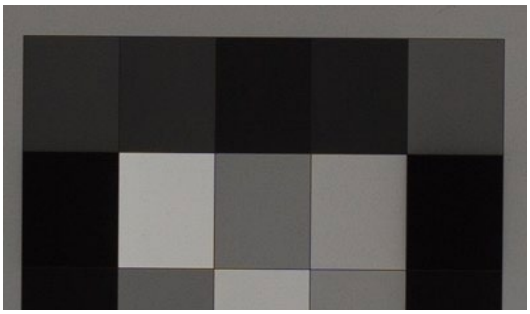


Image without spherical aberration

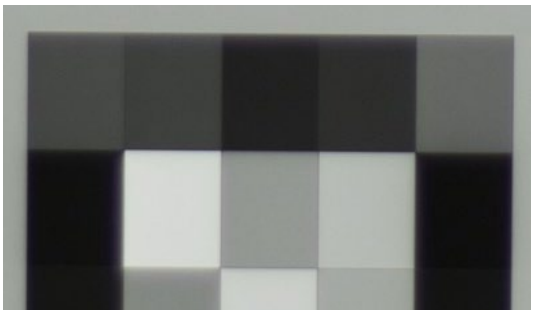


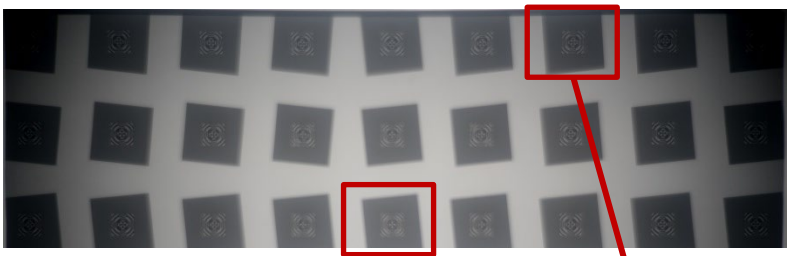
Image with strong spherical aberration

Spherical aberration is caused by spherical lens shapes, especially on fast lenses; lenses with short focal ratios. Stopping down the lens minimizes this effect. Lens designs with aspherical lens elements reduce spherical aberration.

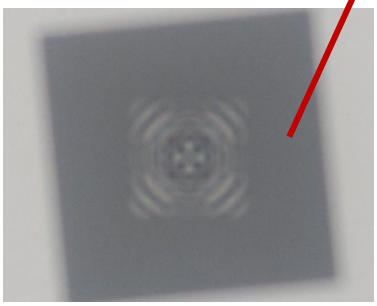
! **Unsatisfactory for mail sorting:** Character recognition requires low spherical aberration.

✓ **Satisfactory for plant growth control:** Detecting the size of a plant or its color may accept spherical aberration.

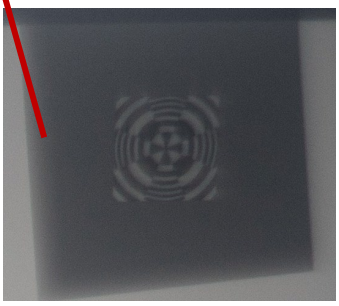
Field curvature



Overview image



Center



Upper left border

Field curvature does not allow the center and corners of flat objects to appear sharp in one image, except when the lens is stopped down. In the example, the corners are much sharper than the image center.

! **Unsatisfactory for microfilm reproduction:** To reproduce high resolution microfilms, field curvature must be low. In the example colors would blur into each other.

✓ **Satisfactory for tire quality control:** With circular objects such as tires, slight field curvature may be acceptable or even helpful.

Distortion

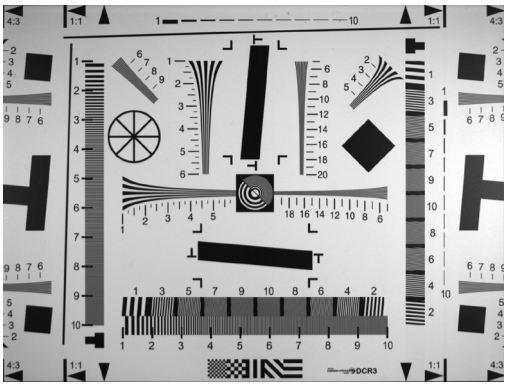


Image without distortion

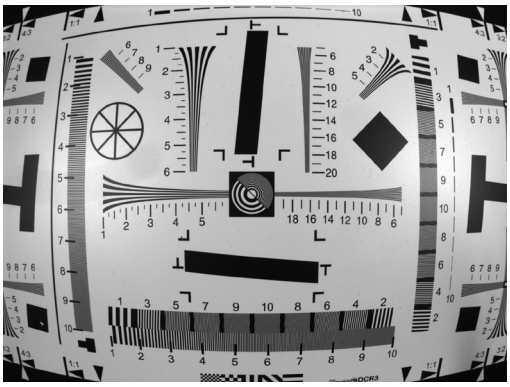


Image with barrel distortion

Caused by distortion, image areas are magnified differently depending on the distance to the center. Typically, lenses show barrel, cushion, or mustache distortion. Simple barrel or pin cushion distortion can be corrected by software, while mustache type distortion; complex distortion; is not as easy to correct.

! **Unsatisfactory for traffic speed control on a moving system:** For on-board applications in police cars to take high-speed images, dimensions and distance must be recognizable. This requires a low distortion lens.

✓ **Satisfactory with subsequent image processing:** For applications with subsequent image processing on the host PC, this effect could be acceptable.

Lateral chromatic aberration (CA)

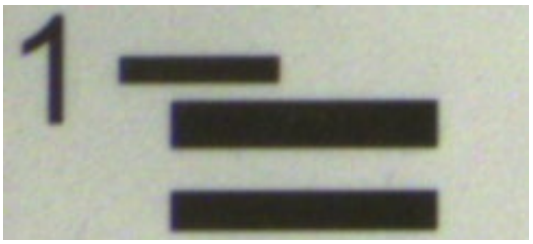


Image without CA

Image with CA

Many lenses do not focus all colors into a single focal point. In the example, the edges of the black image elements show a color fringe to white. The effect increases from the center to the corners of the image, especially at high-contrast edges.

This also applies for monochrome cameras where CA causes a gray fringe from black to white.

Especially with extreme wide-angle lenses or long telephoto lenses, CA increases to the image corners. Manufacturers make great technical efforts to improve corner image quality for wide angle lenses, although these lenses are more expensive than regular lenses.

! **Unsatisfactory for print shop quality control:** To accurately display color offset, CA must be low.

✓ **Satisfactory for plastic sorting:** To detect different plastics, colored edges caused by CA can be ignored as long as flakes or pellets are large enough.

In non-commercial and art photography, axial CA plays an important role for image contents outside the area of focus. Because typical machine vision applications concentrate on contents inside the area of focus, axial CA is not considered in Allied Vision lens tests.

Diffraction

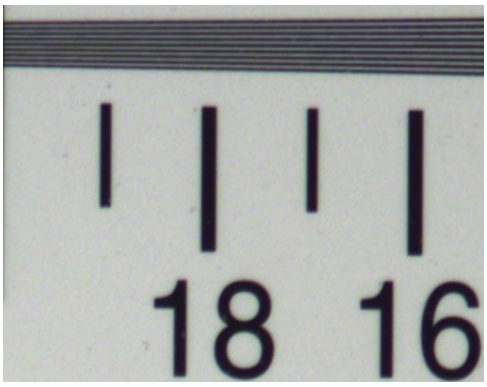


Image without diffraction

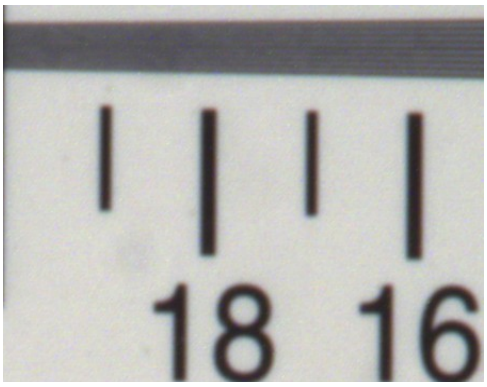


Image with diffraction

Generally, stopping down a lens improves reproduction quality, but it also increases diffraction. Diffraction causes a loss of sharpness. Lenses cannot be optimized for diffraction.

To reduce diffraction for visible light applications, a rule of thumb suggests:

f-stop [number] ≤ pixel size [µm]

A lens with high sharpness at minimum f-stop avoids diffraction, because it does not have to be stopped down to improve sharpness.

! **Unsatisfactory for inspecting printed circuit boards:** Typical lenses would have to be stopped down causing unacceptable diffraction. Specialized lenses can be focused only to a limited range with a small depth of field, but they do not have to be stopped down causing diffraction.

✓ **Satisfactory for fruit sorting:** To acquire a sharp image of fruit at a different distance, stopping down the lens may cause diffraction. The aberration may be acceptable, as long as immature green apples can be separated from mature red apples

Vignetting

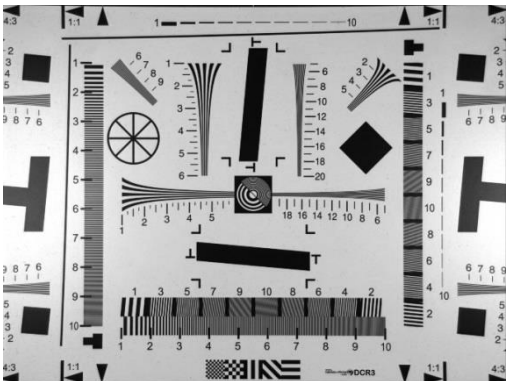


Image without vignetting

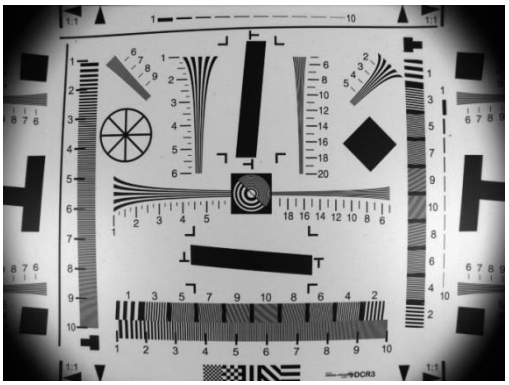


Image with strong vignetting

Vignetting causes darker image corners. Software can reduce the effect, but images have increased noise.

! **Unsatisfactory for image reproduction:** To reproduce an image correctly, brightness must be homogeneous over the image area

✓ **Satisfactory with uneven illumination:** In some applications, corners are illuminated more brightly than the center. Lens vignetting can compensate, avoiding additional filtering or illumination adjustments. Furthermore, dynamic range is maintained.

Test equipment

The test setup is state-of-the-art and complies with standards in the optical industries. Strict test routines and professional test equipment guarantee reliable test results.

Precision: The camera is mounted on a tripod that can be adjusted very accurately.
Reproducibility: Standard test images and controlled illumination provide stable test conditions.

Software

Imatest Master Test Suite (www.imatest.com) is used for all our lens tests. This software is commonly used by the vision industry due to precision and a large range of tests.

Test charts

Imatest SFRplus Large LVT Film Chart is used to test high resolution cameras and yields highly accurate results. Many other test charts lack the detailed structures to enable precise measurements for high-resolution cameras.

Imatest X-Small LVT Film Chart is used to test lenses for the short-wave infrared spectrum. This test chart is illuminated with halogen broadband illumination. The small chart enables a most homogeneous illumination, with a test chart resolution still high enough for the spatial resolution of SWIR cameras.

Illumination

GTI Graphiclite GLX30 Transparency Viewers enable homogeneous illumination to test lenses through the visual spectrum.

Test camera support

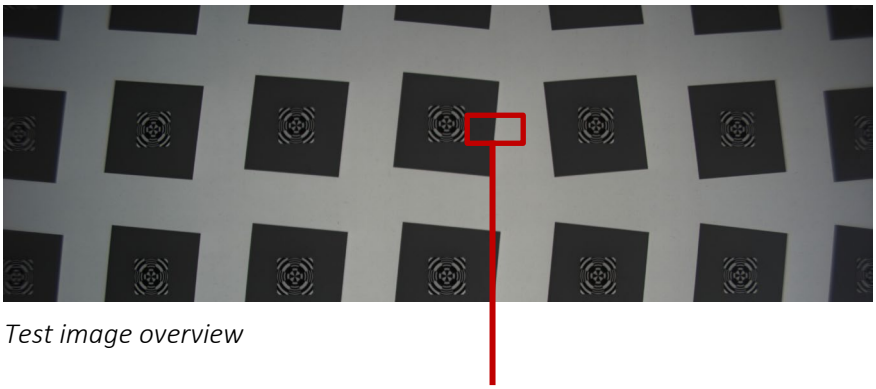
Manfrotto 405 Geared Head is used to align the image with extreme accuracy.

Tests

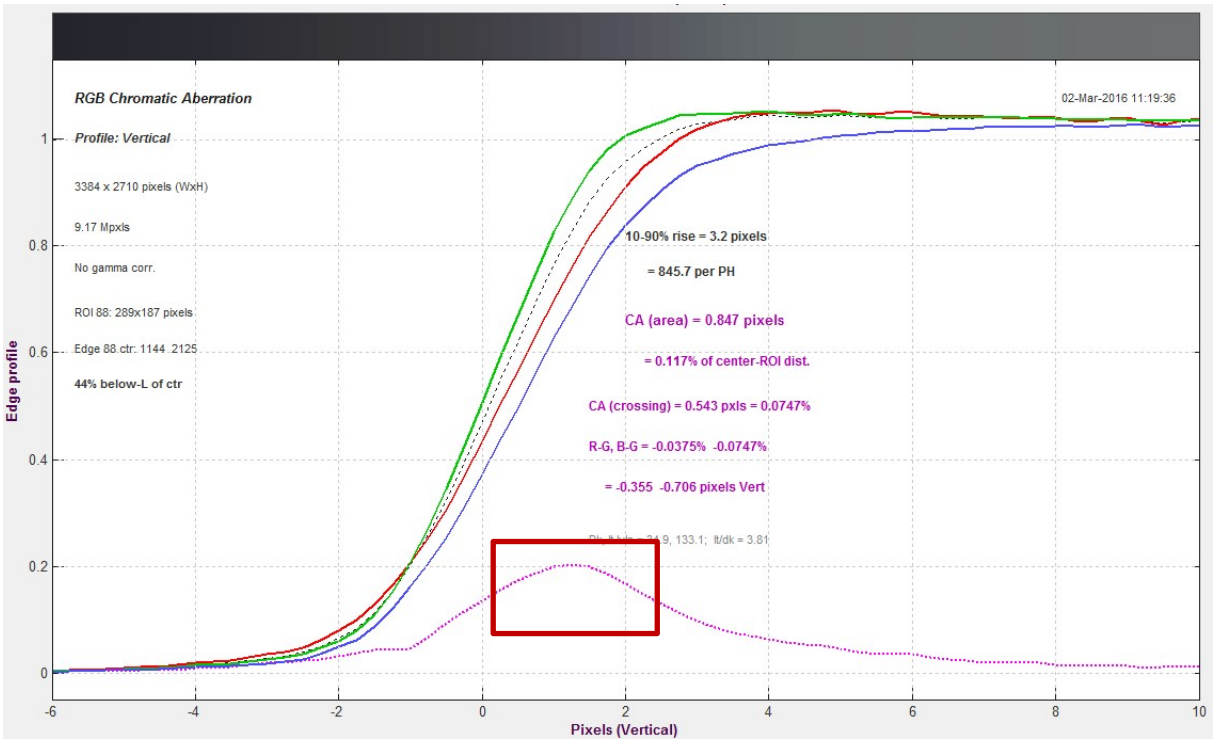
Tests for lateral chromatic aberration (CA) and modulation transfer function (MTF) show how aberration measurements are interpreted.

Test for lateral chromatic aberration (CA)

The test software measures the extent of color fringes at the box edges.



Test image overview



Edge profile diagram

—/—/— *RGB channel*

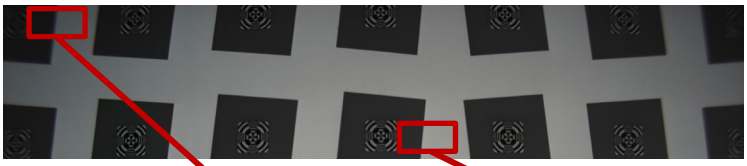
- - - - - - - - *Luminance channel*

- - - - - - - - *RGB channel difference*

The example shows the results of an average lens. With extreme wide angle lenses or long tele lenses, this effect is typically stronger. The peak of the dotted magenta line marks high CA at the box edge.

Test for modulation transfer function (MTF)

The test software measures the exact edge profile with sub pixel accuracy and calculates the MTF from this measurement. The MTF of most lenses varies over the image field. On most lens-camera combinations, the corner details show a lower “sharpness” than the center details. The following graphics show overview, zoom views of edge details, and measurements.

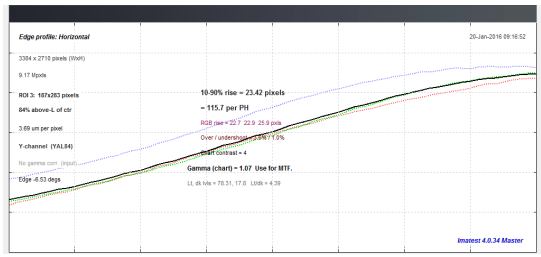


Test image overview

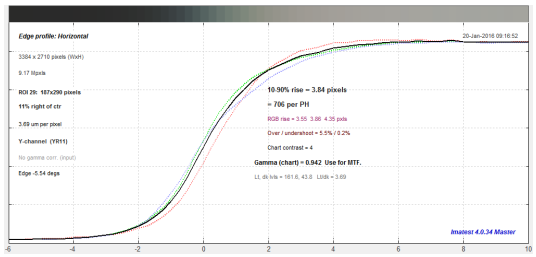
Corner detail: very low edge contrast

Center detail: high edge contrast

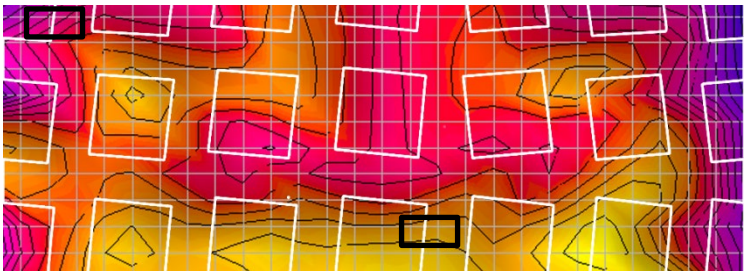
Brightness levels of the corner and center box edges are measured and displayed in curves. The curves show the contrast between the box edges and the background. MTF is high where the curve is steep. The curve for the corner box edges is flatter than for the center box edges. MTF is lower for the corners than for the center of the image.



Corner detail: flat curve = low MTF



Center detail: steep curve = high MTF



MTF level:
High

Low

Imatest 3D MTF diagram blended over test image

The 3D MTF diagram visualizes MTF distribution over the image area. In accordance, MTF is lower for the corners than for the center.

More information and contact

We are experienced to recommend the suitable lens for your application, by turning test results into practical advice. If you need assistance, contact us for more information.

Lens recommendations and personal answers to your questions

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