DXOMARK AUTOMOTIVE/ROBOTICS EVALUATION REPORT

--Sample report--

Robotics/Stereovision camera – Standard report

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P2020 Dynamic Range

Standard compliance

The Dynamic Range measurement is fully compliant with IEEE P2020.

Metric details

The dynamic range measurement is performed on pairs of patches (A, B), with a 2:1 contrast ratio between A and B in the scene

Adjusted CNR (Contrast to Noise Ratio):

$$\mathrm{CNR}(A,B) = \frac{s_A - s_B}{\sqrt{\sigma_A^2 + \sigma_B{}^2}} \cdot \frac{c+1}{c-1} \cdot \frac{1}{\sqrt{2}}$$

With:

- s_A, s_B the mean signal of A and B
- σ_A, σ_B the standard deviation of A and B
- c the contrast between A and B in the scene

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

$$\mathrm{TCG}(A,B) = \frac{\log_2\left(L_{A,image}/L_{B,image}\right)}{\log_2\left(L_{A,scene}/L_{B,scene}\right)}$$

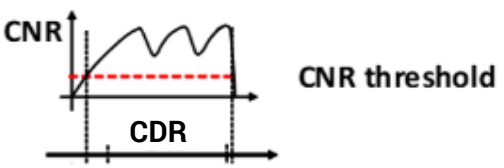
With:

- $L_{A,image}$, $L_{B,image}$ the mean signal of A and B in the image.
- $L_{A,scene}$, $L_{B,scene}$ the luminance of A and B in the scene.

CDR (Contrast Detection Ratio) is the dynamic range measured from CNR:

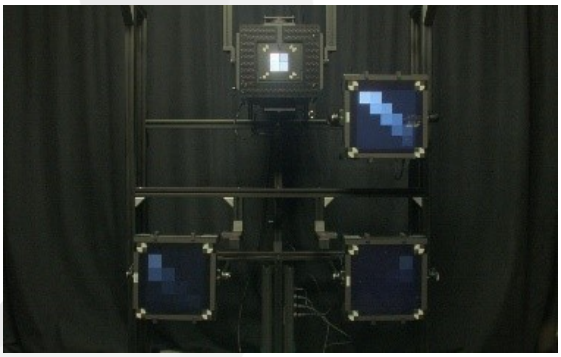
$$\mathrm{CDR}_{dB} = 20\log_{10}\left(\frac{L_{max}[\mathrm{CNR}>1]}{L_{min}[\mathrm{CNR}>1]}\right)$$

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



Measurement setup specifications

The dynamic range setup is an assembly of 4 light panels and charts, delivering 25 patches that can reach 170dB dynamic.



SFR

Standard compliance

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

Metric details

SFR is computed in a linearized image

Metrics are computed in 15 different field positions.

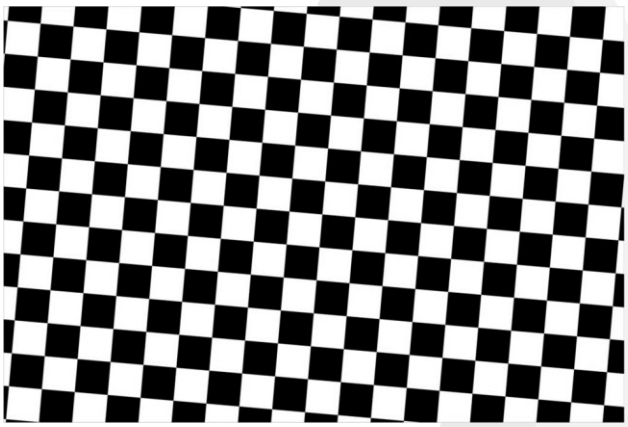
SFR measurement compensates the target printer MTF. The target MTF is measured compared to a true cutter target, and it is then taken into account during the camera MTF measurement

- **MTF** curve with frequency in cycles/pixels
- **MTF10** and **MTF50**: (raw images only) frequency (in cycles/pixel) corresponding to MTF=10% and 50%
- **MTF@Nyq/2** and **MTF@Nyq/16**: (raw images only) MTF value at frequency = 1/2 and 1/16 of Nyquist frequency

Measurement setup specifications

High contrast checkerboard chart

Through focus method is used to find the best focus.



P2020 Flicker Mitigation

Standard compliance

The flicker mitigation measurement is fully compliant with IEEE P2020.

Metric details

Flicker Modulation Index (FMI):

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

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

Flicker Detection Index (FDI):

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

Where:

- P[x] is the probability of x.
- $s(t)$ 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.

Modulation Mitigation Probability (MMP):

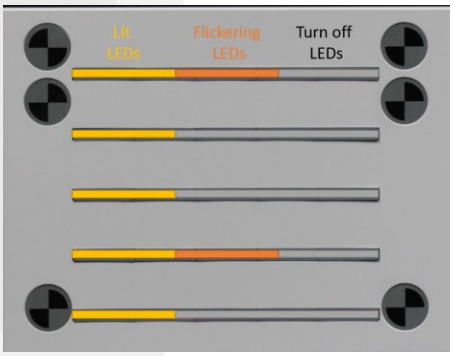
$$MMP = P\left[\overline{s_{ref}}(1-\delta) < s(t) < \overline{s_{ref}}(1+\delta)\right]$$

Where:

- P[x] is the probability of x.
- $s(t)$ 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

Flicker 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.



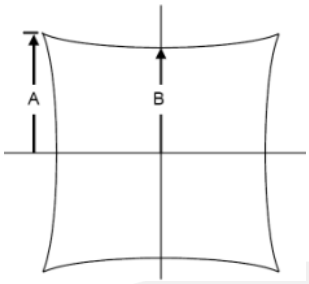
Distortion and lateral chromatic aberration

Standard compliance

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

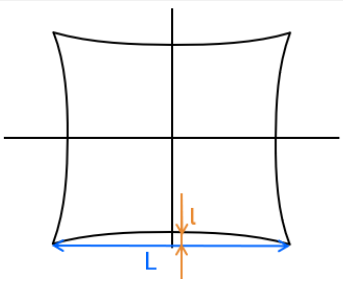
Metric details

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

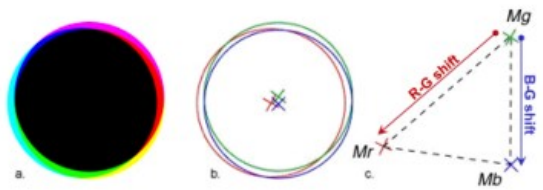


Distortion model reprojection error in pixels and ‰ of of image width, showing the precision of the distortion model.

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



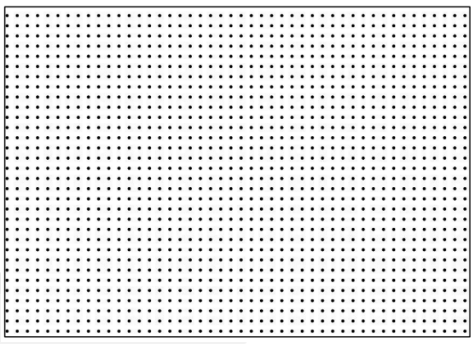
Chromatic aberrations: shift between R and G, and between B and G



Definition of chromatic aberration profiles

Measurement setup specifications

Glass-supported dot chart, offering a very flat surface: less than 1mm planarity difference between the center and the corners of the chart.



Field of View

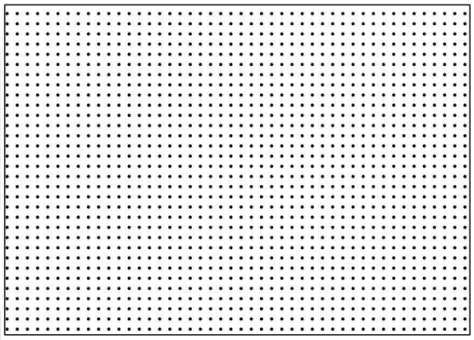
Metric details

Field of view

- The **field of view map** shows the angle between each detected dot, and the center dot of the image
- The **field of view profiles** show the value of the field of view occupied by a disk centered on the image center and whose radius is a varying proportion of the image size in the three directions.
- **Horizontal, Vertical and Diagonal field of view** values, extrapolated to 100% of image size

Measurement setup specifications

Glass-supported dot chart, offering a very flat surface: less than 1mm planarity difference between the center and the corners of the chart.



Vignetting and Color Lens Shading

Standard compliance

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

Metric details

Vignetting:
- **Vignetting Profile:** gray level value divided by the gray level value at the vignetting center, for each radial field position and each color channel.
- **Max attenuation:** $\max(1 - \text{VignettingProfile}) \times 100$
- **Max amplification:** $\max(\text{VignettingProfile} - 1) \times 100$

Color Vignetting:
- **Color Vignetting Profile:** each channel vignetting divided by green (average of G1 and G2 channels for raw images).
- **Max Attenuation:** $\max(1 - \text{ColorVignettingProfile}) \times 100$
- **Max Amplification:** $\max(\text{ColorVignettingProfile} - 1) \times 100$
- **Green Imbalance** (raw images only): maps of the relative difference between G1 and G2 channels.

Measurement setup specifications

Litepanels Gemini LED panel or Integrating sphere RO-LIS-3CR80

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

Center acutance	0.72
Corner acutance	0.62
Max vignetting attenuation	26%
TV distortion	-47%
Chromatic aberrations	< 1 pixel

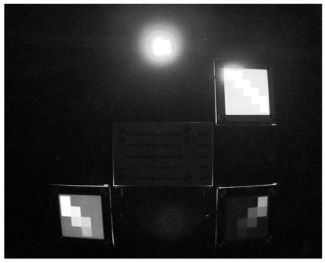
DR P2020	120 dB

Image preview with different amplification factors

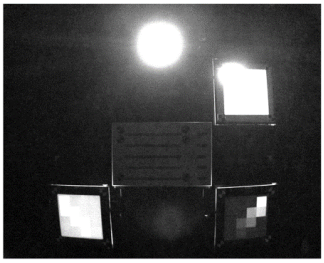
Clipped at 6.4e+04 cd/m^2

Clipped at 6.6e+02 cd/m^2

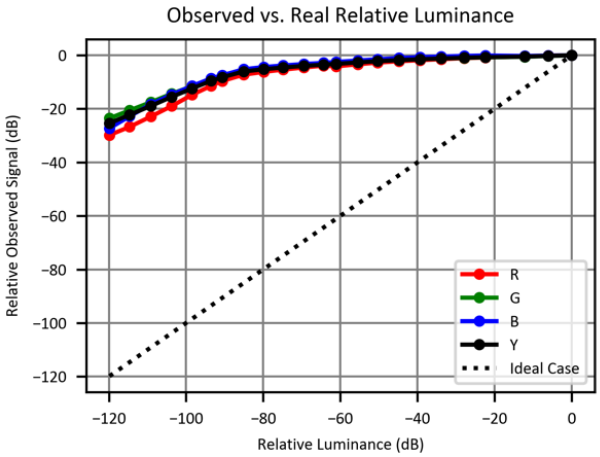
Clipped at 2.1e+01 cd/m^2

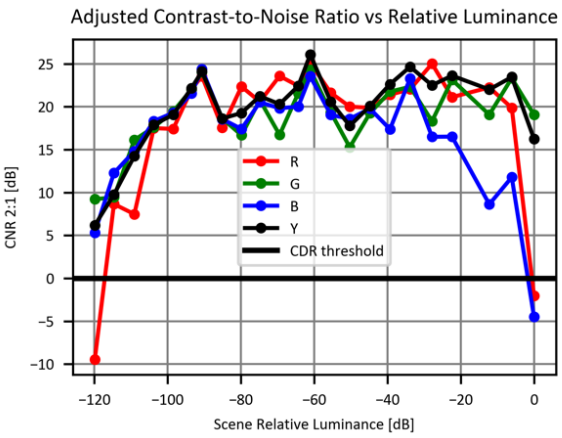


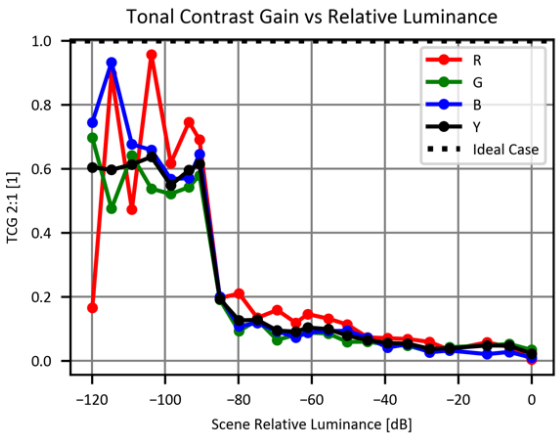
Clipped at 1.0e+00 cd/m^2



123dB setup with maximum scene luminance 64000 cd/m²

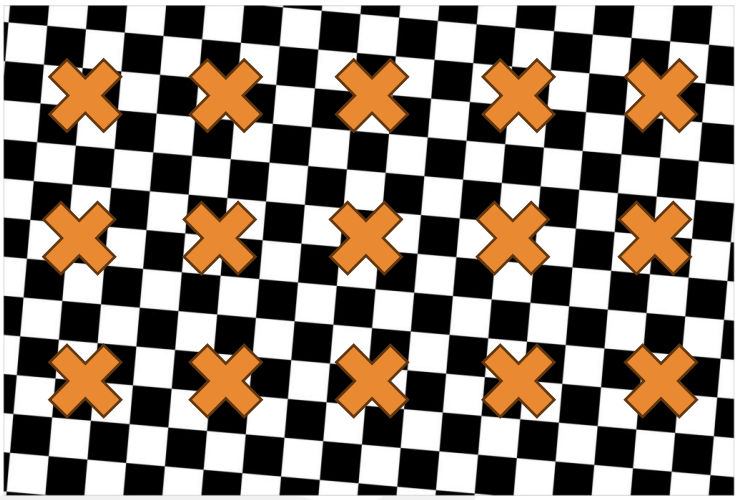




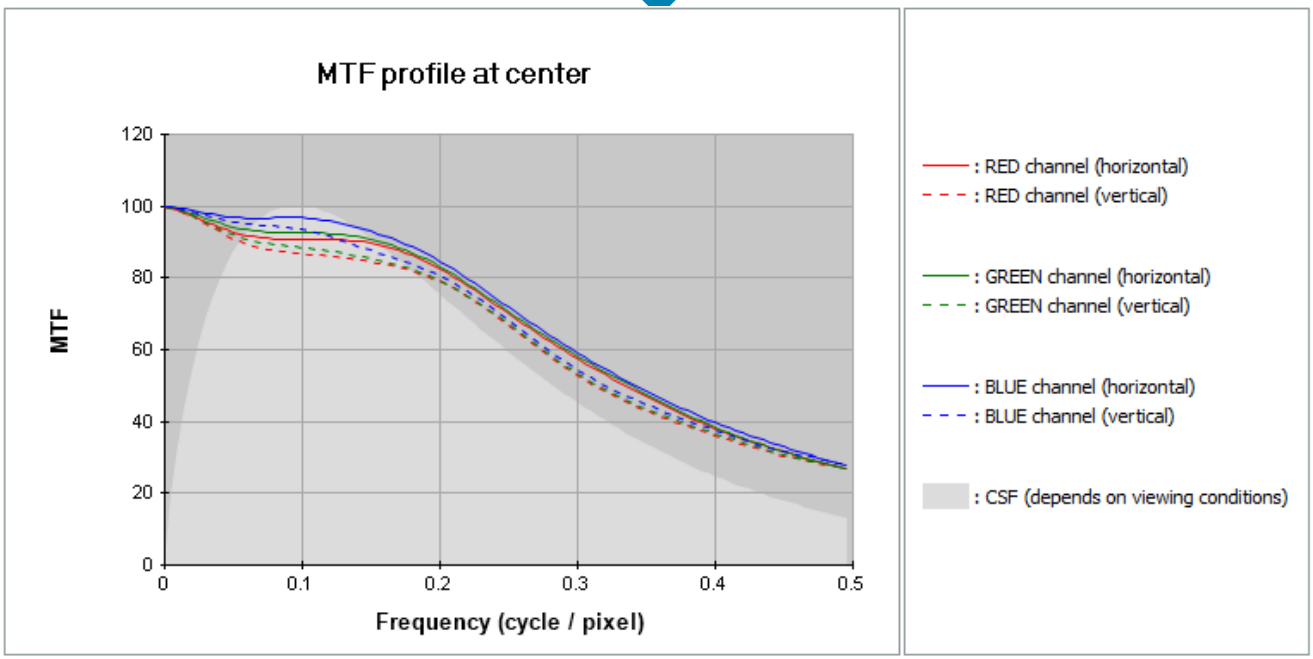


	R	G1	B	G2
CDR (dB)	117 dB	120 dB	118 dB	120 dB

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

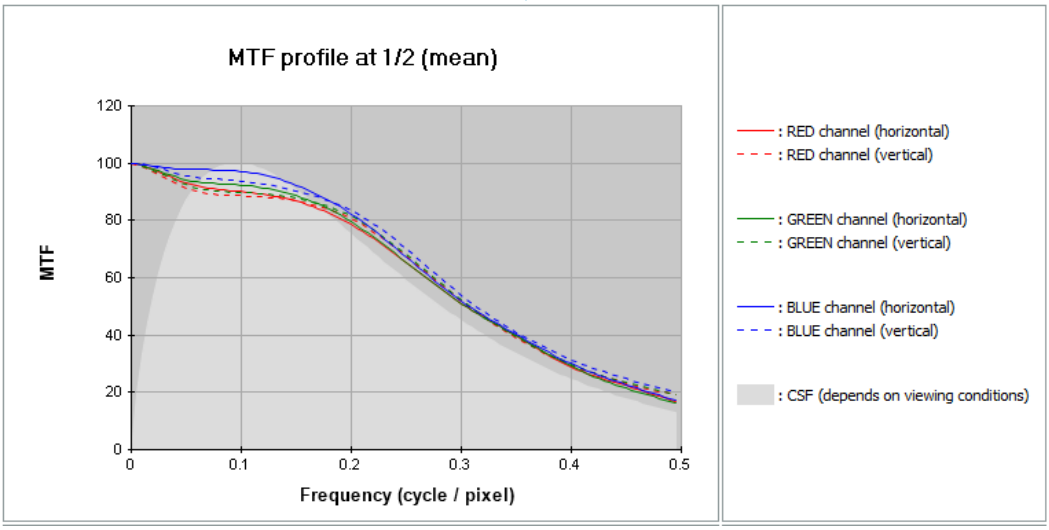


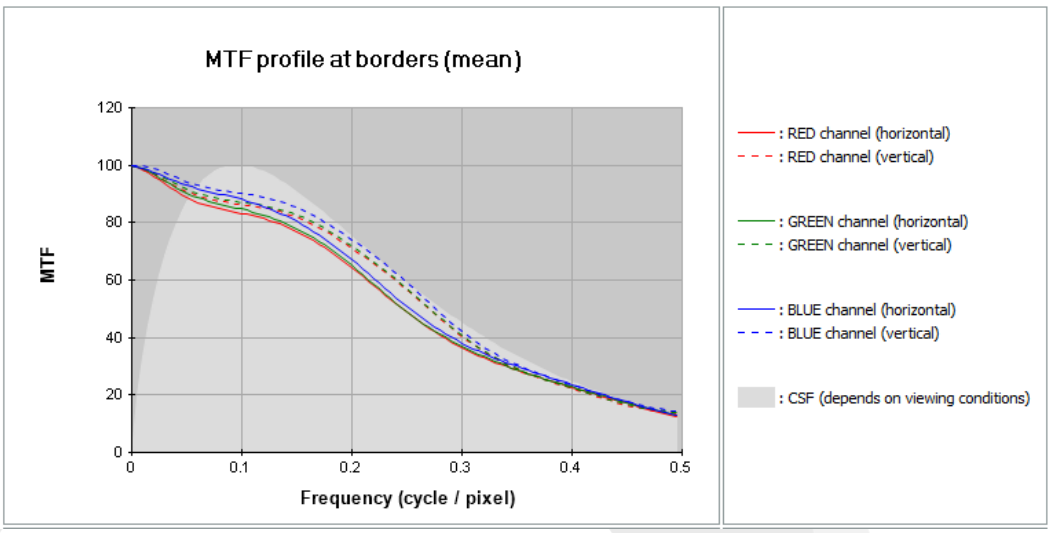
- **Measurement conditions:**
  - Illumination: D65 1000lux
  - Through focus to find the position with best sharpness in the center:
    - DUT to chart distance: 2m
  - Viewing condition for acutance computation:
    - Distance: 600mm
    - Pixel pitch: 0.254mm

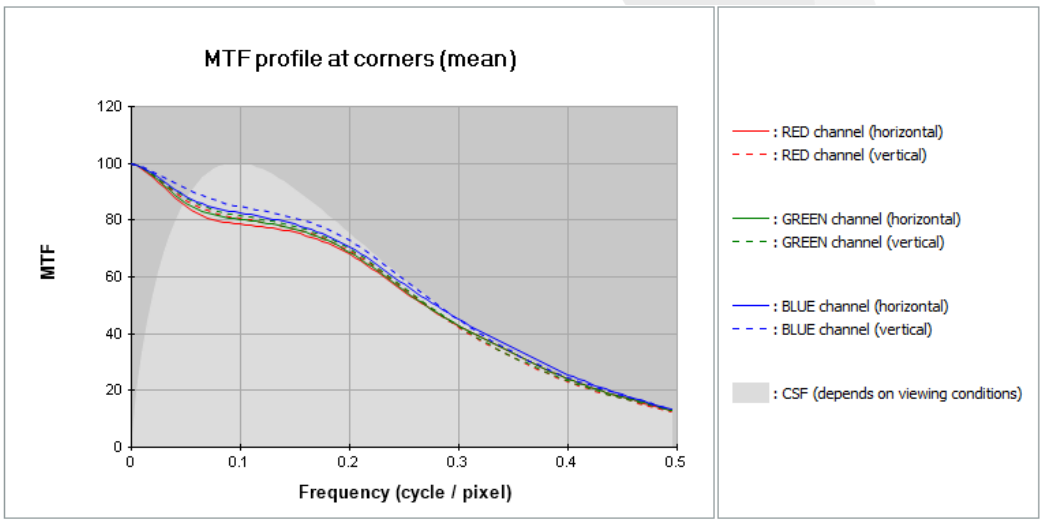


	Center			All corners (mean)		
	R	G	B	R	G	B
Acutance	0.71	0.72	0.74	0.61	0.62	0.64

Conversion factor between cycles/pixels and cycles/degrees	
Pixel/Degree	41.89


MTF profile at 1/2 (mean)
MTF
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
Frequency (cycle / pixel)
: RED channel (horizontal)
: RED channel (vertical)
: GREEN channel (horizontal)
: GREEN channel (vertical)
: BLUE channel (horizontal)
: BLUE channel (vertical)
: CSF (depends on viewing conditions)


MTF profile at borders (mean)
MTF
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
Frequency (cycle / pixel)
: RED channel (horizontal)
: RED channel (vertical)
: GREEN channel (horizontal)
: GREEN channel (vertical)
: BLUE channel (horizontal)
: BLUE channel (vertical)
: CSF (depends on viewing conditions)


MTF profile at corners (mean)
MTF
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
Frequency (cycle / pixel)
: RED channel (horizontal)
: RED channel (vertical)
: GREEN channel (horizontal)
: GREEN channel (vertical)
: BLUE channel (horizontal)
: BLUE channel (vertical)
: CSF (depends on viewing conditions)

- **Measurement conditions:**
  - 10 LED PWM frequencies in Hz: 50, 51, 60, 66, 84, 108, 139, 179, 230, 296, 381, 490
  - 1 LED PWM duty cycle: 50%
  - test conditions:
    - Background at 10000 lux, LED light intensity at 3000 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

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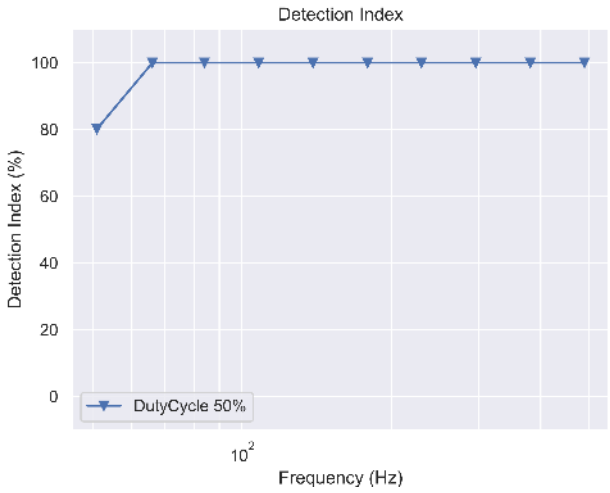
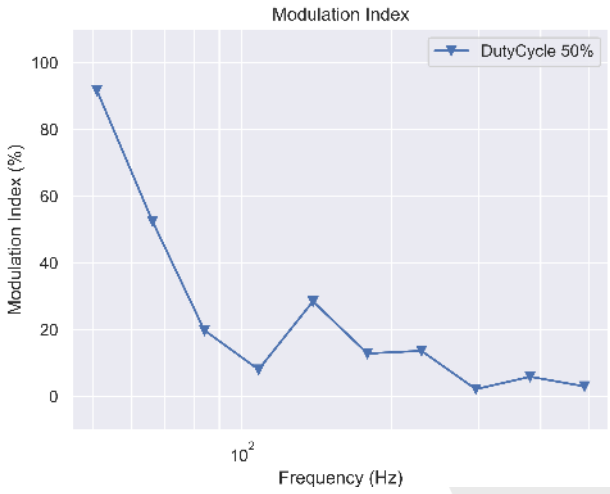
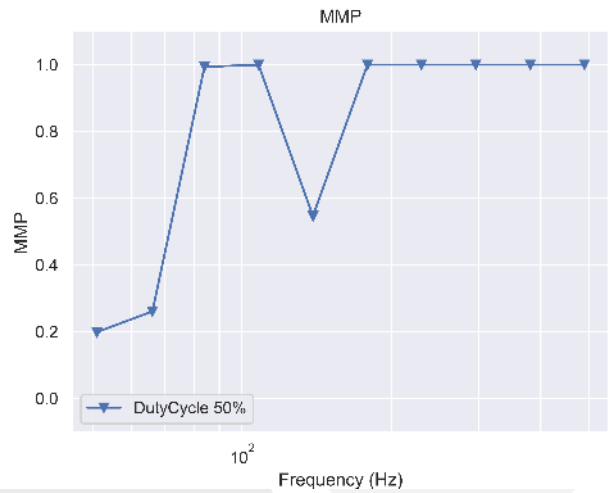
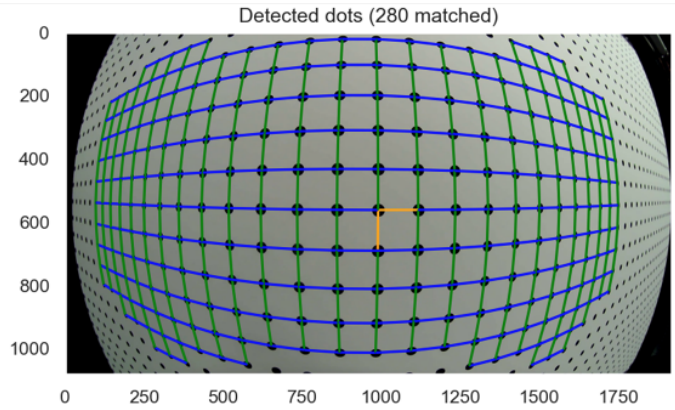
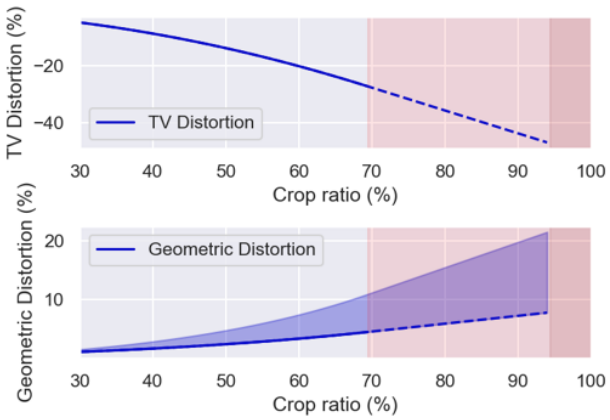
Background at 10000 lux, LED light at 3000 cd/m²

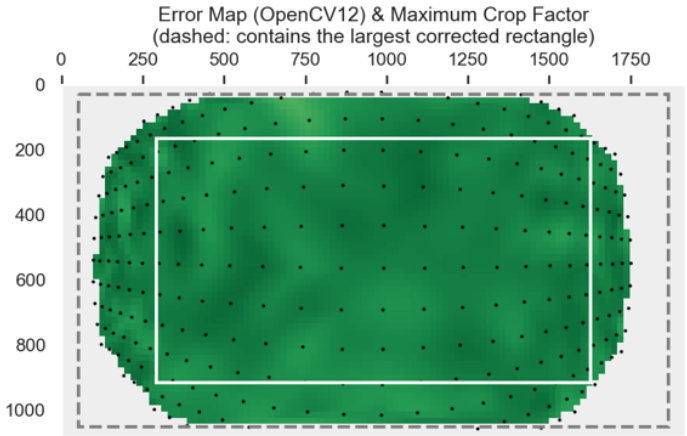


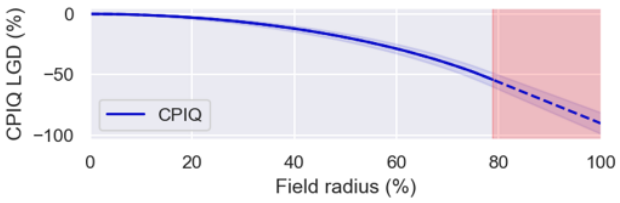


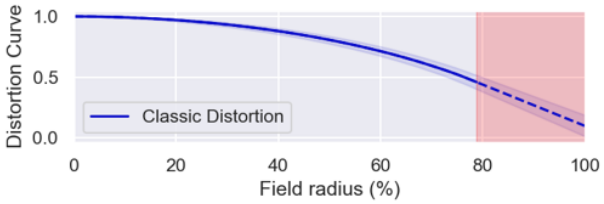


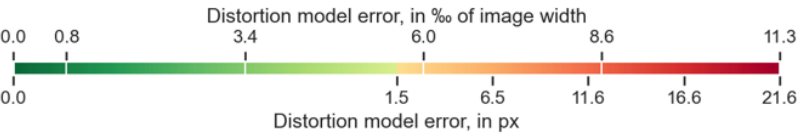






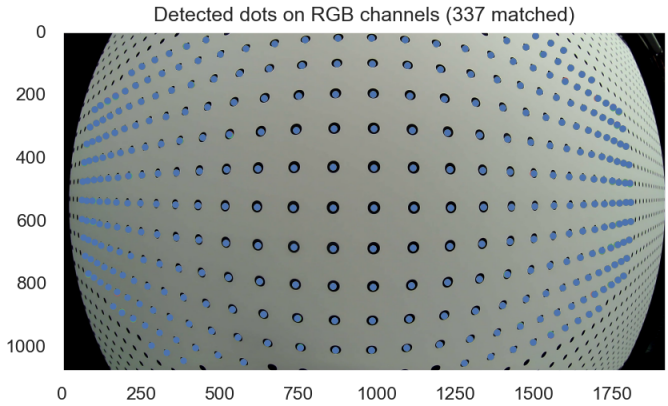


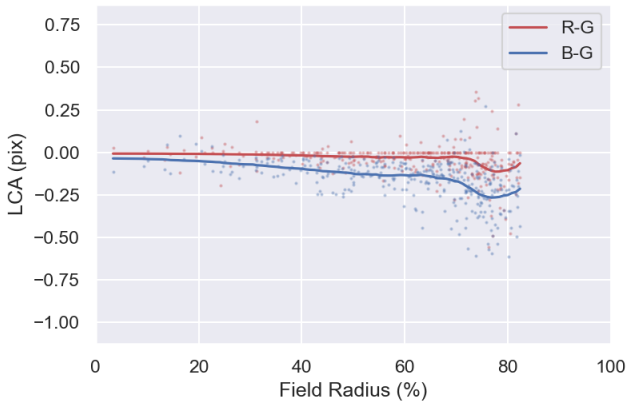


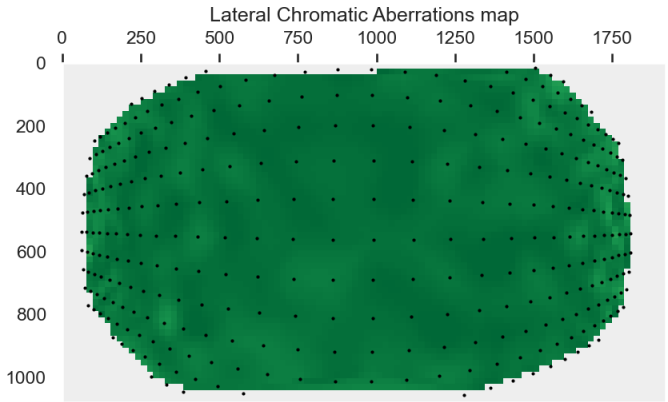


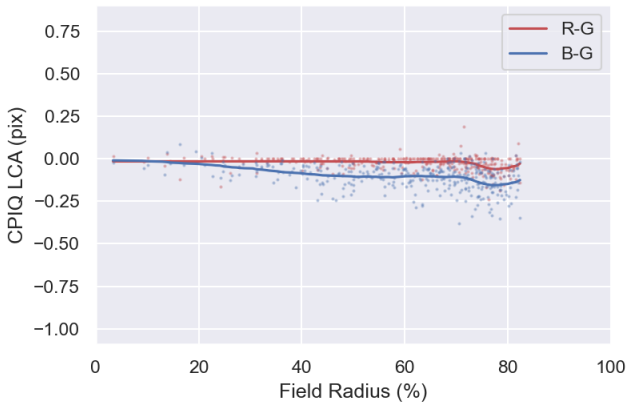
	Results	Results (non extrapolated)
TV Distortion	-46.83%	-27.27%
Geometric Distortion (avg)	+7.81%	+4.55%
Geometric Distortion (Max)	+21.48%	+11.00%

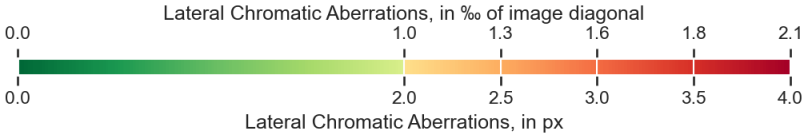
Good fitting of the distortion model (small reprojection error)





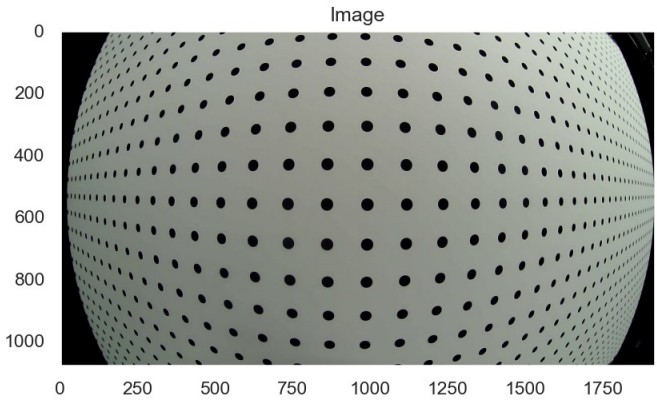


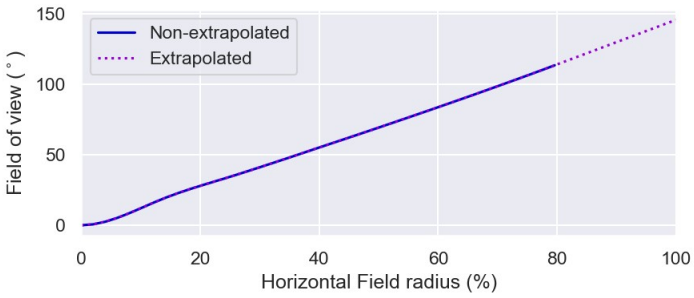


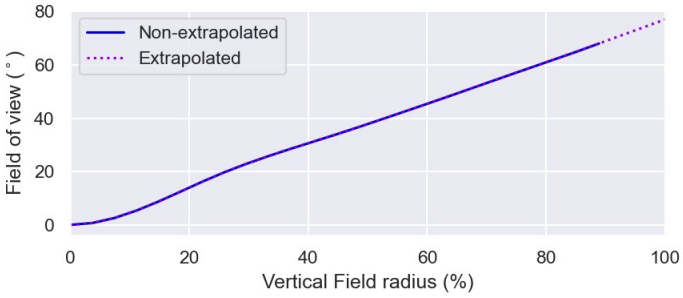


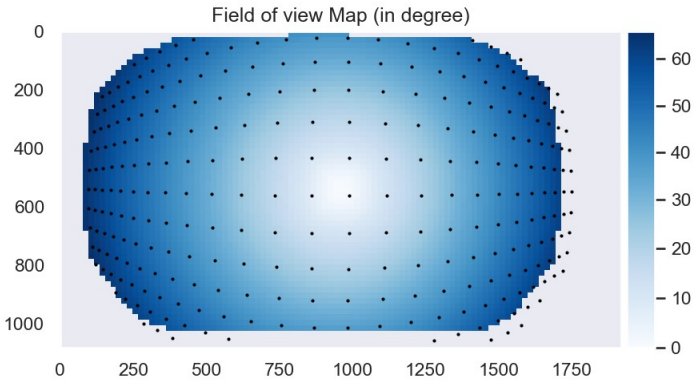
CPIQ Max LCA (Pixels)	-0.15 px
CPIQ Max LCA (Percent)	-0.01 %
CPIQ Max LCA (JND)	0.00

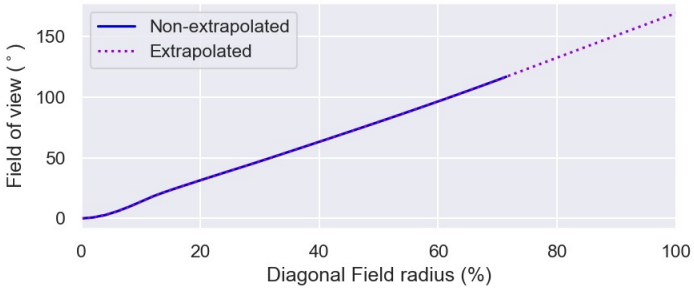
Chromatic Aberrations are negligible (less than 1 pixel in the full measurement area)







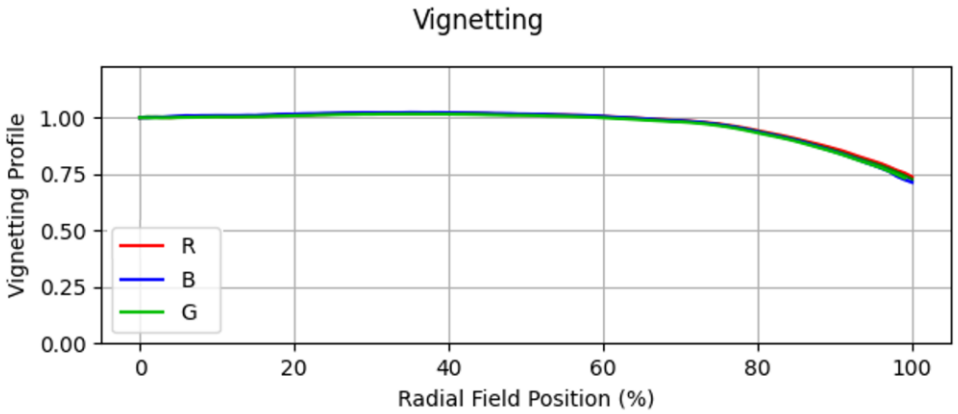




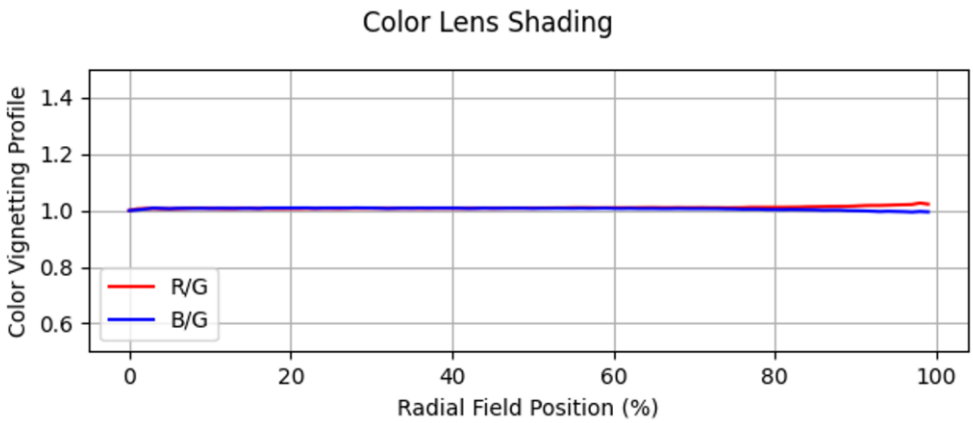
	H. FoV	V. FoV	D. FoV
Non-extrapolated	113.41 °	67.98 °	116.96 °
Extrapolated	145.64 °	77.01 °	169.55 °
	Tilt	Pan	
Orthofrontality	2.5 °	0.68 °	

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

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



	R	G	B
Max Attenuation	24.5 %	25.6 %	27.5 %
Max Amplification	2.0 %	2.0 %	2.3 %



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

Vignetting Measurement done with illuminant D50
Results: Good vignetting and color lens shading performance

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