Test Lab Services Report

Commercial Borescope Image Quality Test

Report ID: SAMPLE03

Requested by:

Customer

Prepared by:

Imatest, LLC

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Contents

About Imatest

Imatest is a leader in image quality testing that has been headquartered in Boulder, Colorado since 2004. Imatest team members include a range of engineering disciplines including imaging science, computer science, physics, electrical, and mechanical engineering.

Imatest software, test charts, equipment, and services enable the imaging industry to develop the best products possible. We serve customers across many industries, including automotive, mobile, consumer electronics, security, aerospace, and medical. We provide the tools, resources, and knowledge to test all types of imaging systems, from satellites to camera phones, in visible light or infrared. Imatest helps eliminate bias by providing independent, impartial image quality testing for both design and manufacturing. Our clients can be confident they are testing the aspects of their systems that matter most to their customers. Our team is dedicated to enabling the imaging industry to provide accurate measurements that will help them improve the quality of their imaging products.

Overview of Test Lab Services

As experts in the field of image quality testing, leave the IQ lab work to us. We know that each test lab setup is unique to the needs of your company:

- We help create a customized service that achieves the testing objectives of your organization while working within your budget.
- Trained consultants will spend time with your team to better understand your needs and create a test plan to meet your project goals.
- Our detail-oriented engineers will test your equipment using our hardware, charts, and software to analyze images and interpret results—saving you time and resources.
- Provide consistent, repeatable, and trustworthy results through rigorous testing protocols, allowing you to build a portfolio of reports.

Service Offerings:

- Sensor evaluation
- Camera hardware design
- ISP tuning
- Benchmarking

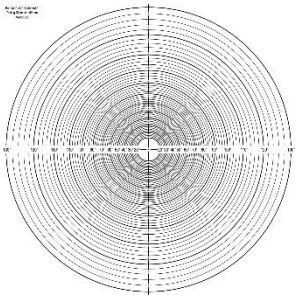
Example Image Quality Metrics we provide:

- MTF (modulation transfer function)
- Dynamic Range
- Low light performance
- Temporal noise
- Motion blur
- And more

For more information, visit www.imatest.com/test-lab-services or contact us at LabServices@imatest.com

Test Capture Setup

Field of View (FOV)



ISO 8600-3 Method A FOV Target

Test Distance: 50 mm
Target: ISO 8600-3 Method A FOV Chart
Device Settings: Defaults, background compensation off
Illumination: Room lights

Procedures for measuring field of view (FOV) are followed in accordance with ISO 8600-3 using the Imatest ISO 8600-3 Method A FOV chart designed for a 50mm capture distance. The setup, shown in Figure 1, consists of the device under test (DUT) mounted on the Imatest Benchtop Test Stand (BTS) using the Endoscope Module V-clamp mounting stage, which allows for vertical adjustment, tilt, and tip. The chart is mounted at a distance of 50 mm from the distal end of the device using the Magnetic Chart Mounting System, which allows for targets to be positioned anywhere on the target plane. The chart is centered within the image field and an image is captured using the device's integrated camera. The FOVs corresponding with largest visible circles in the vertical, horizontal, and diagonal directions are recorded in degrees.

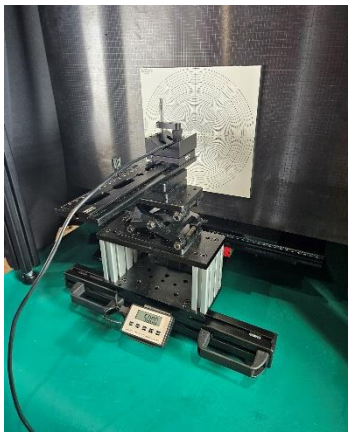
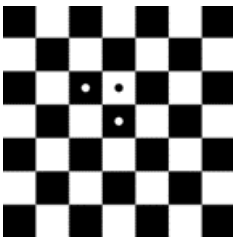


Figure 1

Sharpness and MTF



Checkerboard Chrome on Glass Target

Test Distance: 50 mm
Target: Checkerboard Chrome on Glass Target 2", 7x7 4mm squares
Device Settings: Defaults, background compensation off
Illumination: Imatest Size B 10000 Lux LED Lightbox; 7930 Lux; 6476 CCT (D65)

Procedures for measuring sharpness and modulation transfer function (MTF) are based on ISO 8600-5, but altered for use on a semi-rigid device with an integrated sensor and optics. The DUT is mounted on the test stand using a V-clamp. The Imatest LED lightbox is mounted to the Z-stage of the Benchtop Test Stand and set to maximum intensity and color temperature, which corresponds with standard illuminant D65. The flatfield illumination (without the chart) is characterized for a distance of 50mm from the lightbox surface using a spectrophotometer, yielding an illuminance of 7930 lux, an irradiance of 29.85 W/m^2, and a correlated color temperature (CCT) of 6476 K.

In a dark environment, the checkerboard target is mounted to the lightbox and set to a distance of 50mm from the distal end of the device. The checkerboard is aligned to capture vertical and horizontal slanted edges at the on-axis and various off-axis image points, as specified in the standard. Additional off-axis points (C1 and C2 in Figure 2) are captured to accommodate the rectangular image field.

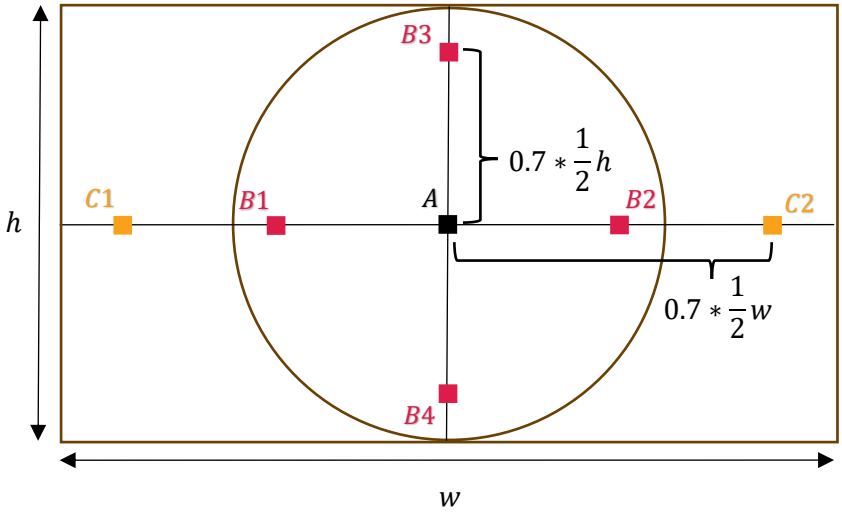


Figure 2

Illustrated in Figure 2, points B1-B4 are located at 70% of the height-based radius from central point A. Additional points C1 and C2 are at 70% of the image length from the image center. The central saddle point of the checkerboard, indicated by fiducial marks, is aligned with each of these points, such that both a horizontal and vertical slanted edge near these points can be extracted for analysis. Images are captured for each of these points, shown in Figure 3, to determine the on-axis, off-axis, and far off-axis sharpness.

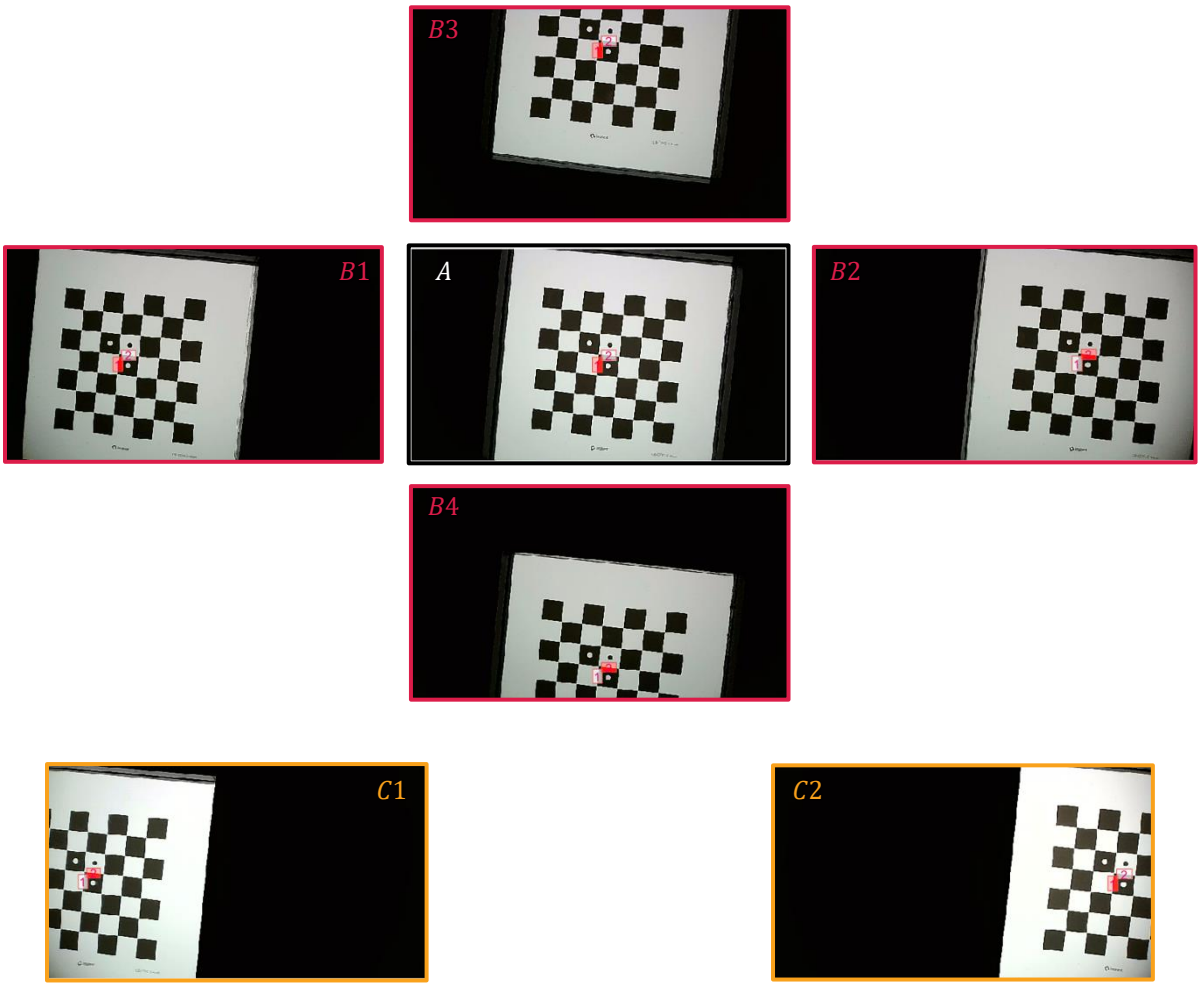


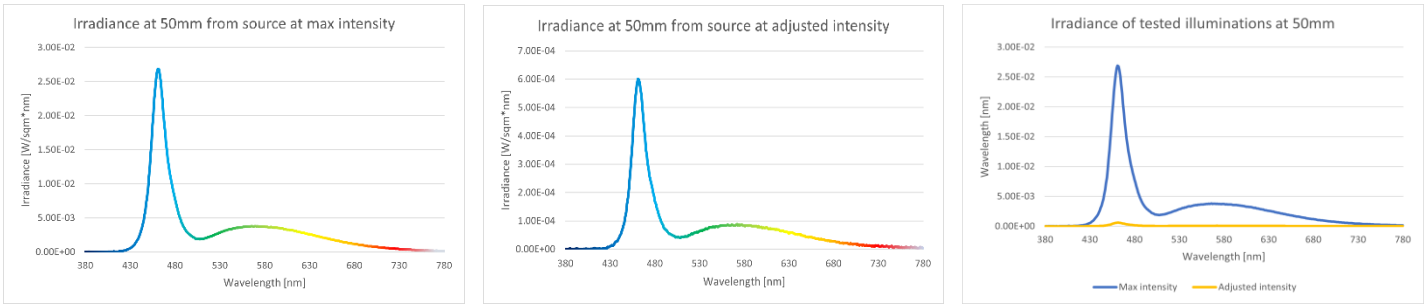
Figure 3

Color Accuracy

Test Distance: 50 mm
Target: ColorGauge Nano
Device Settings: Defaults, background compensation off
Illumination: Integrated LEDs; 255 lux; 5.7 lux

ColorGauge Nano

Images of the ColorGauge Nano centered in the image frame are captured at 50mm under illumination of the 6 integrated dimmable LEDs on the perimeter of the device's distal end to more accurately represent the conditions in which the device is likely to be used. Images are taken at two light intensities: 1) maximum intensity (255 lux at 50mm), and 2) saturation adjustment (greatest illumination without saturating any of the color channels; 5.7 lux at 50mm). A spectrophotometer is used to measure the spectra of each illumination at a 50mm distance, shown in Figures 4a-4c.



a) *b)* *c)*

Figure 4

Uniformity

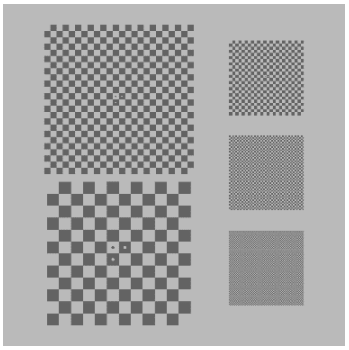
Test Distance: 50 mm
Target: Imatest 10,000 Lux LED Lightbox
Device Settings: Defaults, background compensation off
Illumination: Imatest Size B 10000 Lux LED Lightbox; 7930 Lux; 6476 CCT (D65)

Imatest LED Lightbox

Flatfield images are captured at a distance of 50mm from the surface of the Imatest LED Lightbox to the distal end of the device. The size B lightbox has a uniformity of 95%, and is set to maximum output intensity and CCT, which corresponds to a measured illuminance of 7930 lux, irradiance of 29.85 W/m^2, and CCT of 6476 K at a 50mm test distance. The illuminated field fills the image frame, and 10 images are captured and averaged for analysis.

Distortion

Test Distance: 50 mm
Target: Checkerboard Photographic Multi-Size Test Chart
Device Settings: Defaults, background compensation off
Illumination: Aputure Light Storm LS1c LED Panel (2); D65; 550 lux



Checkerboard Photographic Multi-Size Test Chart

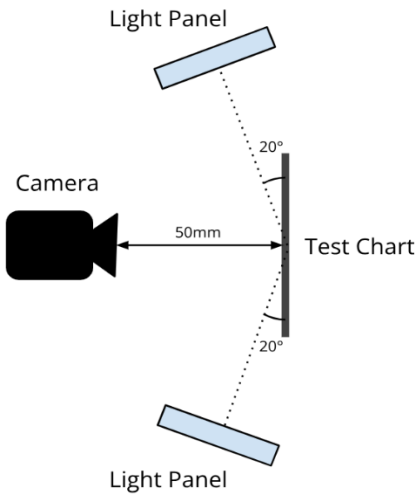


Figure 5

The Checkerboard Multi-Size Reflective Test Chart is mounted on the Imatest Benchtop Test Stand using the magnetic chart mounting system at a distance of 50mm from the distal end of the device. The central saddle point of the 4mm frequency chart, indicated by fiducial marks, is aligned with the center of the image field. The chart is illuminated with D65 light by two Aputure Light Storm LS 1c LED Light Panels using a standard lighting configuration to reduce glare, as depicted in Figure 5. The illumination measured at the chart surface is 550 lux. An image of the checkerboard target is captured using the integrated camera sensor for analysis.

Analysis Results and Observations

Field of View (FOV)

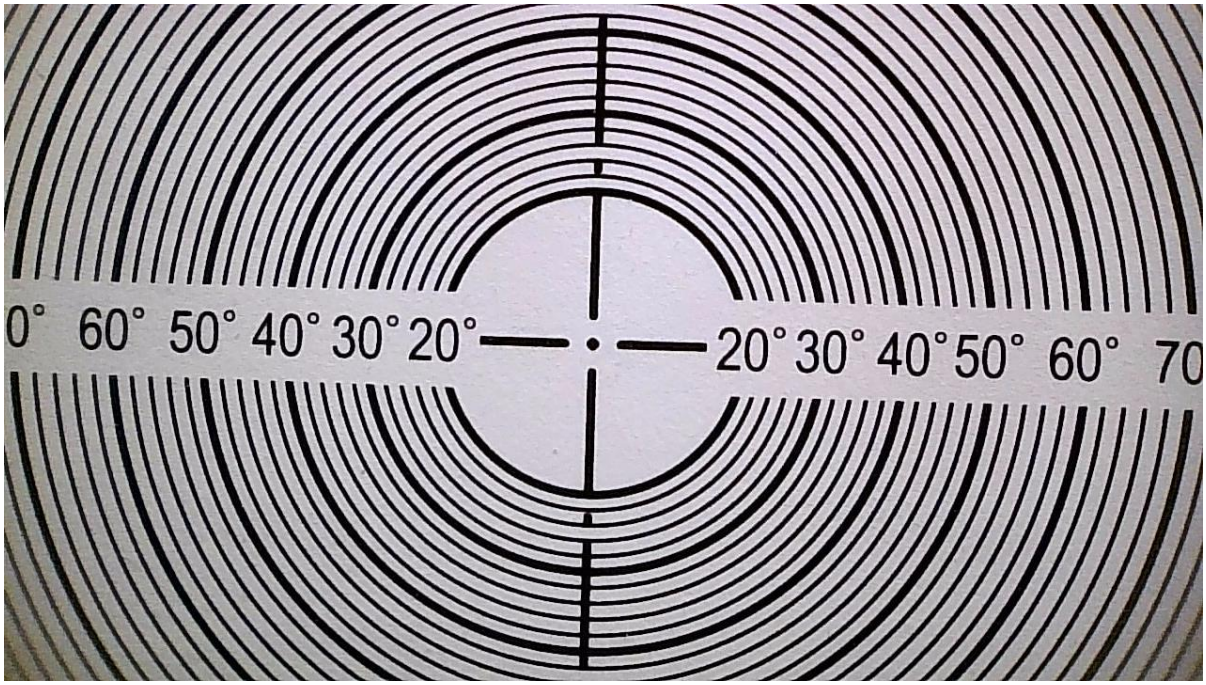


Figure 6

ISO 8600-3 Method A is followed to find the FOV of the device. The FOV is determined by the largest circle visible within the image frame. For non-circular images, such as that captured by the device shown in Figure 6, the segments of the largest visible circle are considered.

Direction	Measured FOV	Specified FOV
Horizontal	71°	66°
Vertical	43°	unspecified
Diagonal	79°	unspecified

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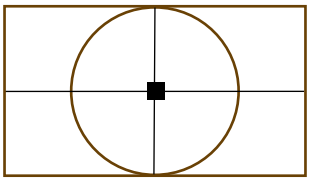
MTF and Sharpness

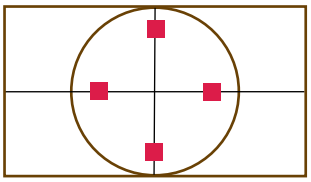
On-Axis (Point A)

	Horizontal Edge Results	Vertical Edge Results
10-90% Rise	1.93 px	2.02 px
Peak MTF	1.00	1.00
MTF50P	0.26 C/P	0.25 C/P
MTF Area	0.29 C/P	0.28 C/P



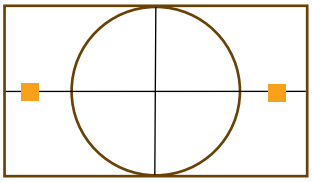
Off-Axis (Points B1-B4 Averaged)

	Horizontal Edge Results	Vertical Edge Results
10-90% Rise	2.14 px	1.91 px
Peak MTF	1.00	1.00
MTF50P	0.27 C/P	0.30 C/P
MTF Area	0.28 C/P	0.31 C/P

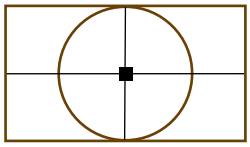


Wide Off-Axis (Points C1-C2 Averaged)

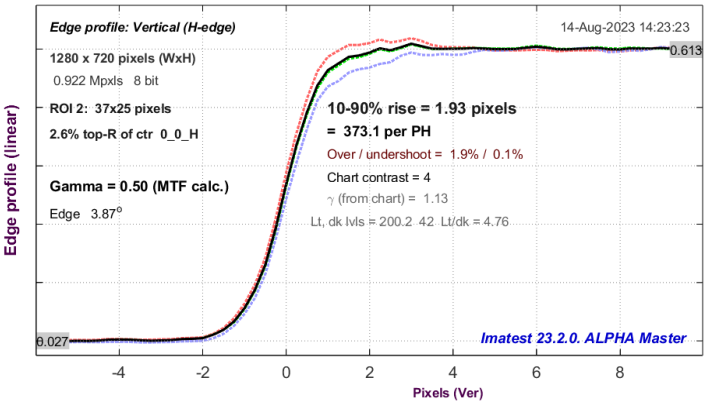
	Horizontal Edge Results	Vertical Edge Results
10-90% Rise	1.54 px	1.93 px
Peak MTF	1.00	1.00
MTF50P	0.36 C/P	0.27 C/P
MTF Area	0.34 C/P	0.29 C/P

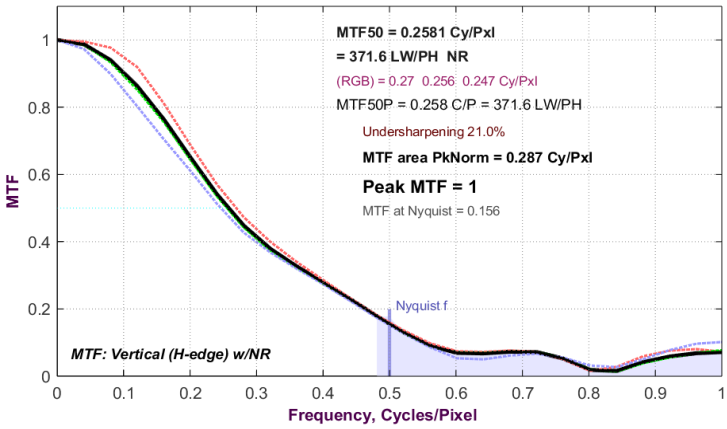


On-Axis Edge and MTF (Point A)

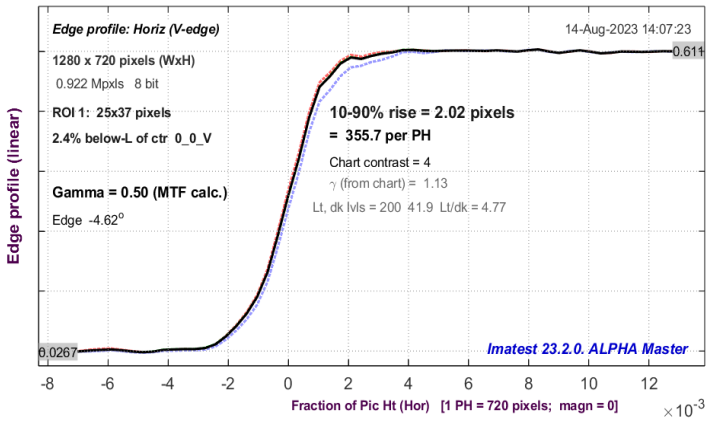


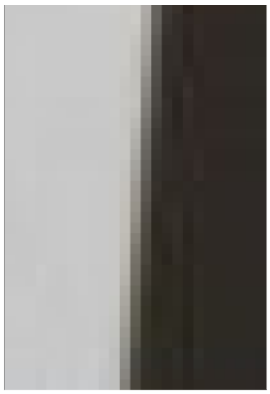
Horizontal Edge Results	
10-90% Rise	1.93 px
Peak MTF	1.00
MTF50P	0.26 C/P
MTF Area	0.29 C/P

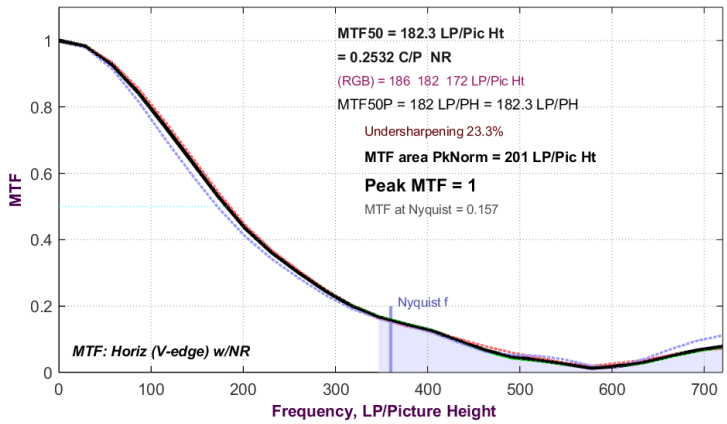




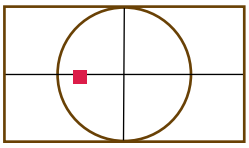
Vertical Edge Results	
10-90% Rise	2.02 px
Peak MTF	1.00
MTF50P	0.25 C/P
MTF Area	0.28 C/P



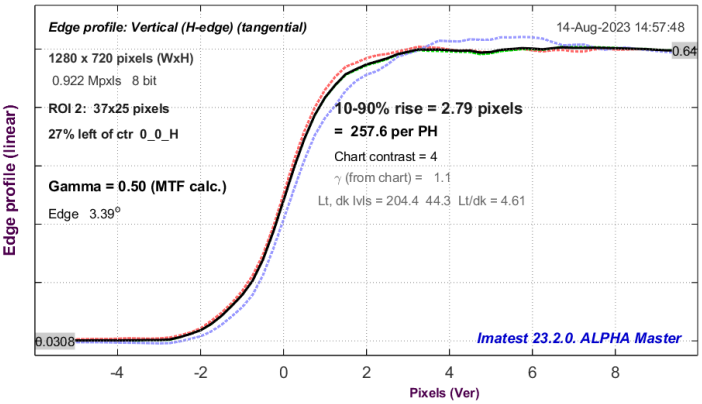


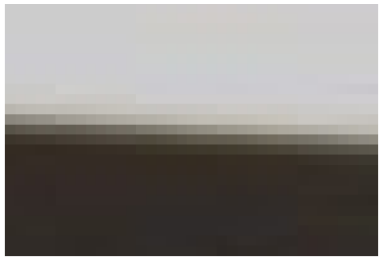


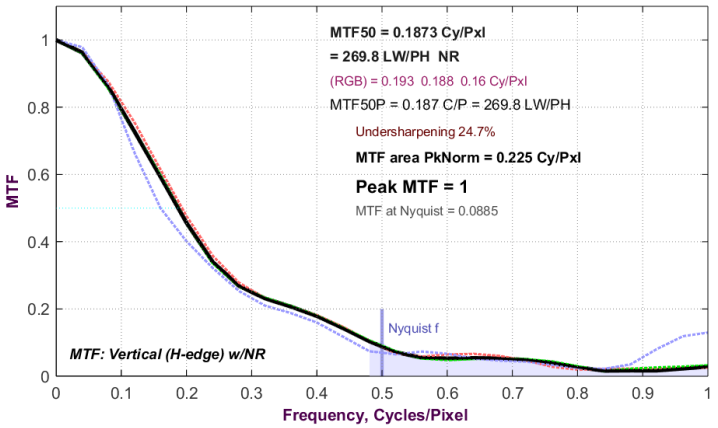
Off-Axis Edge and MTF (Point B1)



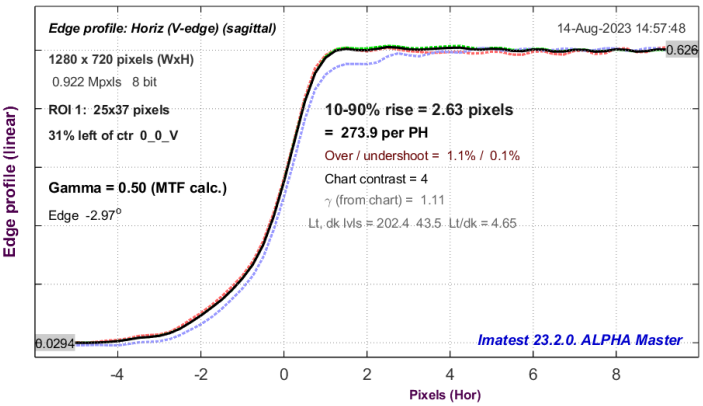
Horizontal Edge Results	
10-90% Rise	2.79 px
Peak MTF	1.00
MTF50P	0.19 C/P
MTF Area	0.23 C/P

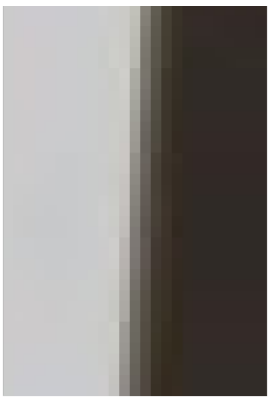


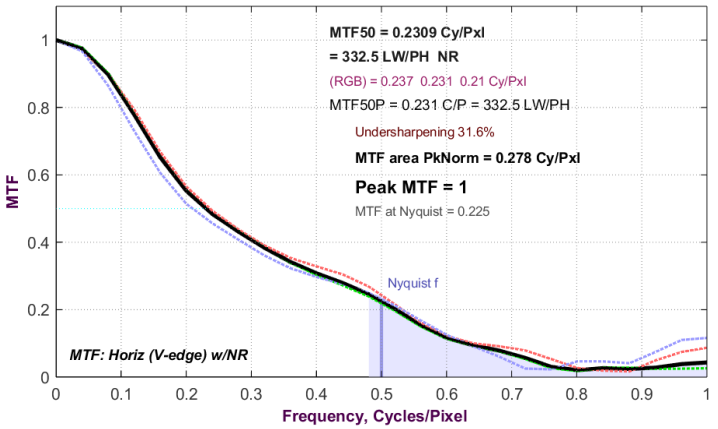




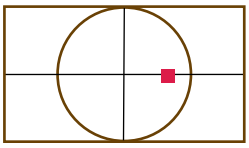
Vertical Edge Results	
10-90% Rise	2.63 px
Peak MTF	1.00
MTF50P	0.23 C/P
MTF Area	0.28 C/P



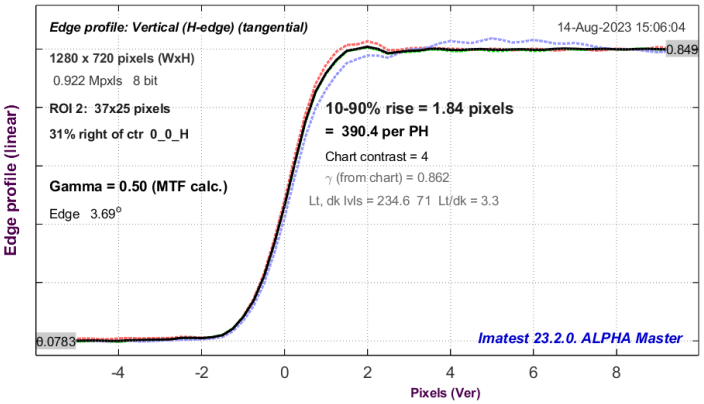


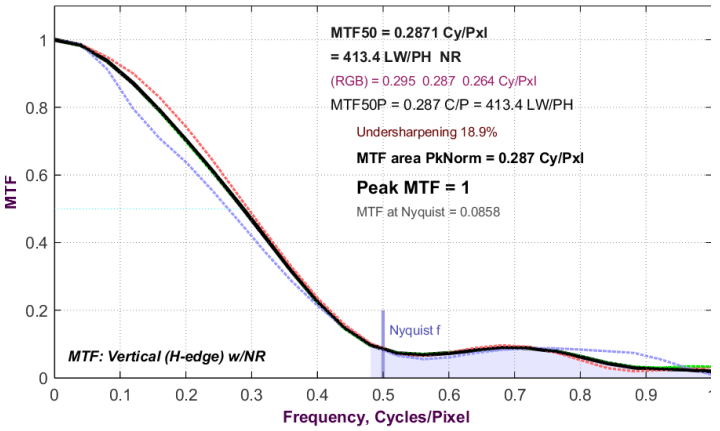


Off-Axis Edge and MTF (Point B2)

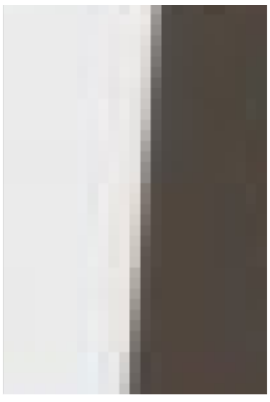


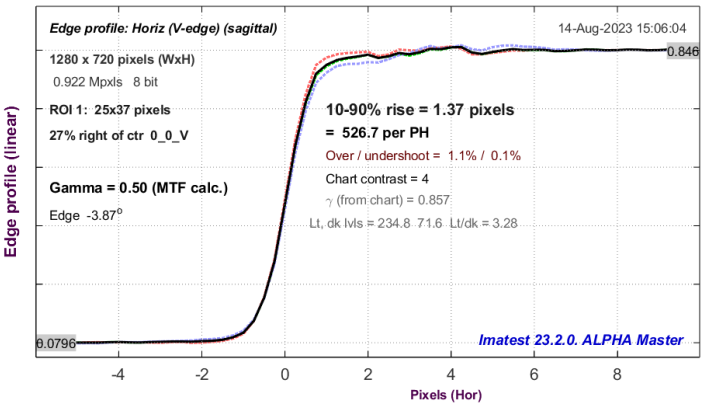
Horizontal Edge Results	
10-90% Rise	1.84 px
Peak MTF	1.00
MTF50P	0.29 C/P
MTF Area	0.29 C/P

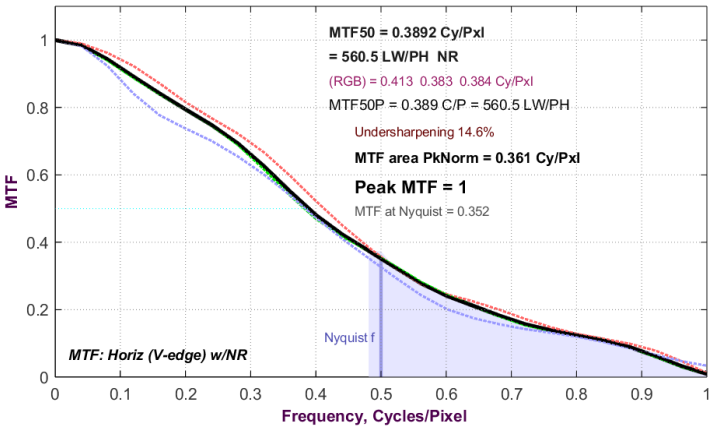


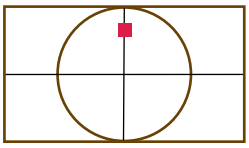


Vertical Edge Results	
10-90% Rise	1.37 px
Peak MTF	1.00
MTF50P	0.39 C/P
MTF Area	0.36 C/P



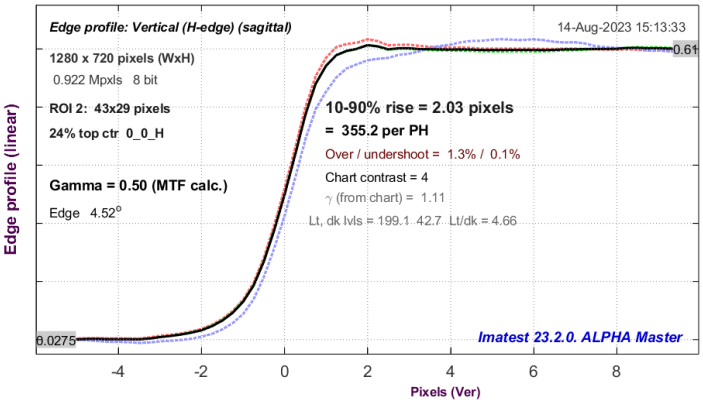


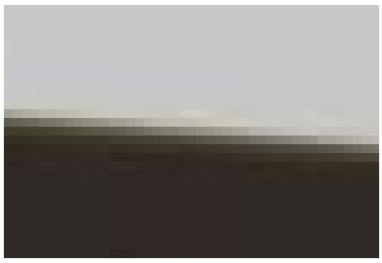


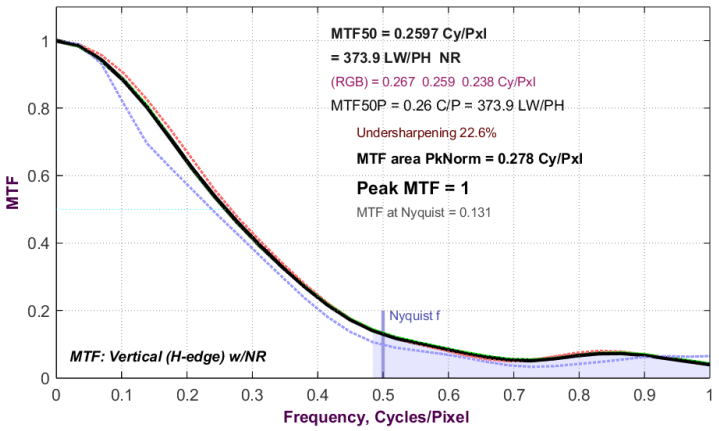


Off-Axis Edge and MTF (Point B3)

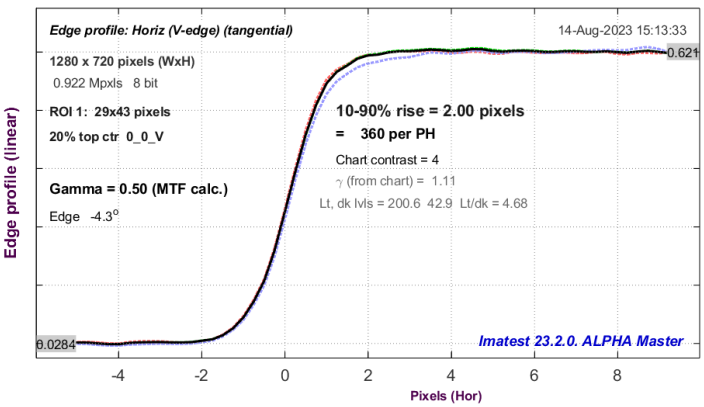
Horizontal Edge Results	
10-90% Rise	2.03 px
Peak MTF	1.00
MTF50P	0.26 C/P
MTF Area	0.28 C/P

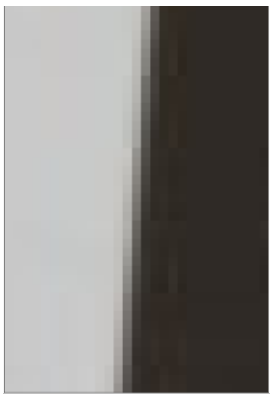


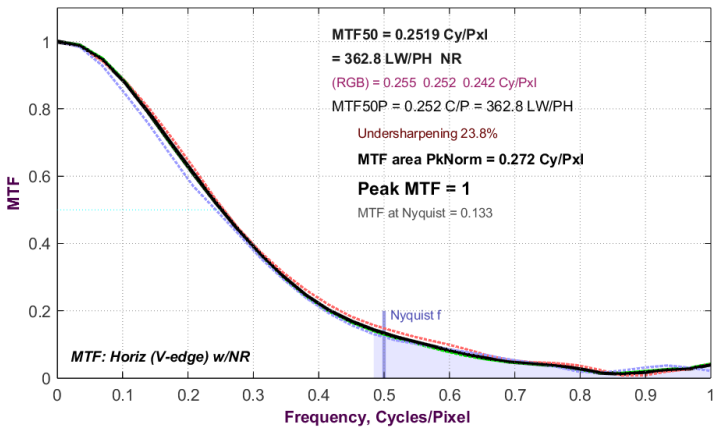




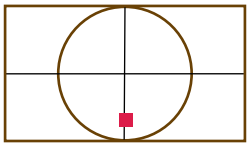
Vertical Edge Results	
10-90% Rise	2.00 px
Peak MTF	1.00
MTF50P	0.25 C/P
MTF Area	0.27 C/P



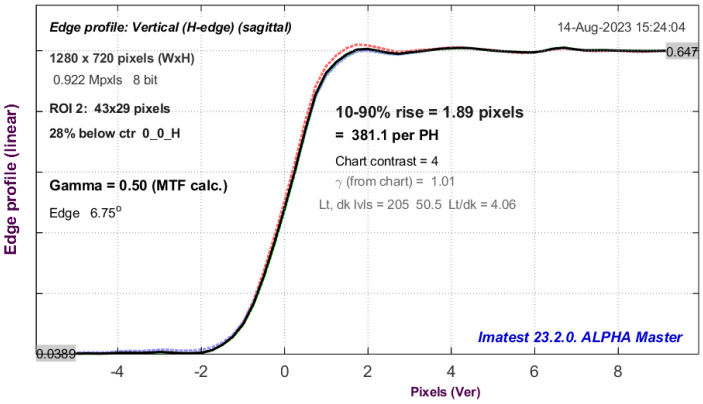


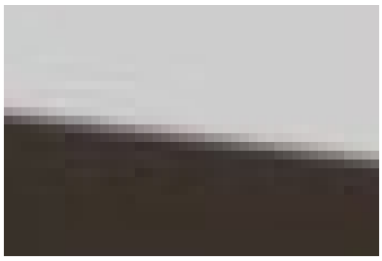


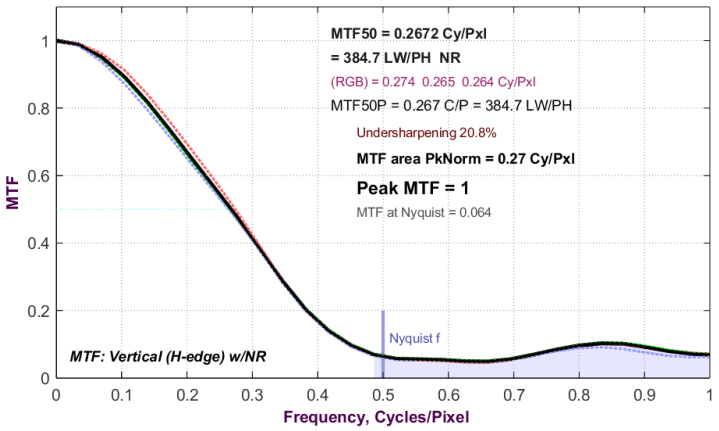
Off-Axis Edge and MTF (Point B4)



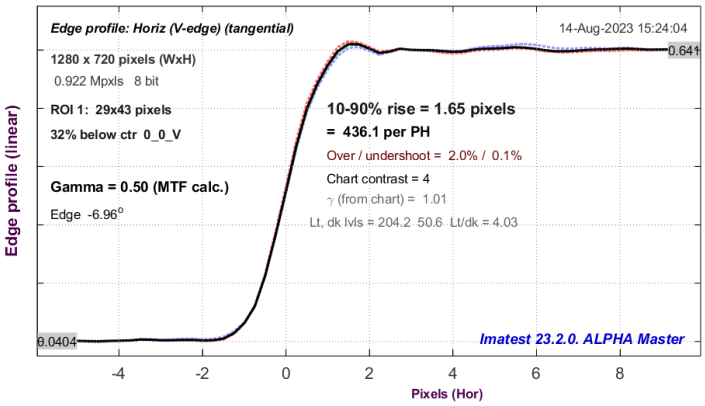
Horizontal Edge Results	
10-90% Rise	1.89 px
Peak MTF	1.00
MTF50P	0.27 C/P
MTF Area	0.27 C/P

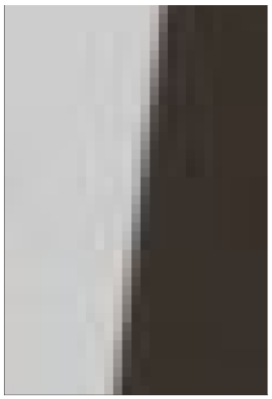


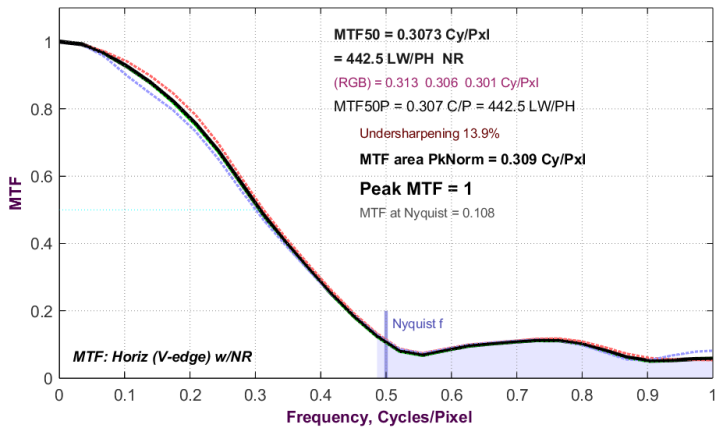


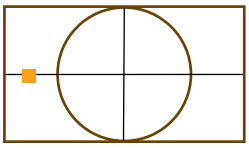


Vertical Edge Results	
10-90% Rise	1.65 px
Peak MTF	1.00
MTF50P	0.31 C/P
MTF Area	0.31 C/P



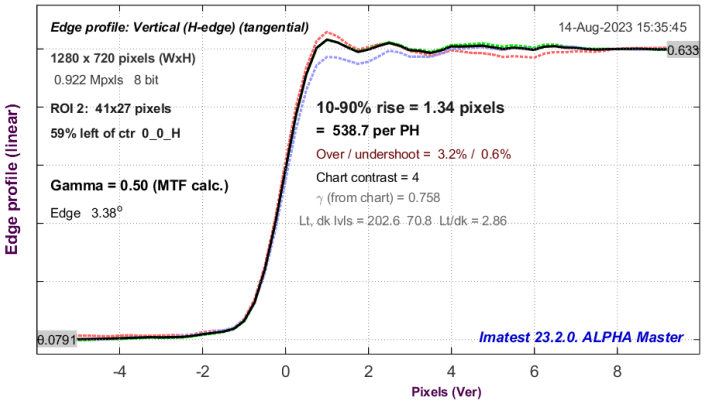


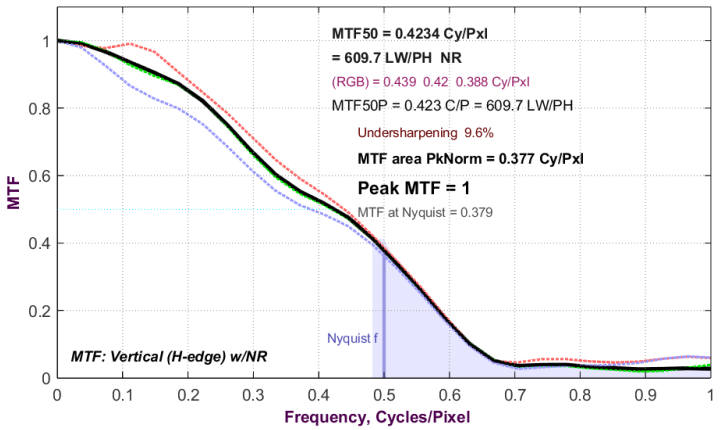




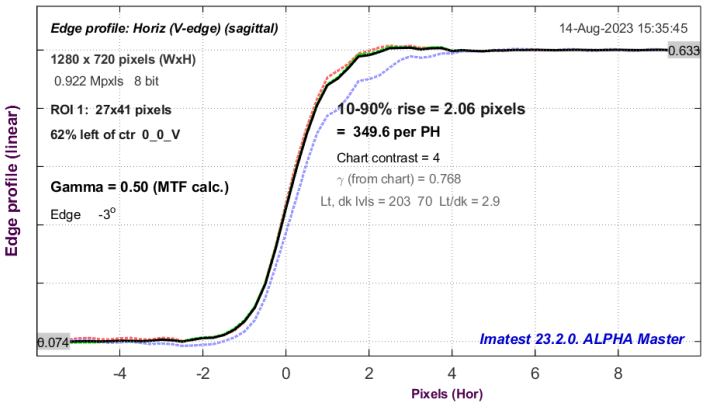
Off-Axis Edge and MTF (Point C1)

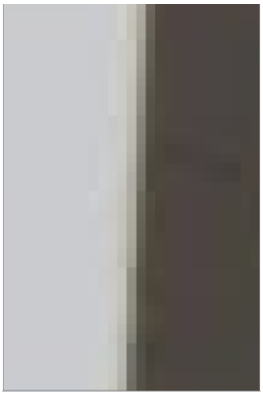
Horizontal Edge Results	
10-90% Rise	1.34 px
Peak MTF	1.00
MTF50P	0.42 C/P
MTF Area	0.38 C/P

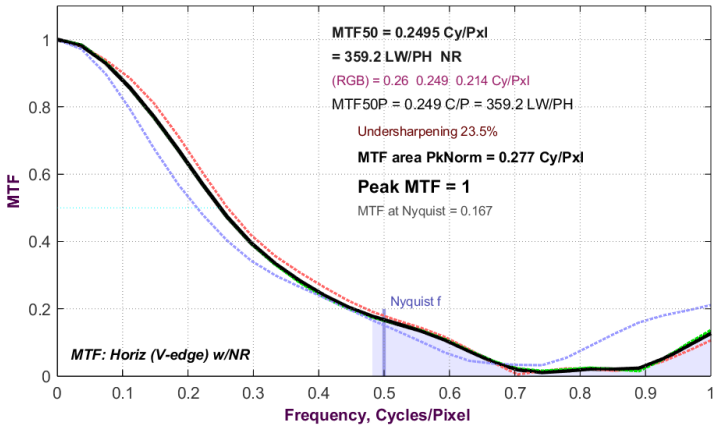


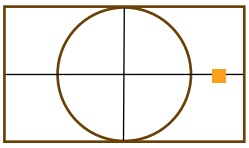


Vertical Edge Results	
10-90% Rise	2.06 px
Peak MTF	1.00
MTF50P	0.25 C/P
MTF Area	0.28 C/P



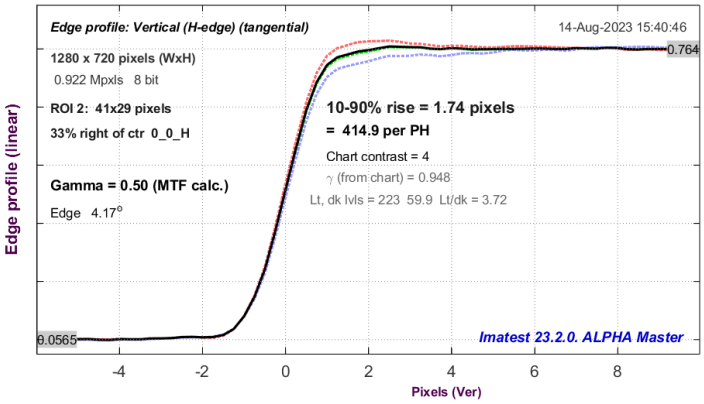


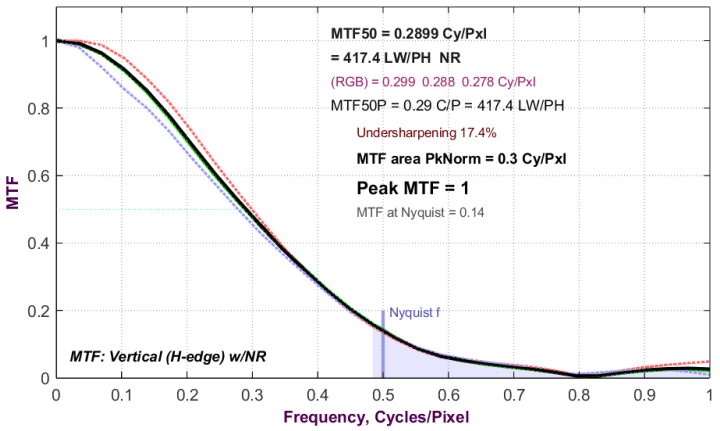




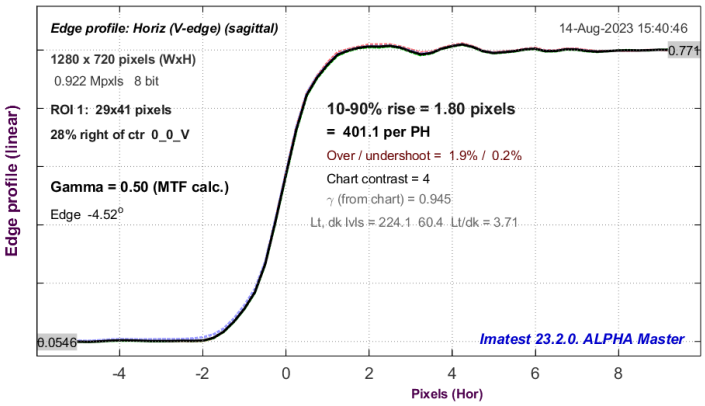
Off-Axis Edge and MTF (Point C2)

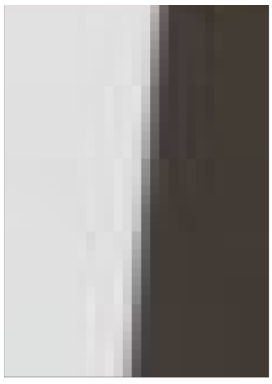
Horizontal Edge Results	
10-90% Rise	1.74 px
Peak MTF	1.00
MTF50P	0.29 C/P
MTF Area	0.30 C/P

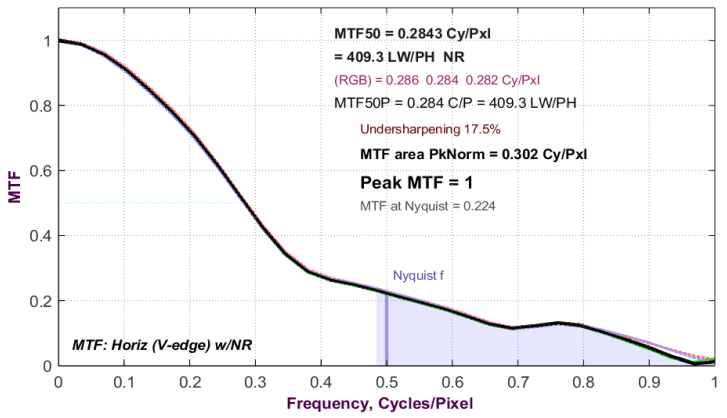




Vertical Edge Results	
10-90% Rise	1.80 px
Peak MTF	1.00
MTF50P	0.28 C/P
MTF Area	0.30 C/P

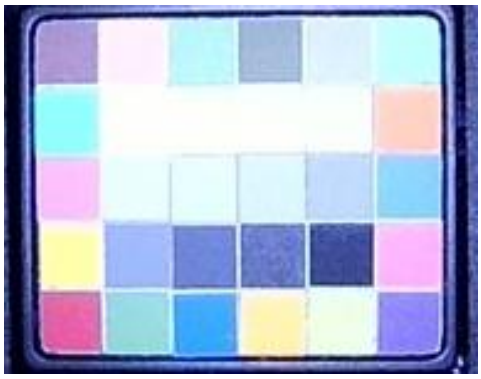


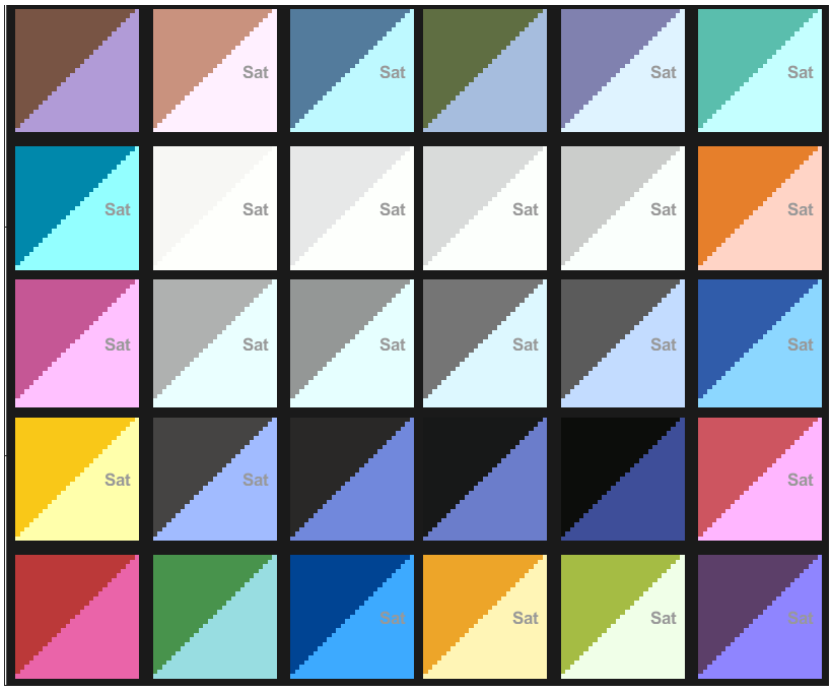




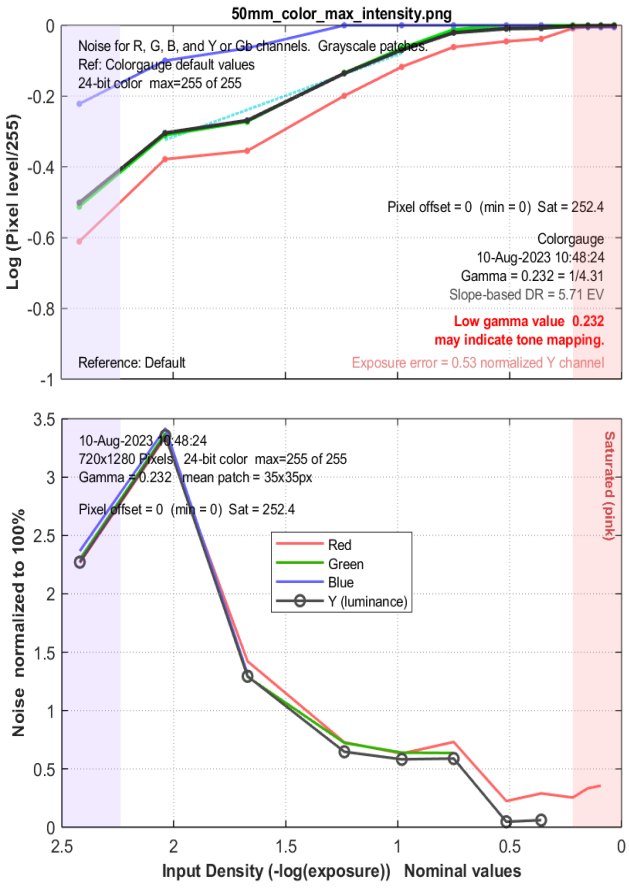
Color Accuracy

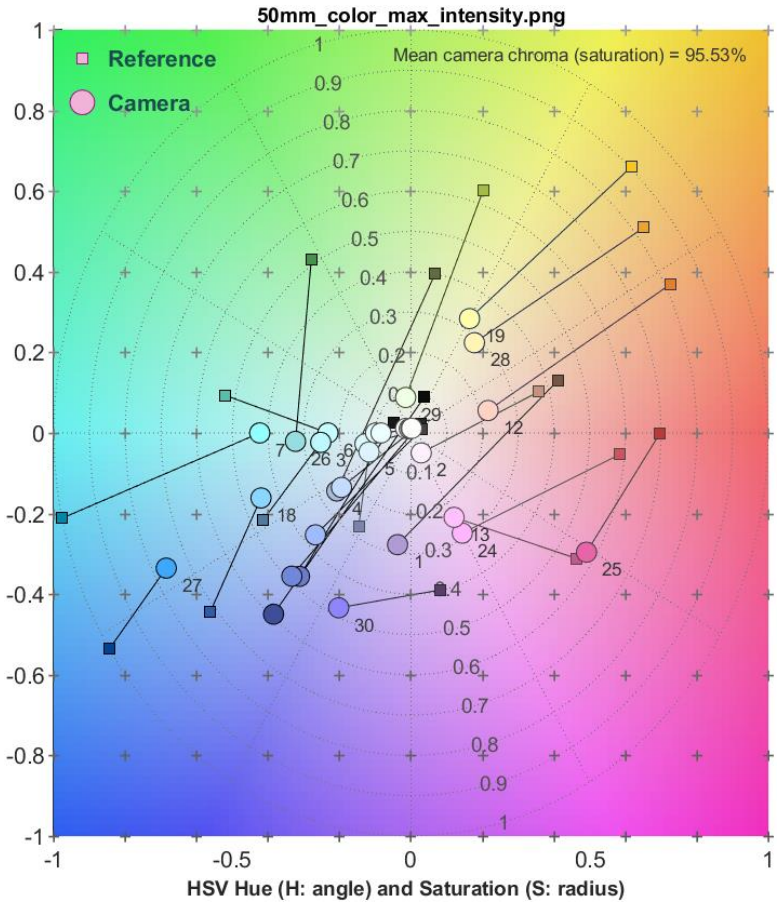
Illumination 1: Maximum Intensity (255 Lux) @ 50mm Distance



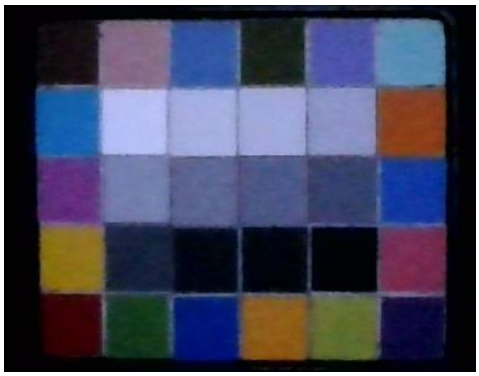


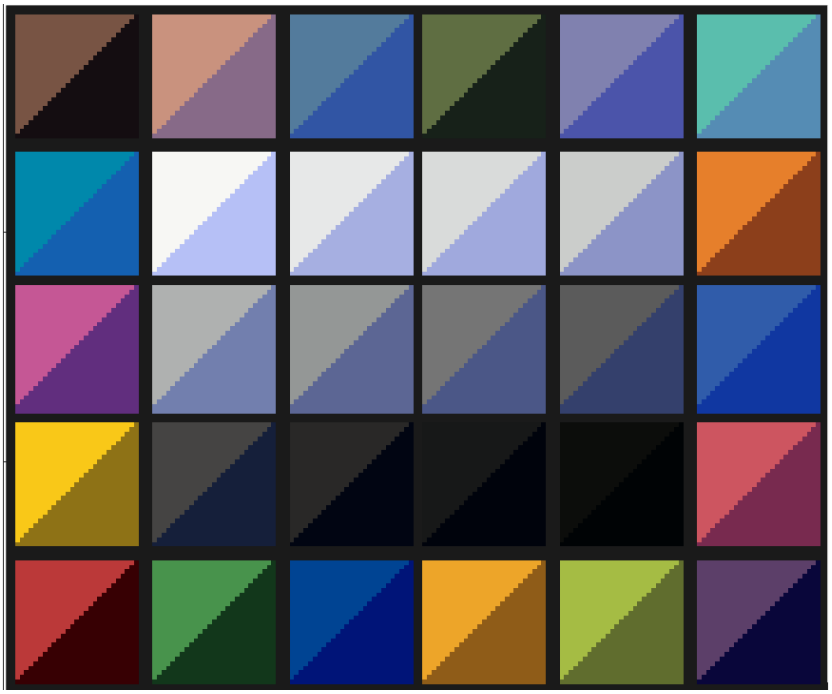
Color Metric	Mean Value
ΔE^*_{ab}	43.8
ΔE_{00}	29.2
ΔC^*_{ab}	28.2
ΔC_{00}	15.0



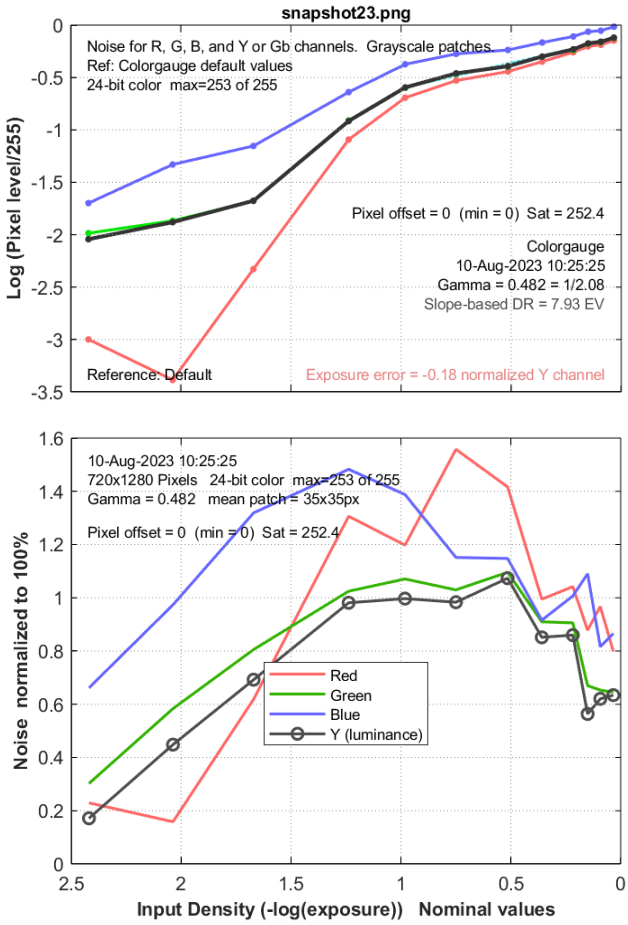


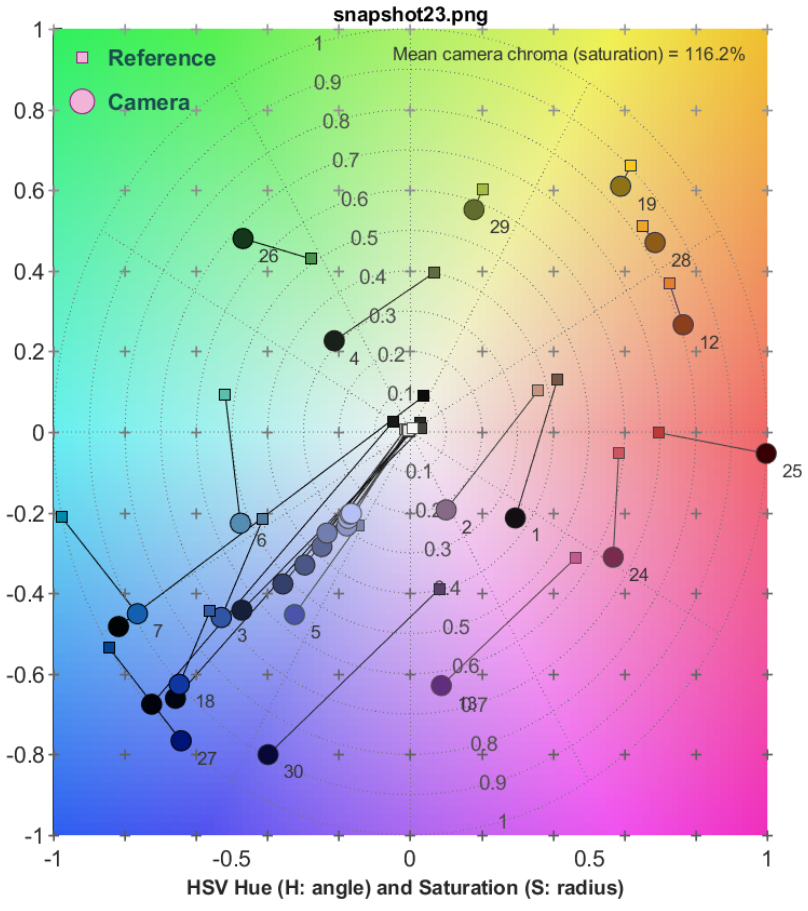
Illumination 2: Saturation Adjusted (5.7 Lux) @ 50mm Distance





Color Metric	Mean Value
ΔE^*_{ab}	32.7
ΔE_{00}	21.6
ΔC^*_{ab}	24.6
ΔC_{00}	12.8





Uniformity

The captured flatfield image from the DUT is shown in Figure 7.

Figure 7

The luminance contour plot in Figure 8 shows normalized pixel level contours for the image file luminance channel, where luminance is defined as 0.2125*R + 0.7154*G + 0.0721*B.

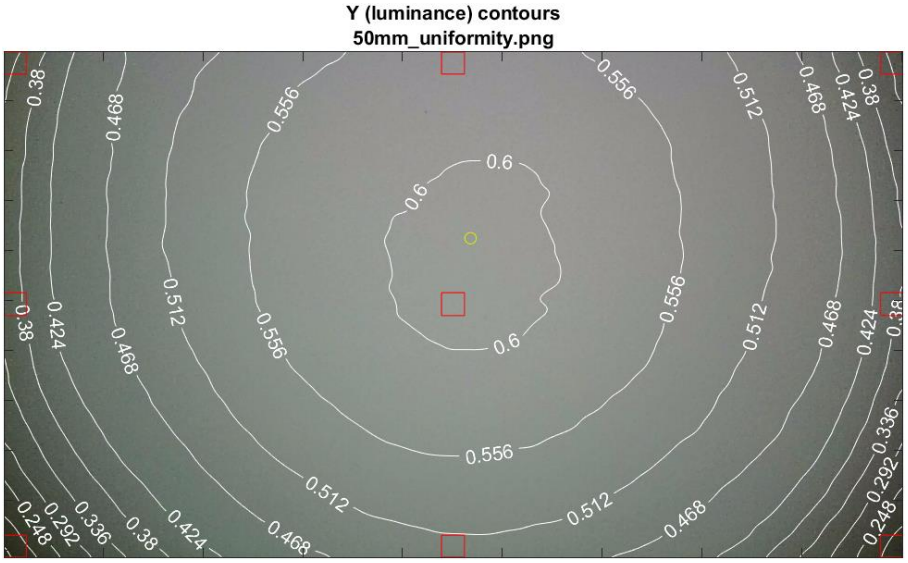


Figure 8

Distortion

Lens (optical) distortion is an aberration that causes straight lines to curve near the edges of images. The simplest approximation is the 3rd order equation, $r_u = r_d + kr_d^3$ where r_d is the distorted radius and r_u is the undistorted radius.

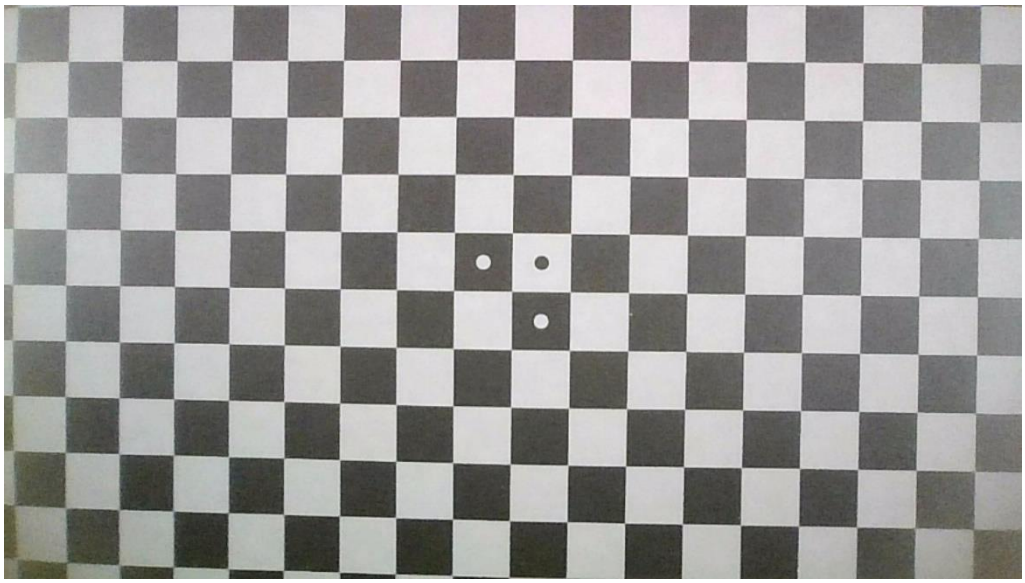


Figure 9

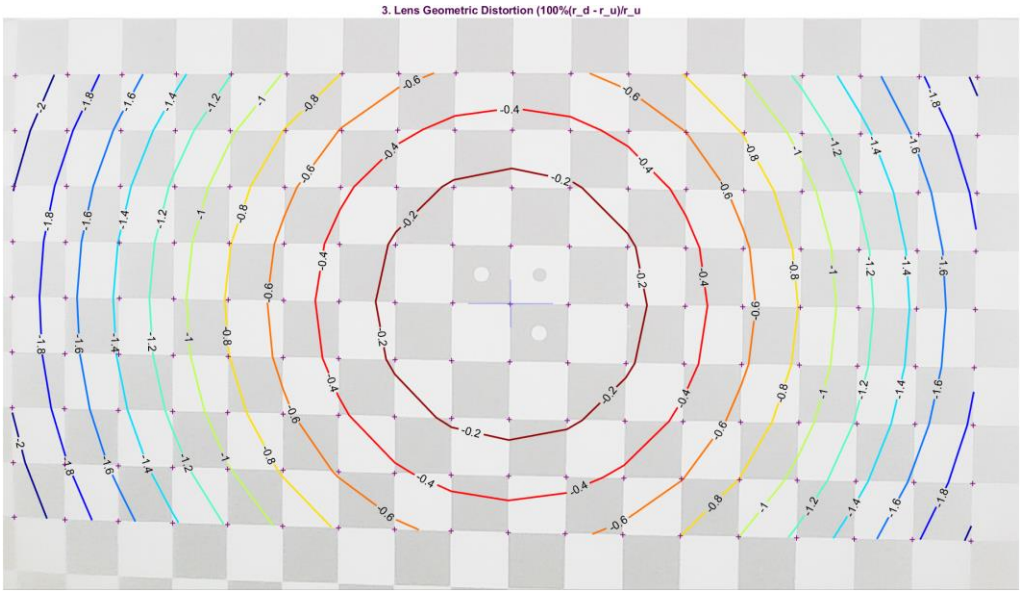


Figure 10

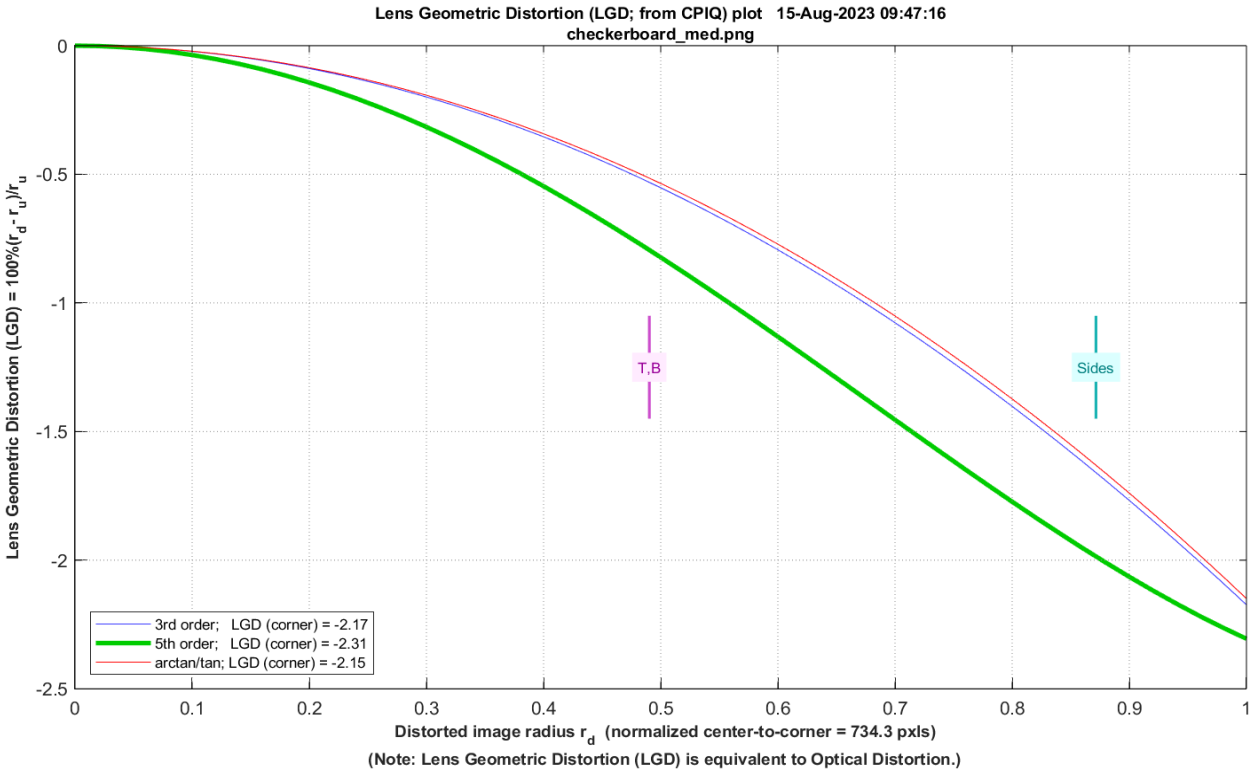


Figure 11

Distortion Metric	Mean Value
3rd Order	$k_1 = 0.022$
5th Order	[0.036, -0.013]
Atan/tan	0.025
Convergence Angles	H: 10.8°; V: -3.67°