DXOMARK ROBOTIC STEREOVISION MODULE EVALUATION REPORT

--Sample report--

8 bits image sensor and lens evaluation

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Table of content

Chip total size	165x40x35 mm
Pixel size	3 µm
Max resolution	1920 x 1080
Full frame rate	60 fps
Lens FOV (H/V/D)	110° / 80°/ 120°
Baseline distance	120 mm
Shutter control	Global shutter

Testing Conditions

Mode sensor	Default
Frame Grabber	vRGB-E2s
SW version	13.12
Output	RGB

Framerate	30 fps
Image resolution	1920 x 1080
Exposure time (ms)	16
Gain	1

Overall Performance

DR (SNR1 40°C)	20 dB
Saturation (D65)	1200 cd/m²
Dark (40°C)	26e-
Full Well Capacity	847860e-
Dark flatness	3.1

DR P2020	17 dB
Noise Autocorrelation	3 x 3

Measurement description

1. SFR / Resolution

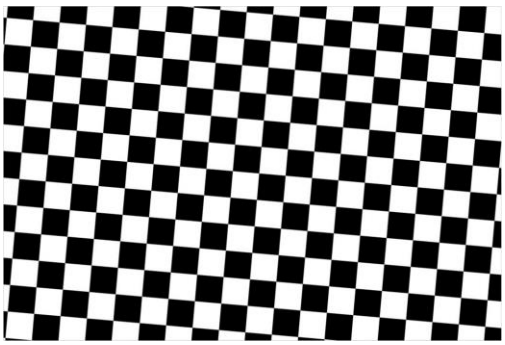
Standard compliance

The SFR measurement is fully compliant with the standard ISO 12233.

Metrics details

The SFR is computed in a linearized image.

Measurement setup specifications



SFR measurement compensate the target printer MTF. The target MTF is measured compared to a true cutter target, and it is then taken into account during the camera MTF measurement.

Measurement description

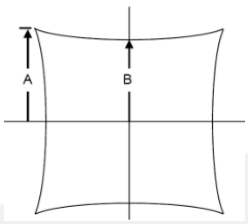
2. Distortion and lateral chromatic aberration

Standard compliance

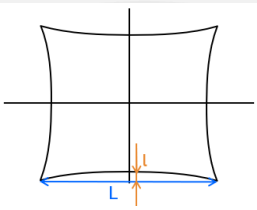
The lens distortion measurement is fully compliant with the standard ISO 17850, and the chromatic aberration measurement is fully compliant with the ISO 19084 standard.

Metrics details

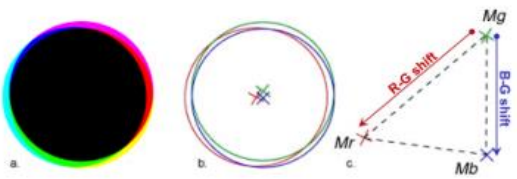
TV distortion: $100 \cdot \frac{A-B}{B}$, with A and B defined on the following figure:



Geometric distortion: $100 \cdot \frac{l}{L}$, with l and L defined on the following figure:

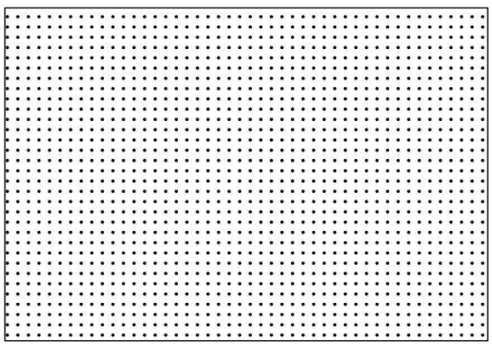


Chromatic aberrations: shift between R and G, and between B and G:



Definition of chromatic aberration profiles

DOT Chart:



Measurement setup specifications

Measurement description

3. Vignetting/Color Lens Shading

Standard compliance

The Vignetting/Color Lens Shading measurement is fully compliant with the standard ISO 17957.

Metrics details

Vignetting Profile: gray level value divided by the gray level value at the vignetting center, for each radial field position and each color channel.

Color vignetting: each channel vignetting divided by green (average of G1 and G2 channels) vignetting.

Measurement setup specifications

Integrating sphere RO-LIS-3CR80 with 5100K.

Measurement description

4. Flicker Mitigation

Standard compliance

The flicker mitigation measurement is fully compliant with the standard draft IEEE/P2020 published in dec 2022.

Metrics details

The Flicker Modulation Index (FMI) is defined as:

$$FMI = 100 \times \frac{s_{max} - s_{min}}{s_{max} + s_{min}}$$

Where s_{max} and s_{min} are respectively the maximum and minimum values of the measured signal for the considered time-range of the video.

The Flicker Detection Index (FDI) is defined as:

$$FDI = P\left[\frac{s(t) - s_{off}}{s_{off}} \geq \text{th}\right]$$

Where:

- P is the probability.
- $s(t)$ is the measured signal.
- s_{off} is the measured signal when the PMW signal is off.
- th is a minimum threshold above which the LED is considered visible.

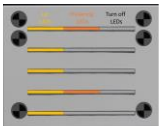
The Modulation Mitigation Probability (MMP) is defined as:

$$MMP = P\left[\overline{s_{ref}}(1-\delta) < s(t) < \overline{s_{ref}}(1+\delta)\right]$$

Where:

- P is the probability.
- $s(t)$ is the measured signal.
- $\overline{s_{ref}}$ is the expected signal.
- δ is a parameter defining the lower and upper bounds of the signal interval in which the device is considered as able to successfully mitigate the LED flickering.

Measurement setup specifications



The flickering is generated by the DXOMARK Led Universal Timer.

This device provides a light modulated by a square signal with frequency in range [50, 2000] Hz, adjustable duty cycle, phase and intensity.

Measurement description

5. Dynamic Range

Standard compliance

The Dynamic Range measurement is fully compliant with the standard draft IEEE/P2020 published in dec 2022.

Metrics details

The CNR (Contrast to Noise Ratio) between a pair of ROIs A and B is defined as:

$$CNR(A,B) = \frac{s_A - s_B}{\sqrt{\sigma_A^2 + \sigma_B{}^2}}$$

Where:

- s_A and s_B are respectively the mean signals of the ROIs A and B
- σ_A and σ_B are respectively the standard deviations of the ROIs A and B

The TCG (Tonal Contrast Gain) is the transfer function between the scene contrast and the image contrast:

$$TCG(A,B) = \frac{\log_2\left(\frac{L_{A,Image}}{L_{B,Image}}\right)}{\log_2\left(\frac{L_{A,Scene}}{L_{B,Scene}}\right)}$$

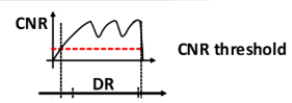
Where:

- $L_{A,Image}$ and $L_{B,Image}$ are the mean signals the ROIs A and B in the image
- $L_{A,Scene}$ and $L_{B,Scene}$ are the luminance values the ROIs A and B in the scene.

Dynamic Range is measured as CDR (Contrast Detection Ratio):

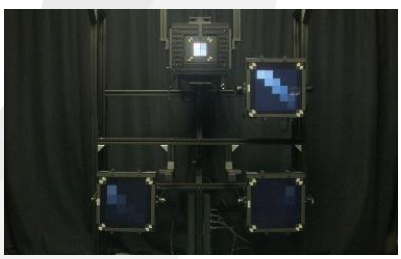
$$CDR_{dB} = 20\log_{10}\left(\frac{L_{max}\,[CNR > 1]}{L_{min}\,[CNR > 1]}\right)$$

Where $L_{max}\,[CNR > 1]$ and $L_{min}\,[CNR > 1]$ are respectively the maximum and the minimum luminance values that verify $CNR > 1$.

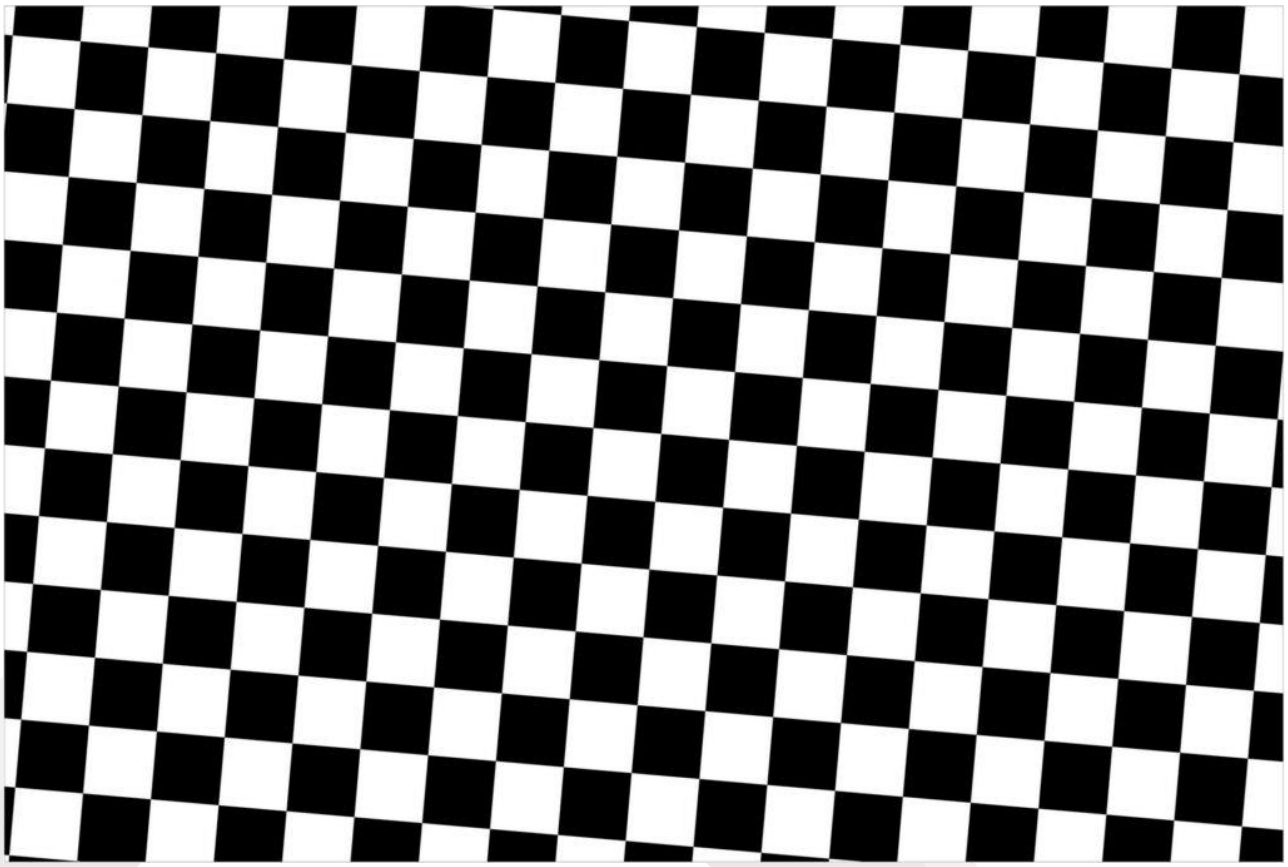


Measurement setup specifications

The dynamic range setup is an assembly of 4 light panels, delivering 25 patches that can reach at least 150 dB dynamic.

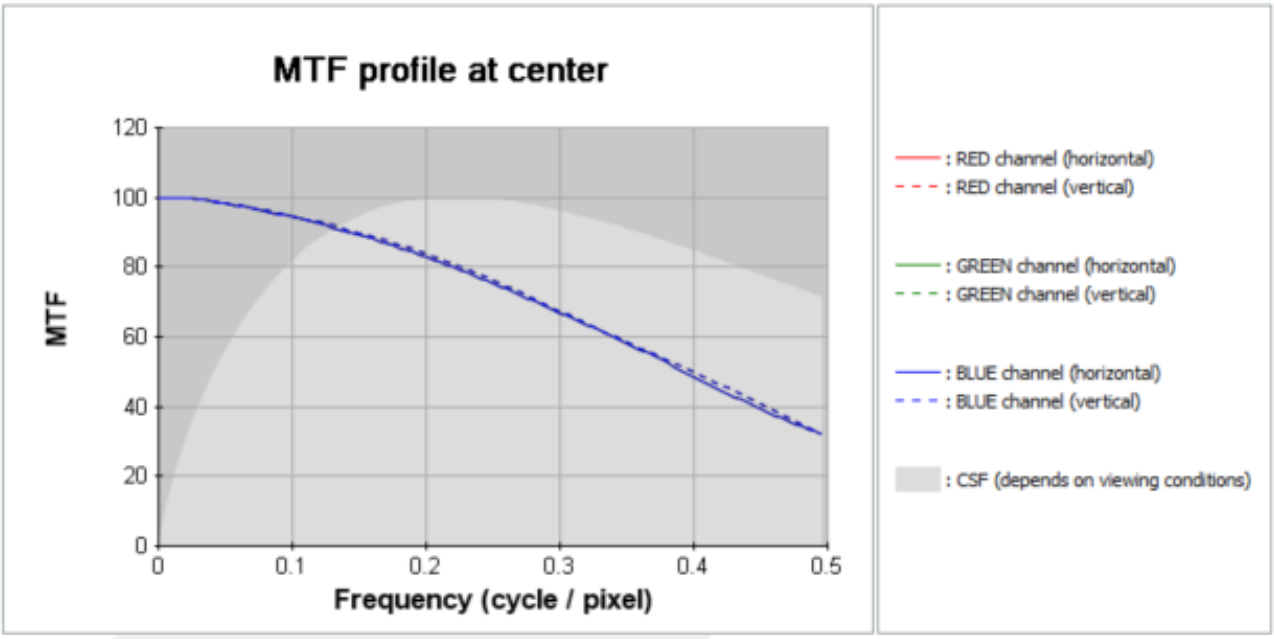


The measurement is performed for different positions in the field of view of the device.



- **Measurement conditions:**
  - Illumination: D65 360lux
  - Through focus to find the best sharpness in the center
  - DUT to chart distance: 7m
  - Number of images averaged: 30
  - Viewing condition for acutance computation:
    - Distance: 600mm
    - Pixel pitch: 0.254mm

- MTF at 7 m, chart illumination : D65 360 lux



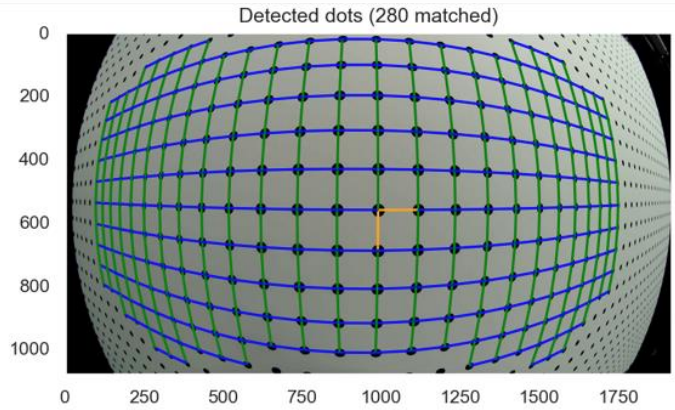
This table contains the averaged values (H and V) of the MTF for the green channel

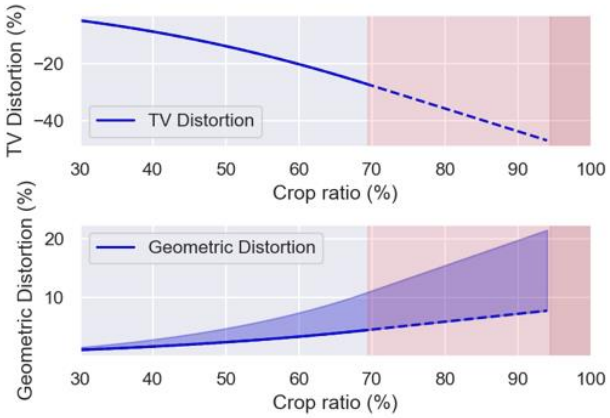
	Acutance	Limiting resolution (MTF 10%)	MTF 50%	Ringing
		cycles/pixel (lp/mm 24x36mm eq)	cycles/pixel (lp/mm 24x36mm eq)	
Center	0.39	0.50 (14.25)	0.40 (11.33)	0%
All corners (mean)	0.40	0.50 (14.25)	0.41 (11.56)	0%

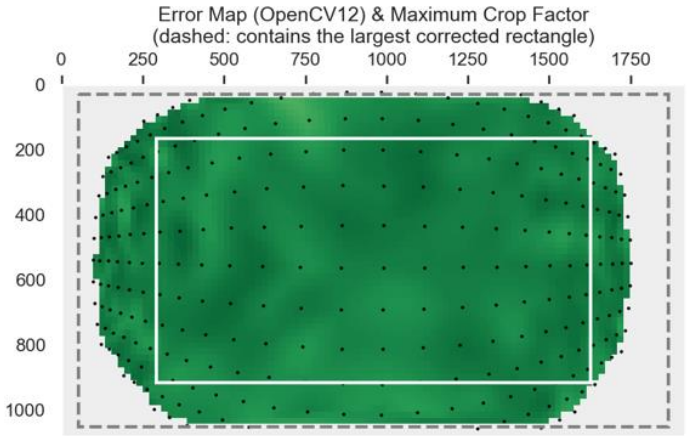
Details:

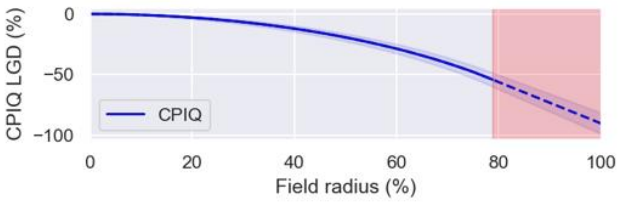
Conversion factor between cycles/pixels and cycles/degrees for viewing conditions [03 - Professional Photo Print (closer)]

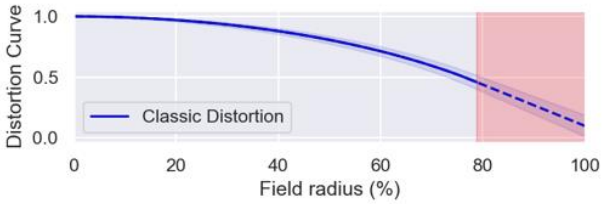
Pixels/Degree	17.933

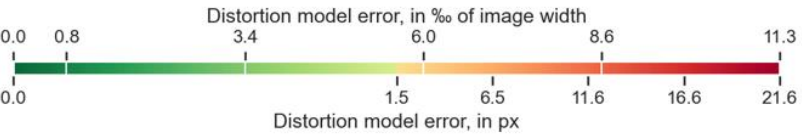






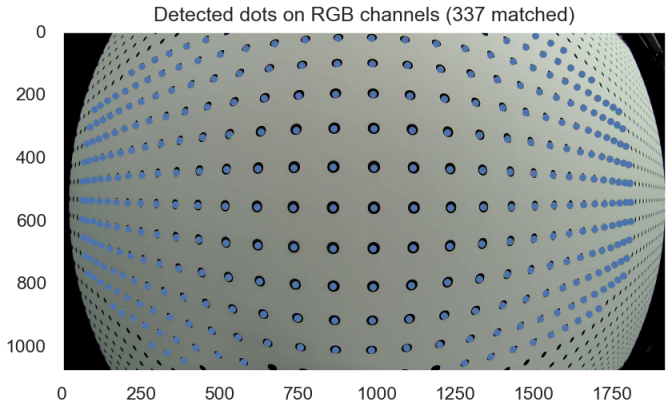


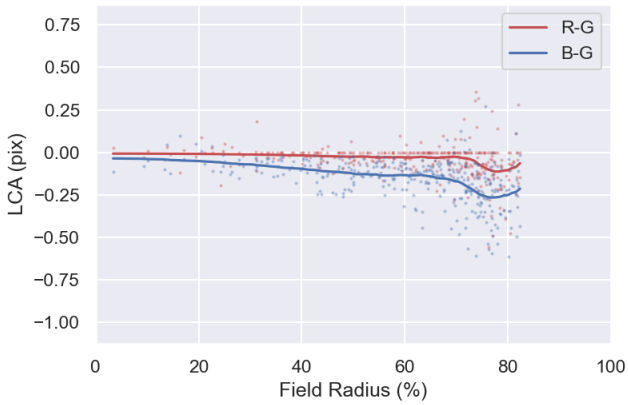


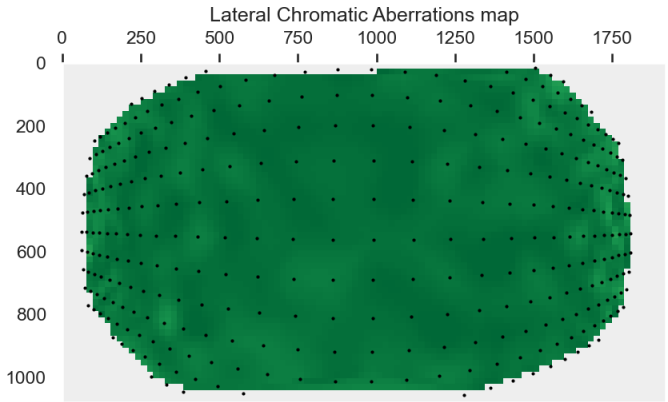


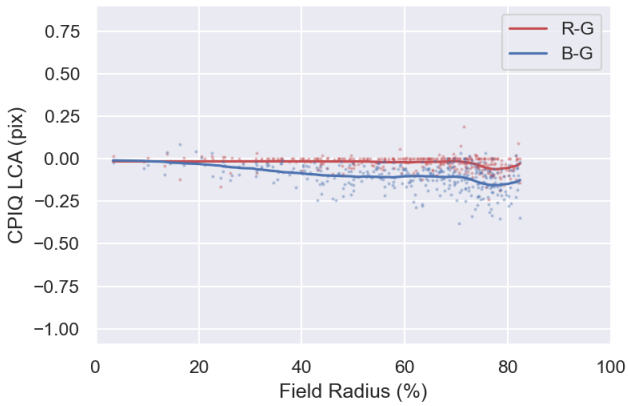
	Results	Results (extrapolated)
TV Distortion	-46.83%	-27.27%
Geometric Distortion (avg)	+7.81%	+4.55%
Geometric Distortion (Max)	+21.48%	+11.00%
CPIQ LGD (Max)	-98.73%	-59.81%
CPIQ LGD (JND)	-15.17%	-15.17%

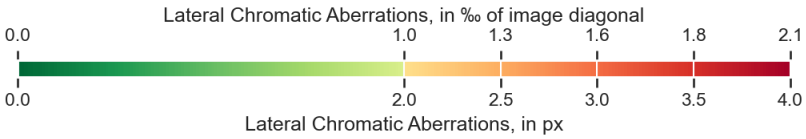
Good fitting of the distortion model (small reprojection error)





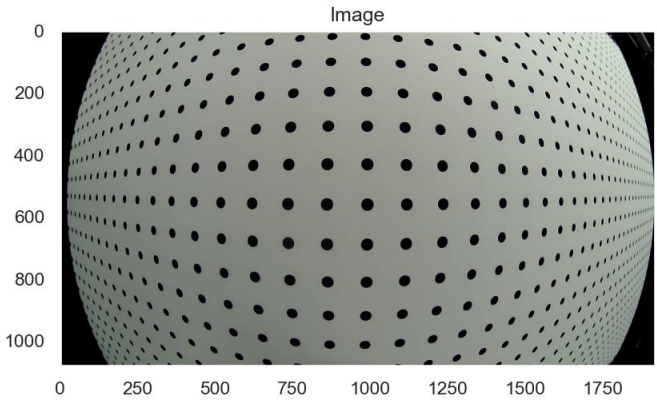


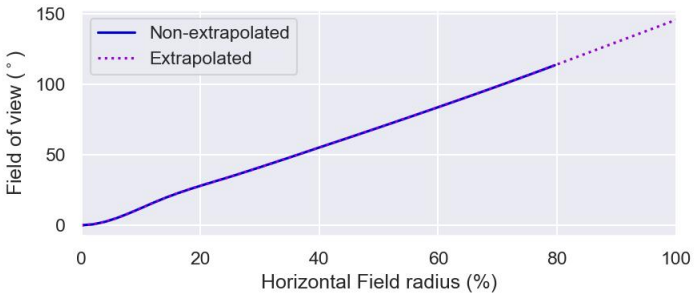


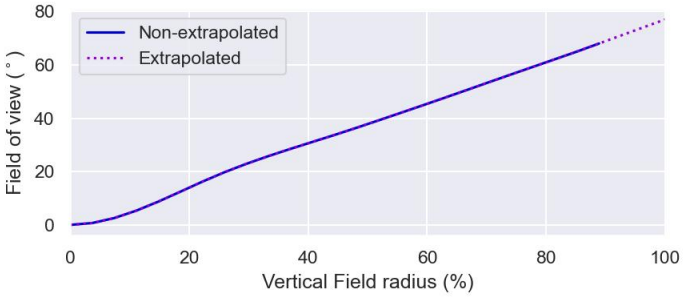


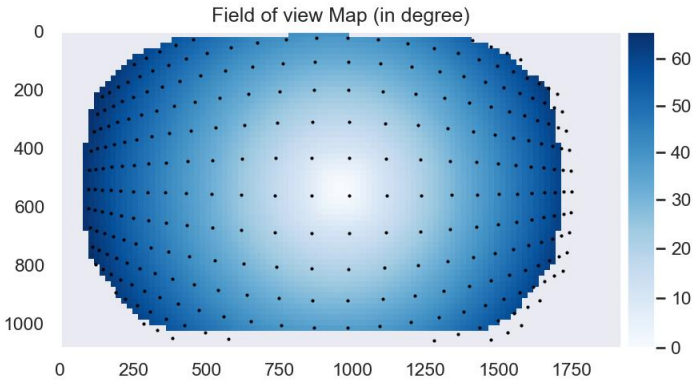
CPIQ Max LCA (Pixels)	-0.15 px
CPIQ Max LCA (Percent)	-0.01 %
CPIQ Max LCA (JND)	0.00

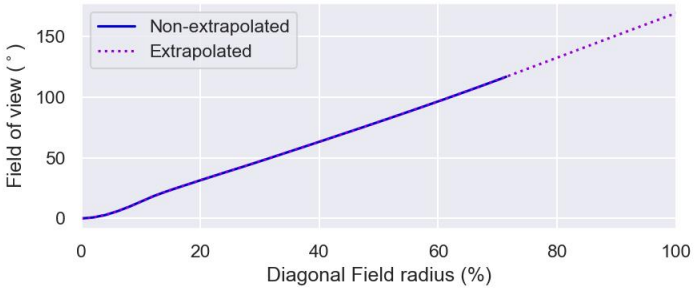
Chromatic Aberrations are negligible (less than 1 pixel in the full measurement area)







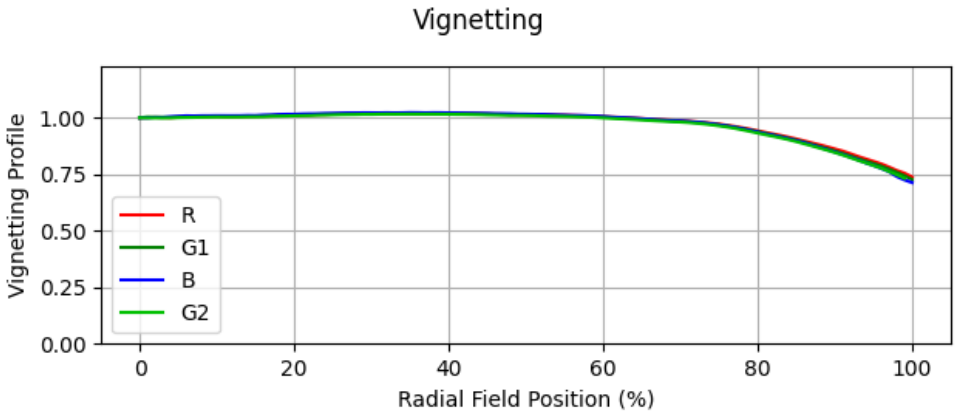




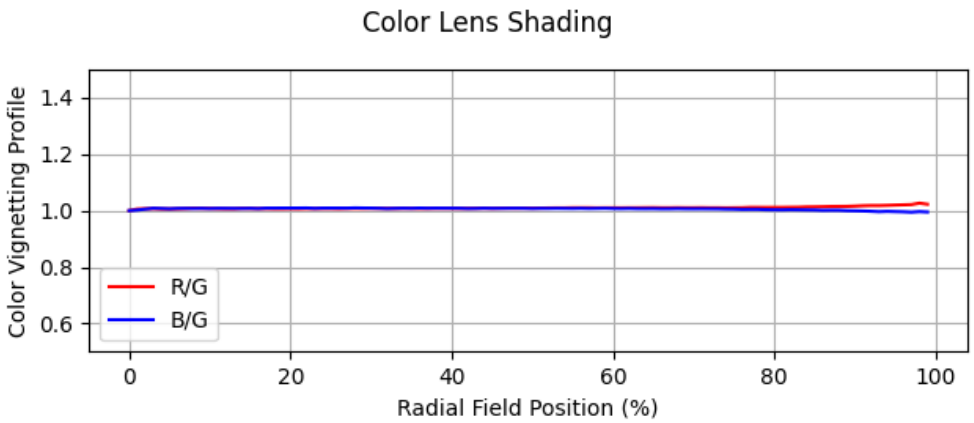
	H. FoV	V. FoV	D. FoV
Non-extrapolated	113.41 °	67.98 °	116.96 °
Extrapolated	145.64 °	77.01 °	169.55 °
	Tilt	Pan	
Orthofrontality	2.5 °	0.68 °	

	Horizontal	Vertical	Diagonal
Field of View	145°	77°	170°

Fisheye lens: The field of view is linear with the field radius



	R	G1	B	G2
Max Attenuation	24.5 %	25.6 %	27.5 %	26.8 %
Max Amplification	2.0 %	2.0 %	2.3 %	1.6 %



	R	B
Max Attenuation	0.8 %	2.3 %
Max Amplification	3.5 %	2.4 %

Green Imbalance	1.2 %

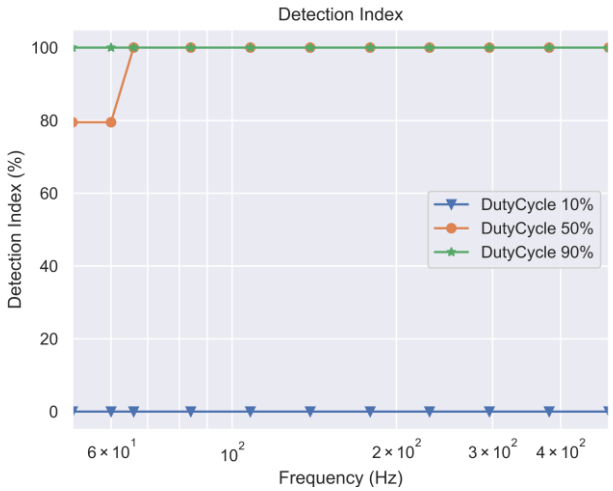
Vignetting Measurement done with an integrating sphere with illuminant D50

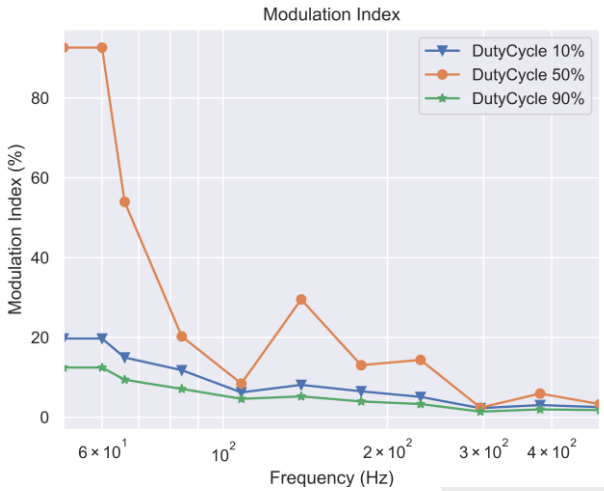
Results: Good vignetting and color lens shading performance

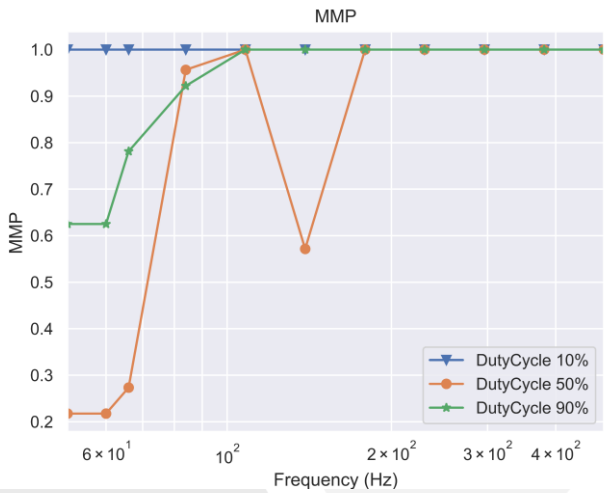
- **Measurement conditions:**
  - 16 LED PWM frequencies in Hz: 50, 51, 60, 66, 84, 108, 139, 150, 179, 200, 230, 296, 300, 381, 490, 1000
  - 3 LED PWM duty cycles: 10%, 50%, 90%
  - 3 test conditions:
    - Background at 10000 lux, LED light intensity at 3000 cd/m²
    - Background at 180 lux, LED light intensity at 90 cd/m²
    - Background at 0.5 lux, LED light intensity at 6 cd/m²

- **Results:**
  - The exposure time is 10ms:
    - Significant flickering for frequencies below 100Hz (1 / exposure time)
    - Limited flickering for high frequencies
  - No other visible LED flicker mitigation effect
  - The response to flickering is the same for the 3 tested lighting conditions

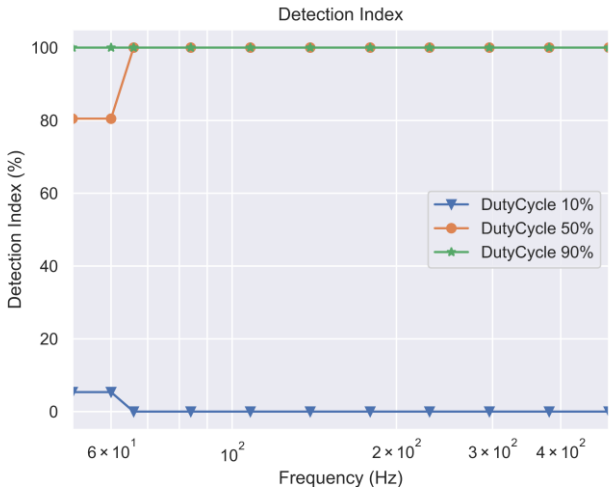
Background at 10000 lux, LED light at 3000 cd/m²

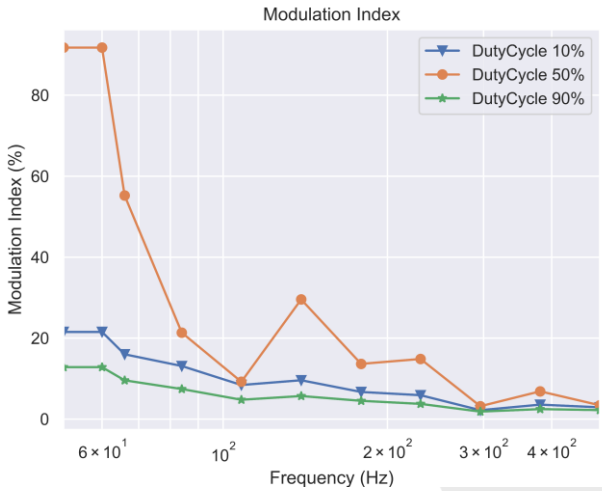


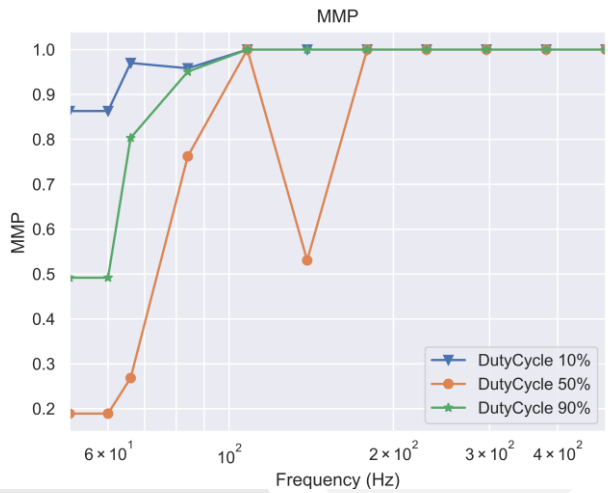




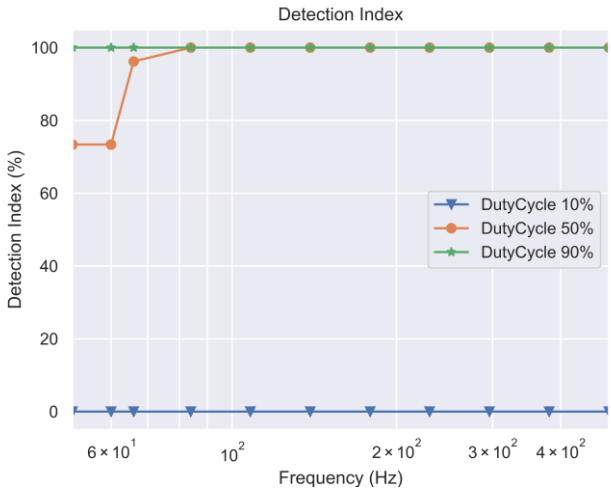
Background at 180 lux, LED light at 90 cd/m²

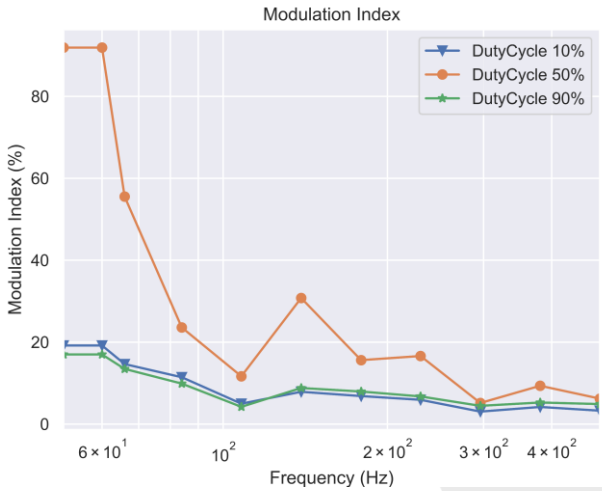






Background at 0.5 lux, LED light at 6 cd/m²





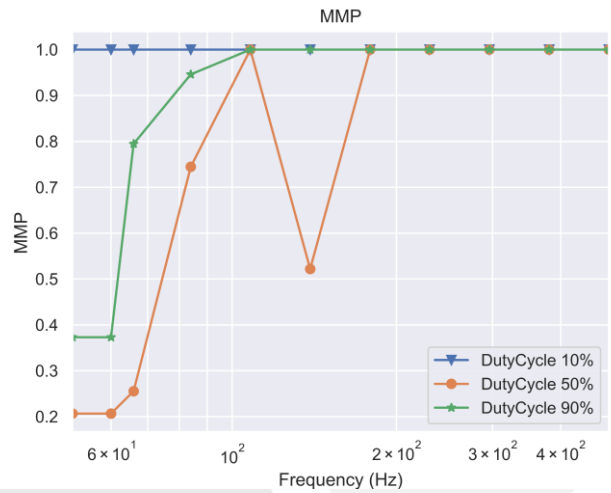
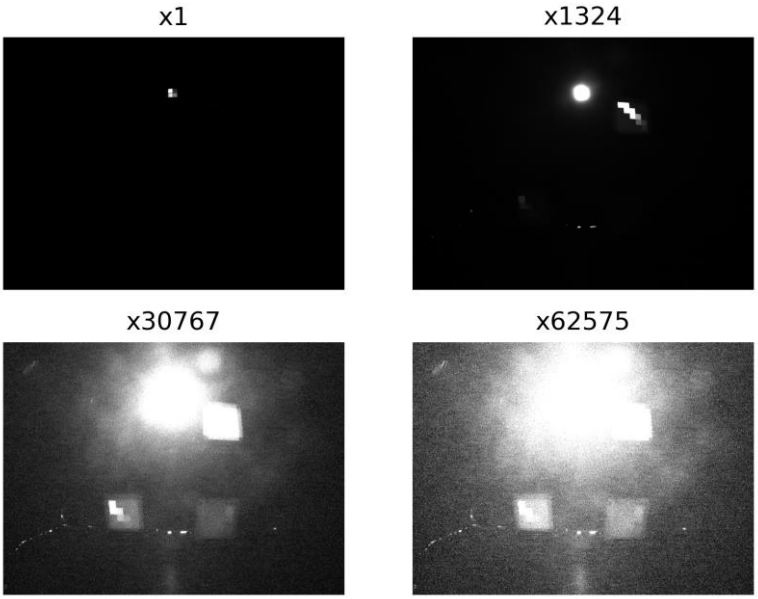
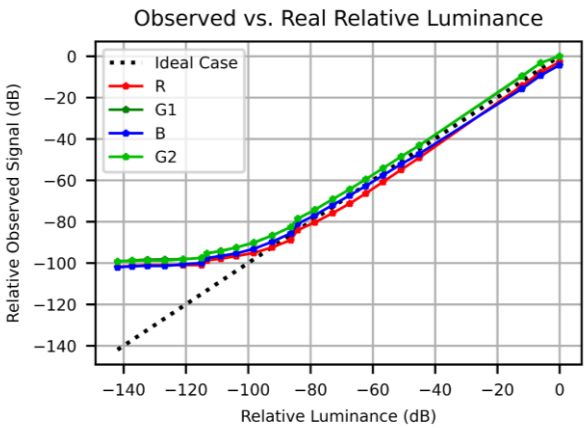
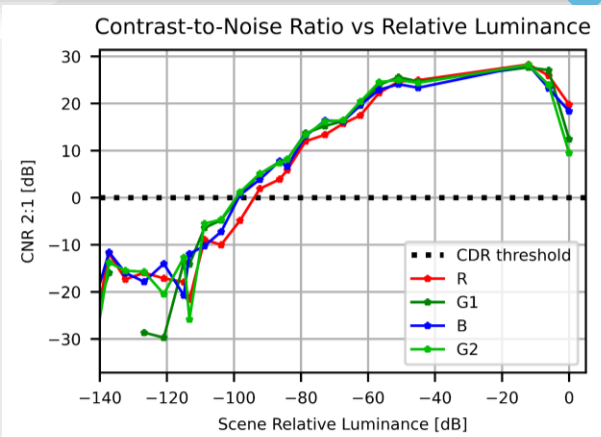


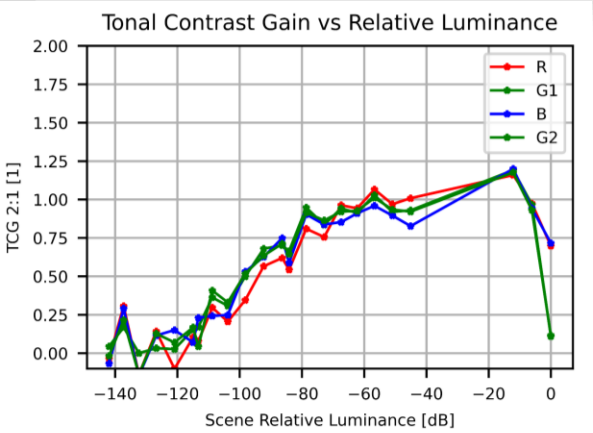
Image preview with different amplification factors



150dB setup with maximum scene luminance 37000 cd/m²







	R	G1	B	G2
CDR (dB)	94 dB	99 dB	99 dB	100 dB

The P2020 dynamic range (CDR) value is only 10dB lower than the sensor level dynamic range, which means that the lens is well fitted to the sensor.

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