New generation of optics for imaging colorimeters

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Agenda

1. Main issues for imaging colorimetry
2. Normal incidence measurements => TTO optics
3. High resolution & large field => Scope optics
4. More than luminance & color

General issues for accurate imaging colorimetry

Requirements for an ideal imaging optics

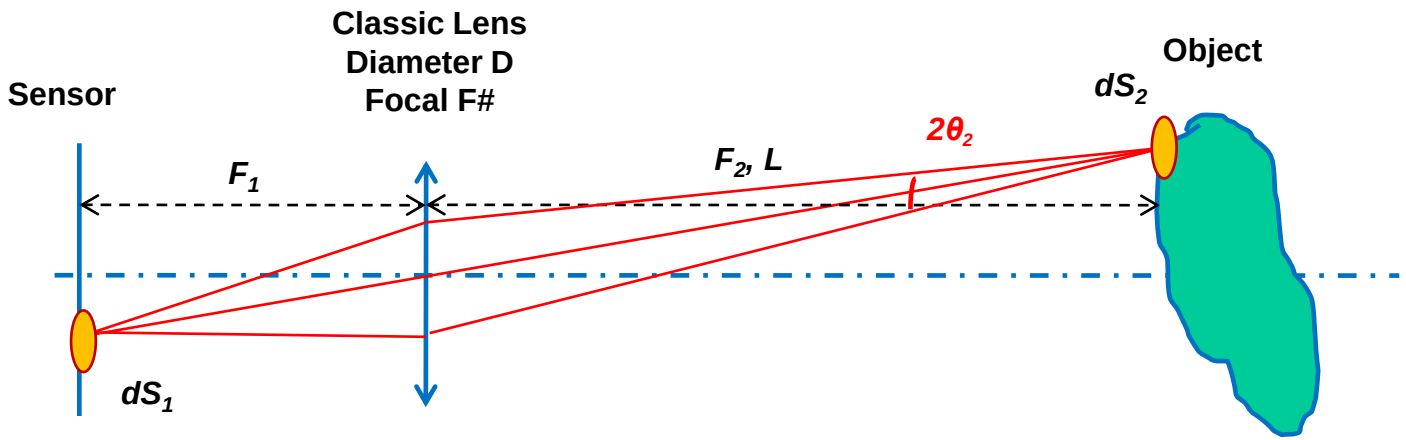
1. Resolution limited by the sensor only
2. Light collection efficiency independent of the distance
3. No distortion
4. No vignetting
5. Same incidence when crossing filters

In practice

1. Not always true especially for high resolution optics
2. Not true: calibration provided at different distances
3. Generally some residual one (problem for image analysis)
4. Present in most of the cases (calibration more complex)
5. No : partially corrected by calibration but loss of accuracy

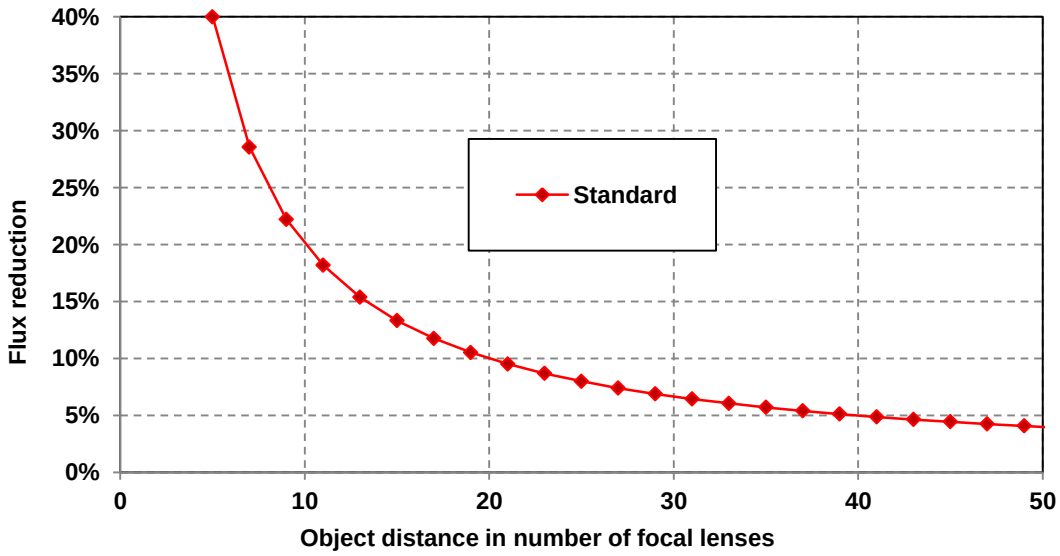
General issues for accurate imaging colorimetry

Standard imaging objective



Flux collected by one element surface of detector

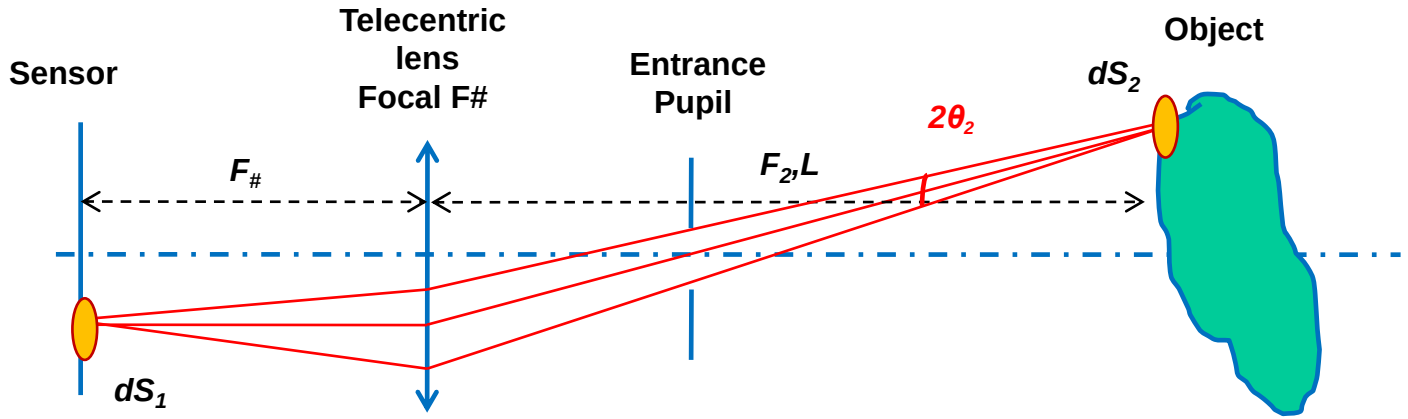
$$d\phi_1 = M_\infty \left(1 - \frac{2F\#}{F_2}\right) dS_1$$



First order dependence with distance

General issues for accurate imaging colorimetry

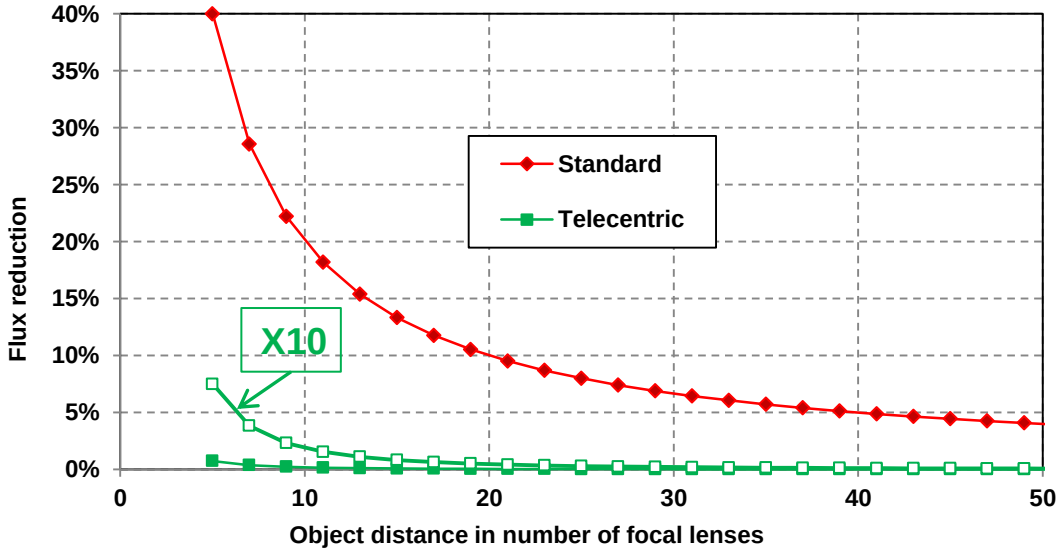
Telecentric imaging objective on sensor side



Flux collected by one element surface of detector

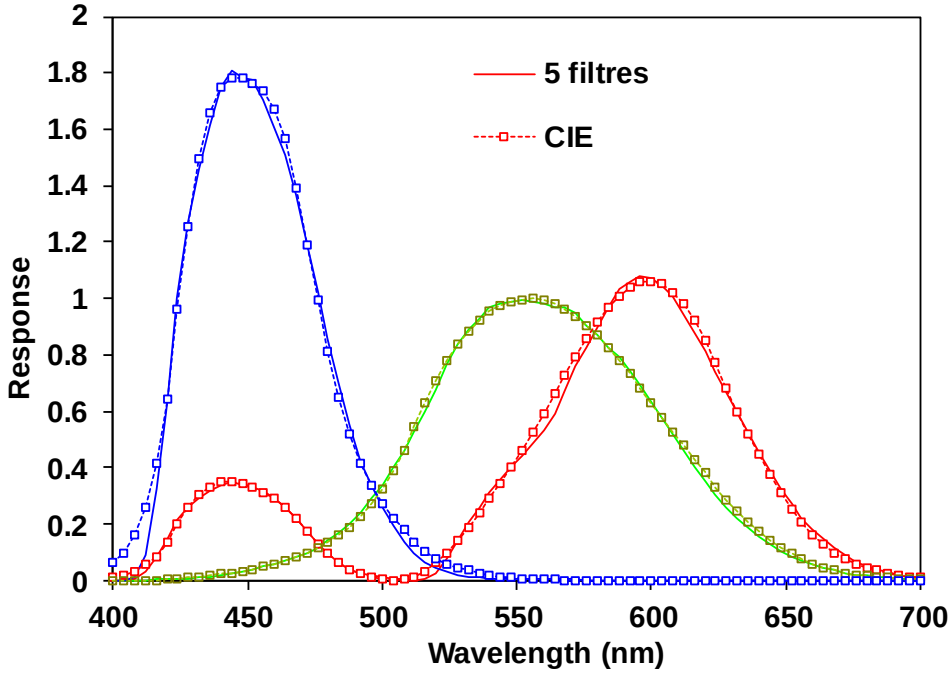
$$d\phi_1 = M_\infty (1 - \frac{3F\#^2}{16F_2^{\ 2}}) dS_1$$

First order dependence with distance



Flux reduction versus working distance

General issues for accurate imaging colorimetry



UMaster uses five color filters matched to the CIE curves:

- Five CCD acquisitions for one color measurement (~20s)
- No need of specific calibration for any target
- Excellent accuracy and optimized exposure

Normal incidence measurements: TTO optics

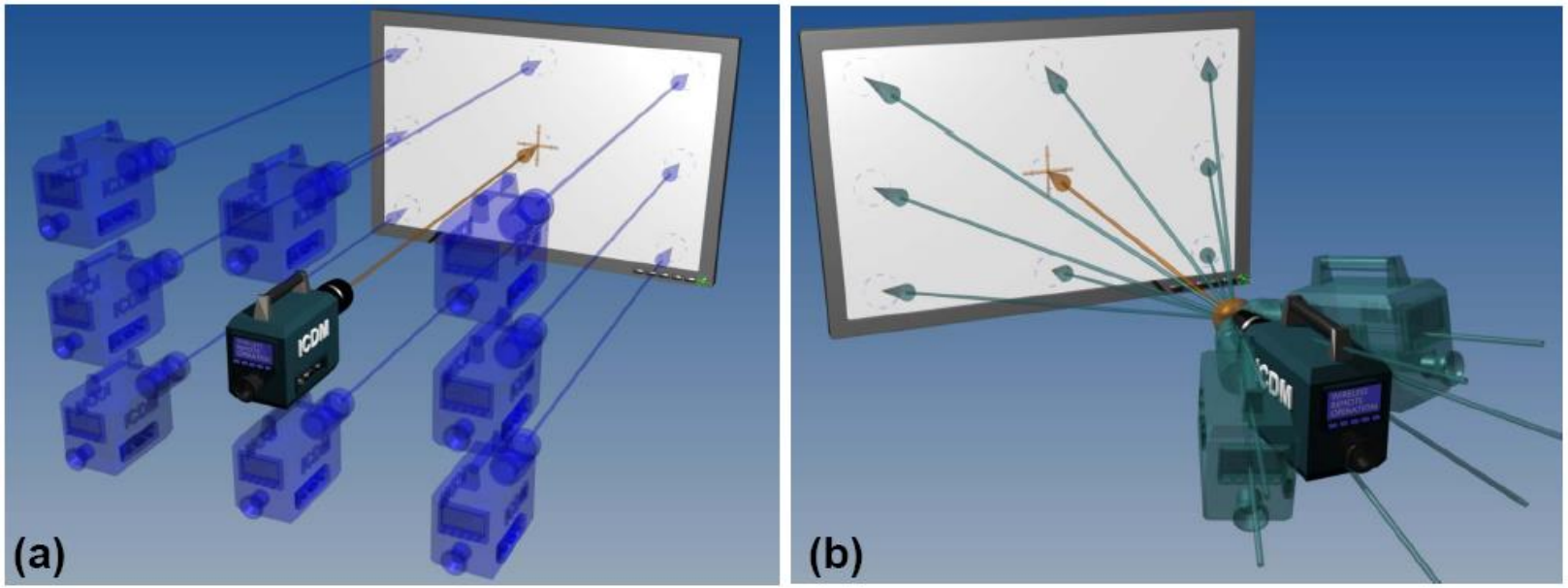
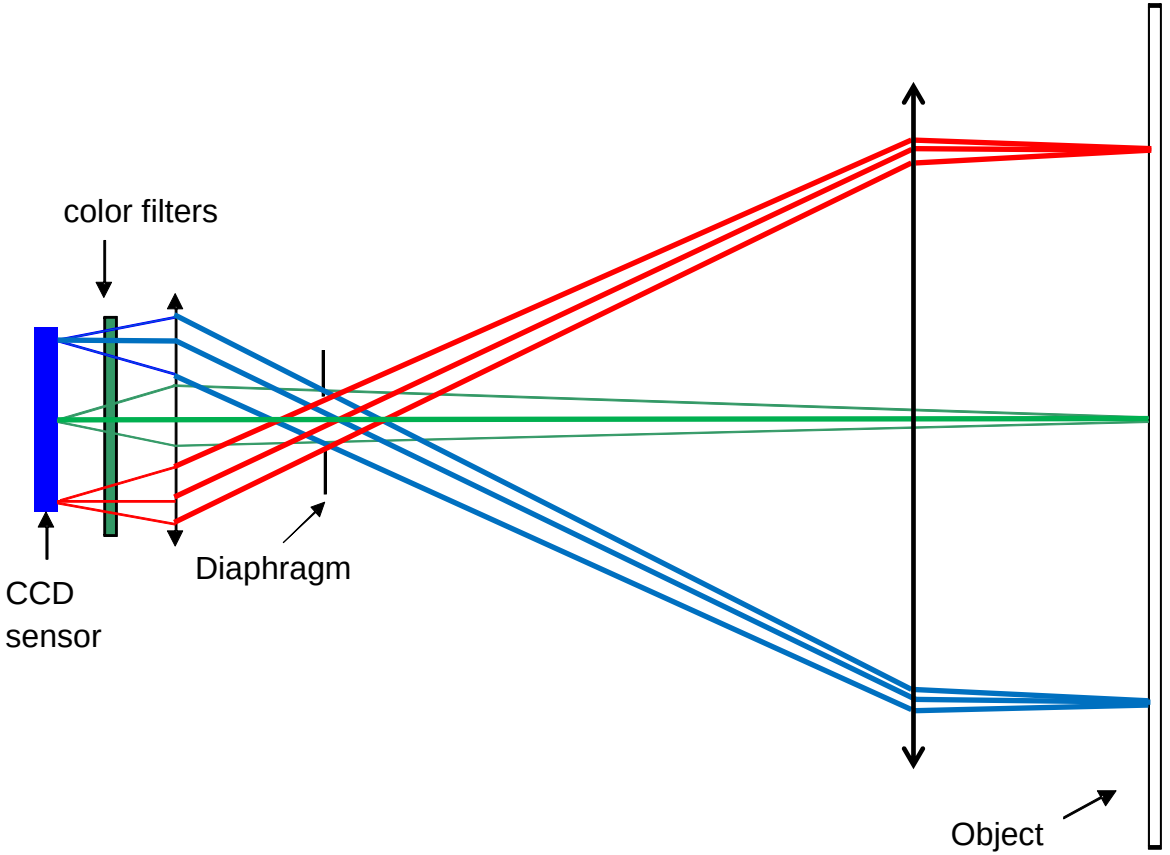


Illustration of two different configurations for samples uniformity measurements in nine locations:
(a) all measurement taken normal to the screen (an infinity observer)
(b) all measurements taken through the vantage point

Information Display Measurements Standard (IDMS) chapter 8 , p. 136, V1.03, 2012

Normal incidence measurements: TTO optics



Optical layout of the double telecentric TTO objectives:

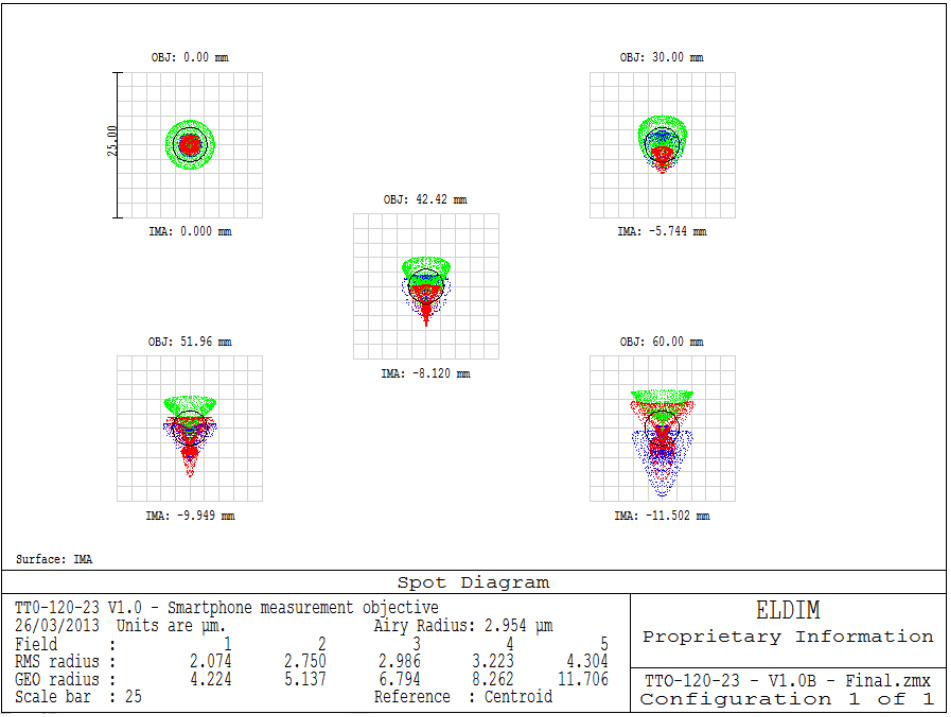
- **Same transmittance of filters in all the field of view**
- **Same light collection conditions for all the field of view**

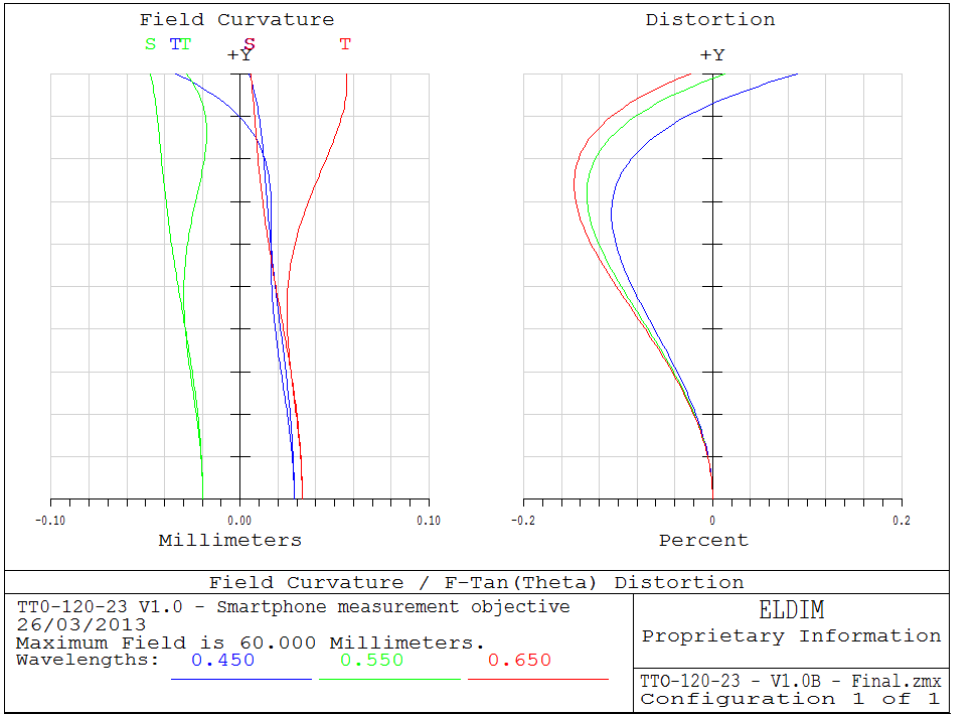
Normal incidence measurements: TTO optics

ELDIM proposes now a series of **double telecentric objectives** with various sizes that allow near normal incidence analysis of **small & medium displays with unprecedented accuracy**. Luminance, color, polarization and radiance can be measured with the new generation of **UMaster** instruments and this new family of optics.

Imaging objective	Working distance (mm)	Magnification	Resolution (µm)	Horizontal size (mm)	Vertical size (mm)	Diagonal (mm)
TTO-110	117	1/5.2	28	94	70	120
TTO-220	200	1/10.4	56	186	140	225

Normal incidence measurements: TTO optics



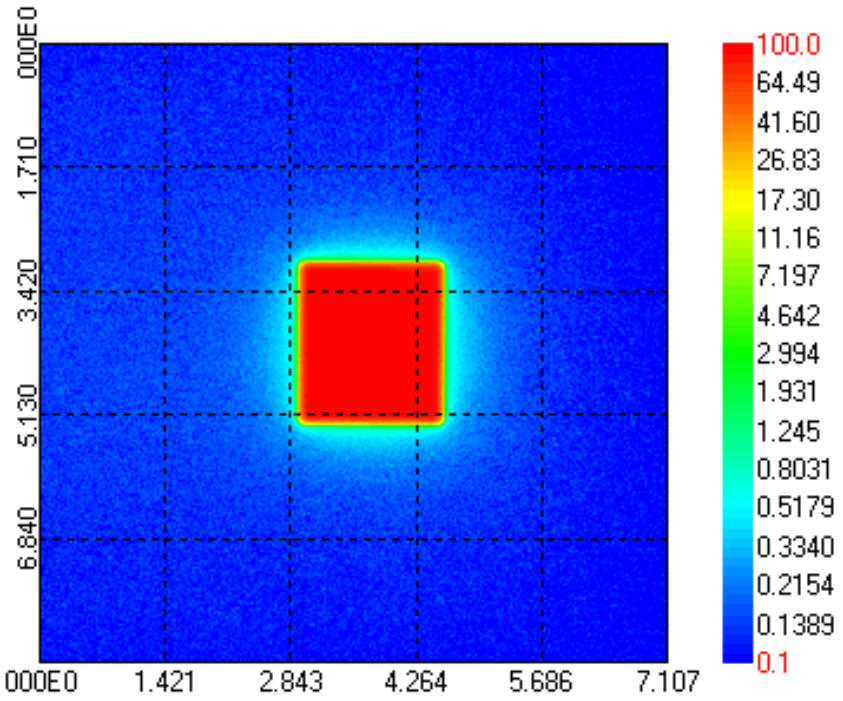


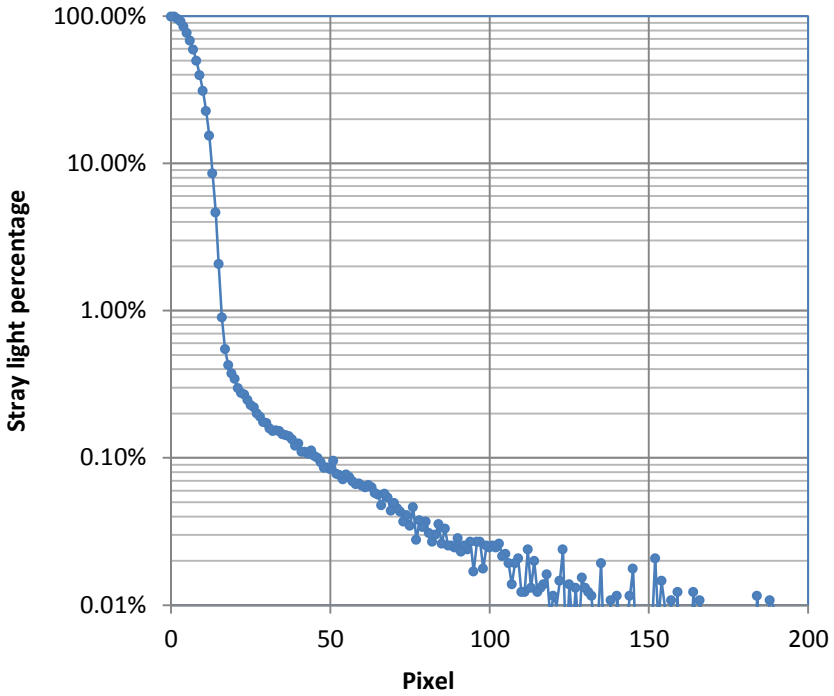
Spot radius at 5 positions in the field of view

Curvature and distortion radius vs field of view (450, 550 and 650nm)

- **Spatial resolution is not limited by the optics**
- **Quasi flat field without distortion**

Normal incidence measurements: TTO optics

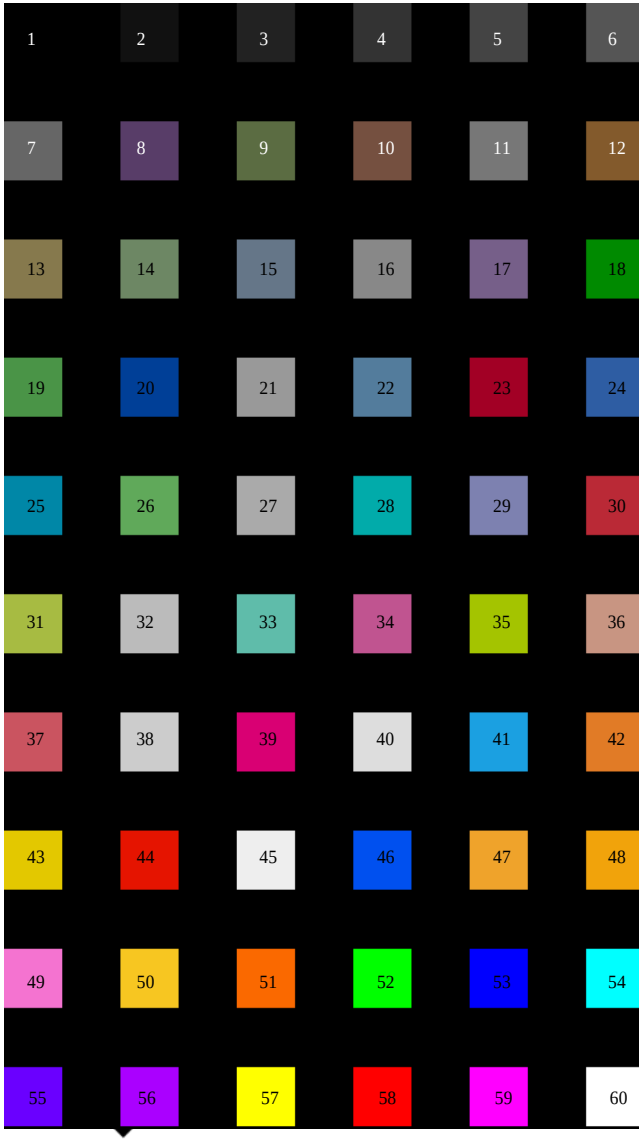




Luminance decrease near the white square for one OLED display (value normalized to the white level)

- **Stray light below 0.5% at 10 pixels of a spot**

Normal incidence measurements: TTO optics



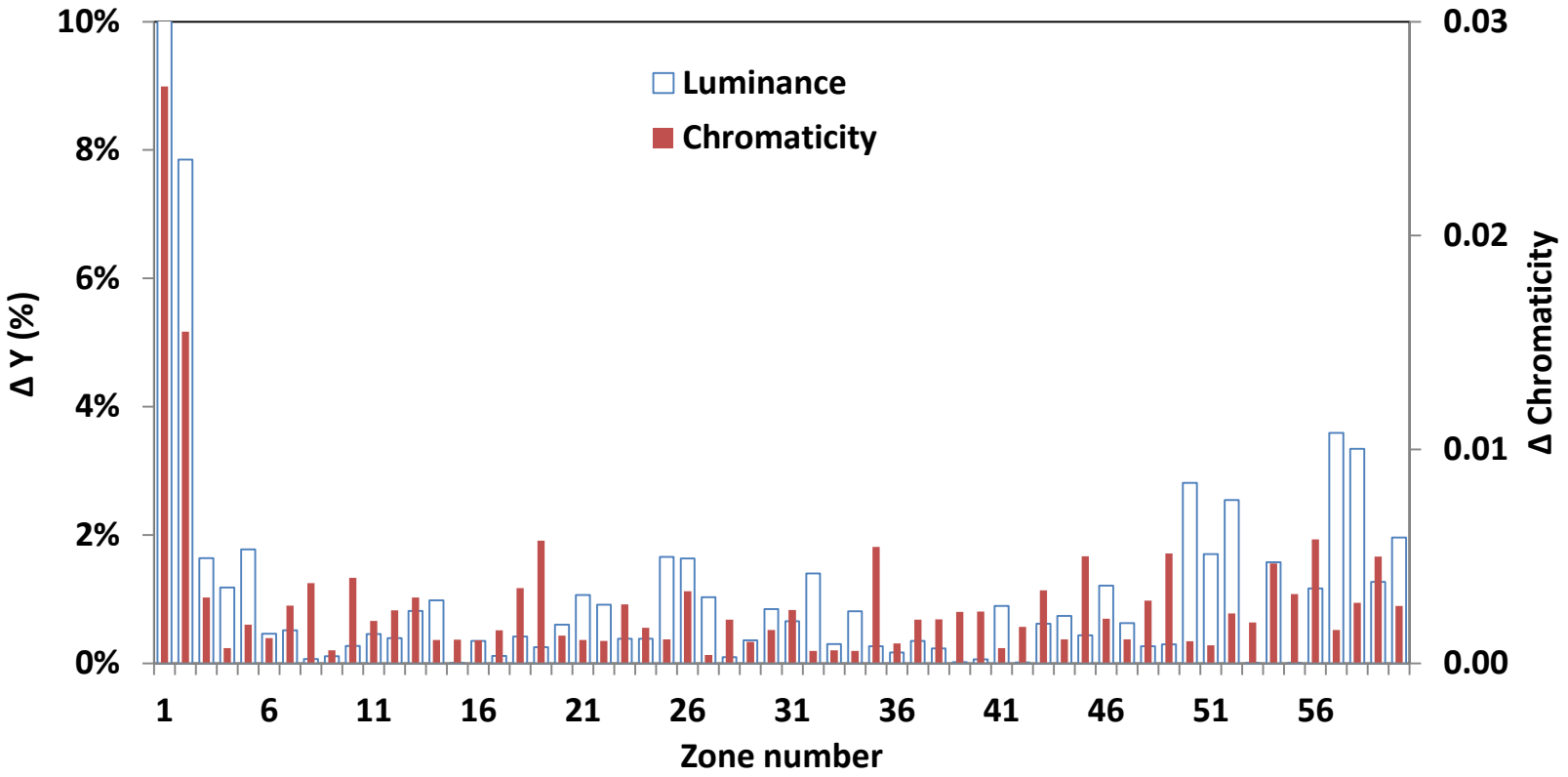
Index		Levels		
New	Color	R	G	B
1		0	0	0
2		17	17	17
3		34	34	34
4		51	51	51
5		68	68	68
6		85	85	85
7		102	102	102
8		88	61	104
9		91	108	66
10		117	80	64
11		119	119	119
12		131	90	44
13		134	121	77
14		109	135	100
15		101	118	136
16		136	136	136
17		118	95	137
18		0	138	0
19		74	148	71
20		0	63	151
21		153	153	153
22		83	124	156
23		162	0	37
24		46	93	163
25		0	135	167
26		96	169	90
27		170	170	170
28		1	171	170
29		125	129	176
30		186	41	54

Index		Levels		
New	Color	R	G	B
31		167	187	66
32		187	187	187
33		95	188	170
34		192	84	144
35		164	196	0
36		200	149	130
37		202	84	96
38		204	204	204
39		217	0	115
40		221	221	221
41		27	160	225
42		225	123	38
43		227	200	0
44		229	20	0
45		238	238	238
46		0	80	239
47		239	163	43
48		241	163	11
49		244	115	208
50		247	198	33
51		250	105	0
52		0	255	0
53		0	0	255
54		0	255	255
55		106	0	255
56		170	0	255
59		255	255	0
57		255	0	0
58		255	0	255
60		255	255	255

Color pattern for color calibration of OLED phone cell displays

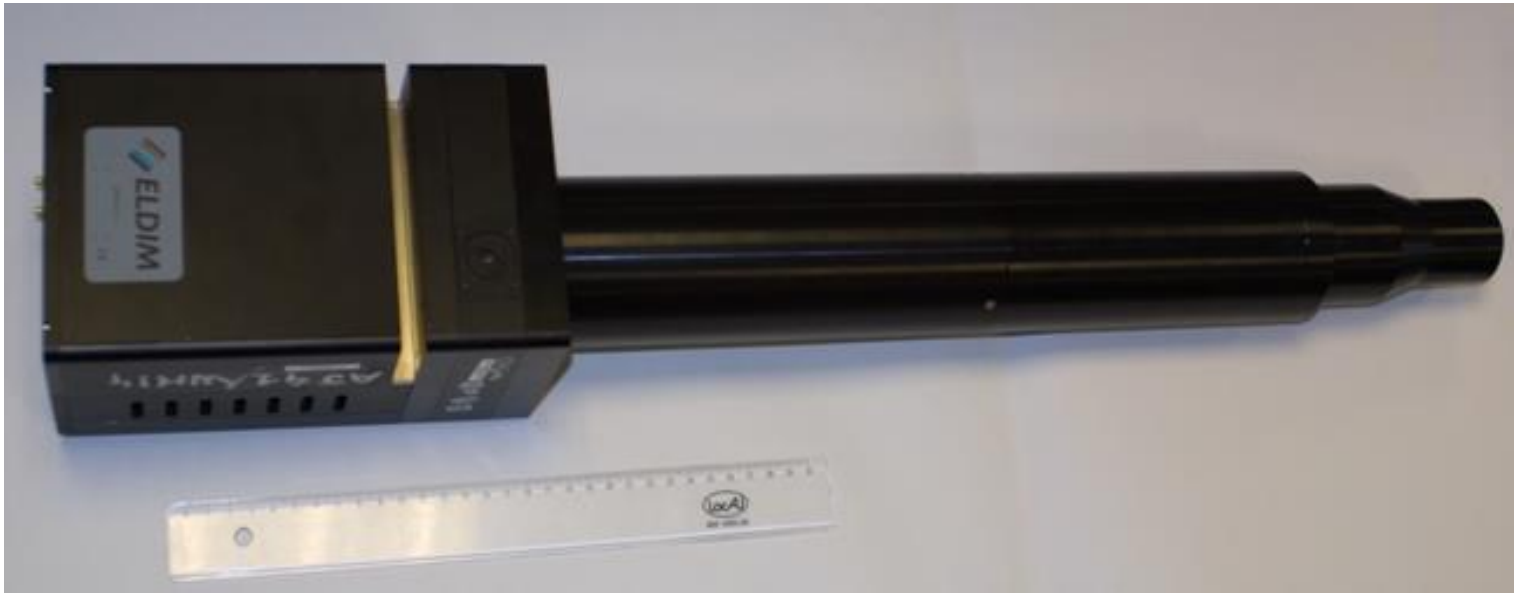
Pattern is optimized to minimize stray light

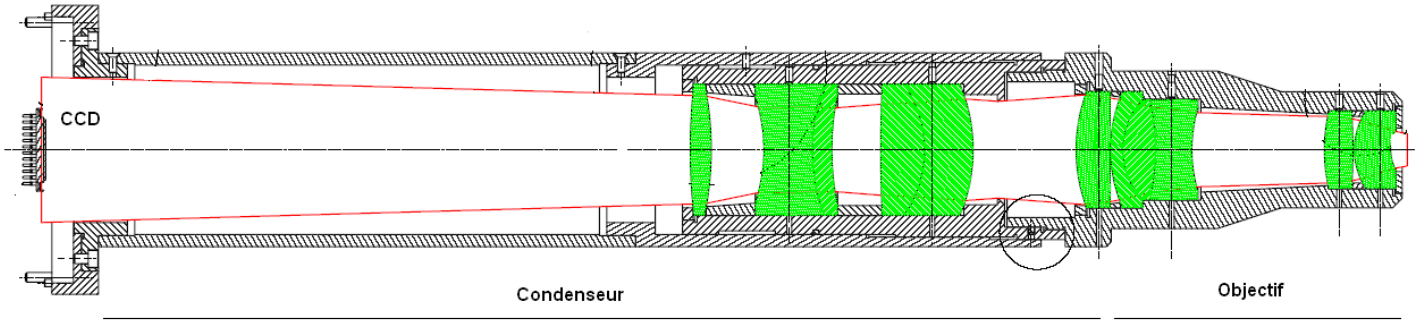
Normal incidence measurements: TTO optics



Luminance and chromaticity deviations for 60 color zones
Reference measurement with a Topcon SR3 spectrophotometer
Measurement are with a color CCD sensor with tristimulus calibration

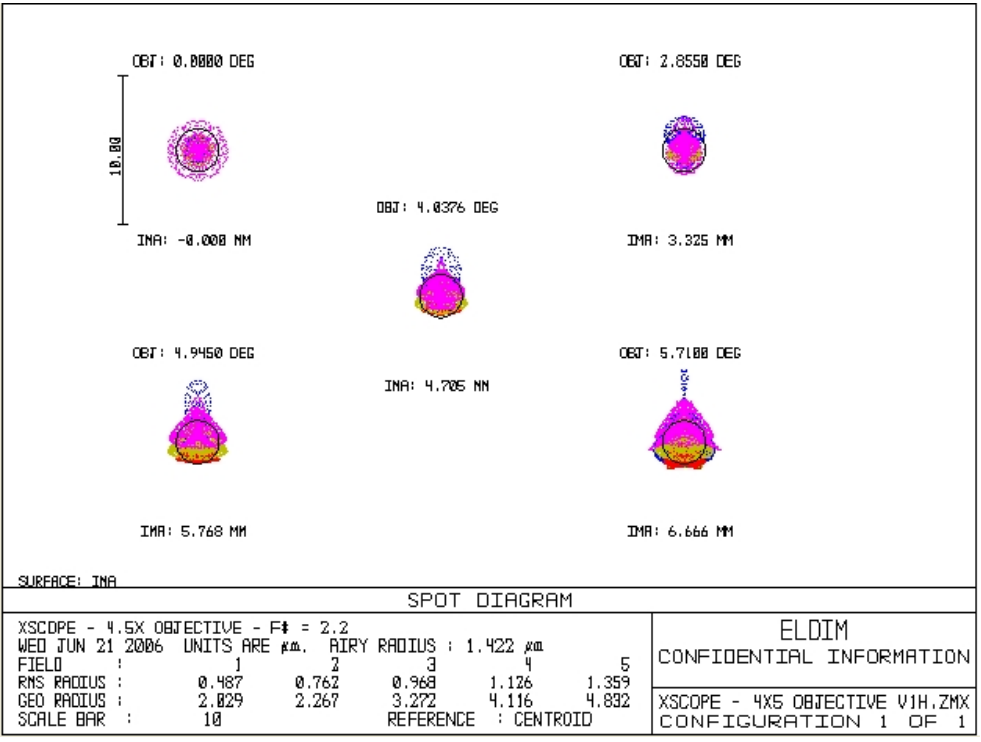
High resolution & large field : XScope optics

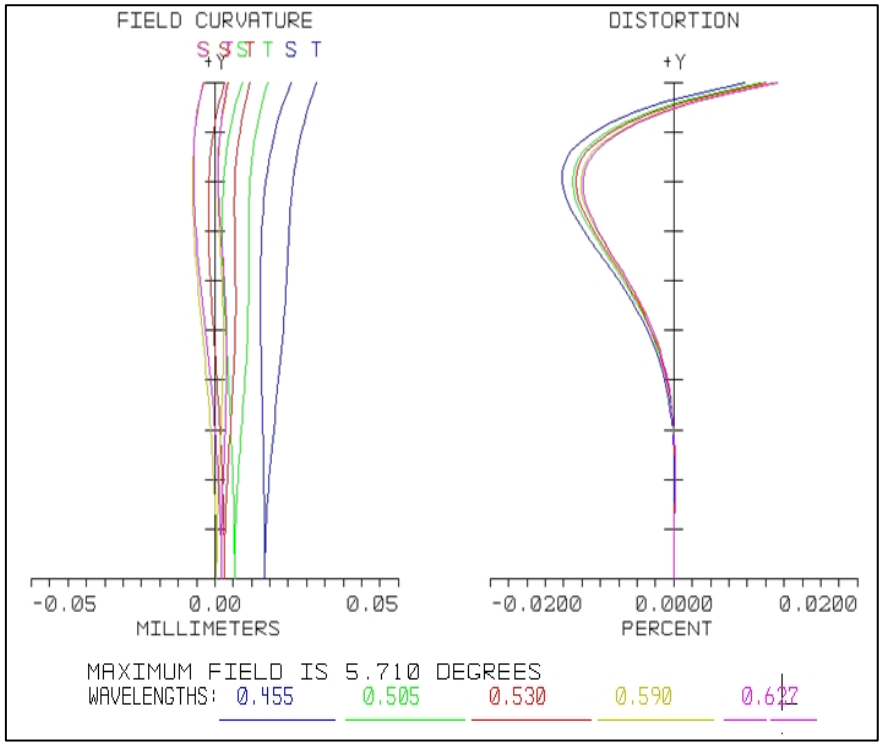




Ultra large field of view and high resolution objective

High resolution & large field : XScope optics



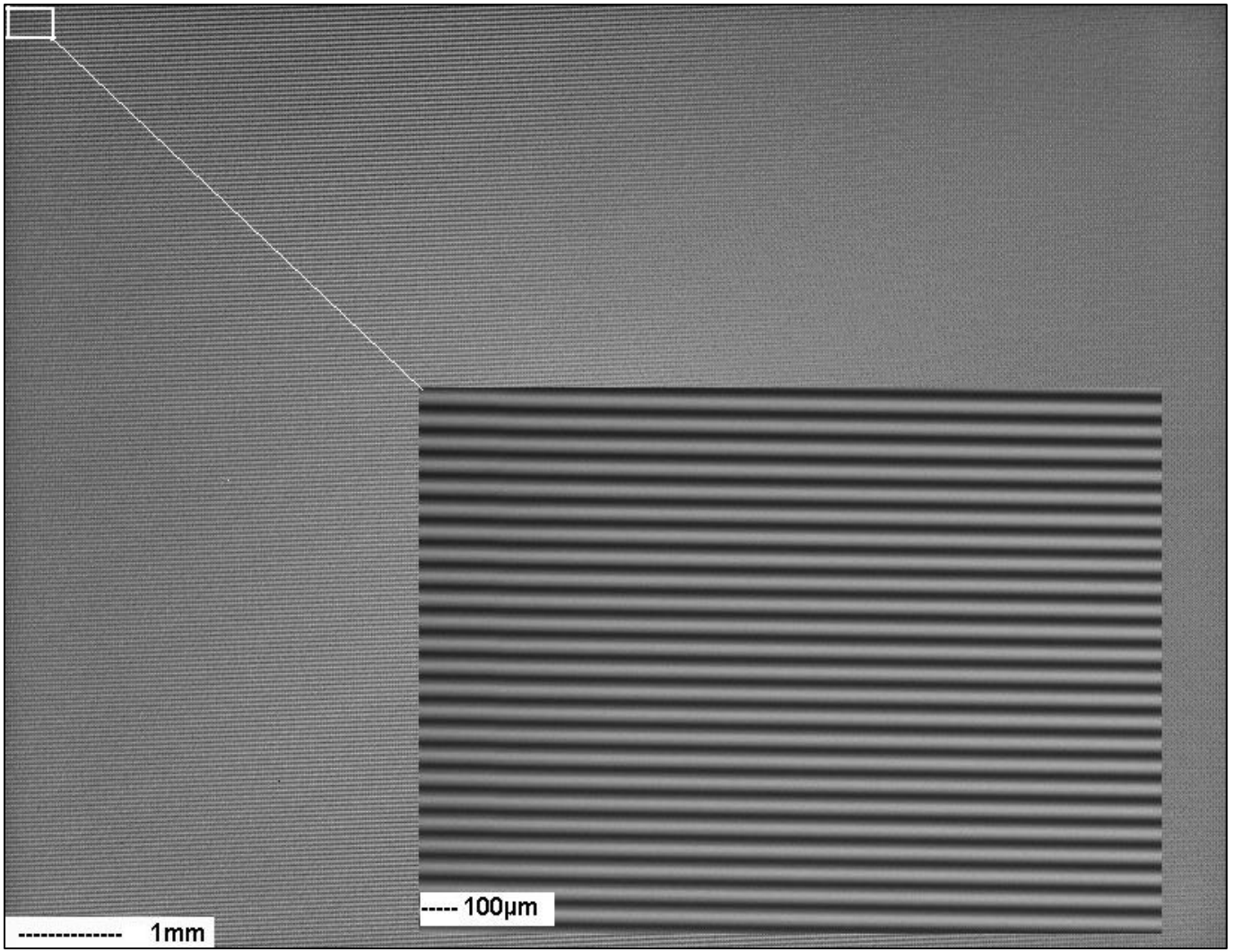


Spot radius at 5 positions in the field of view

Curvature and distortion radius vs field of view (455, 505, 530, 590 and 627nm)

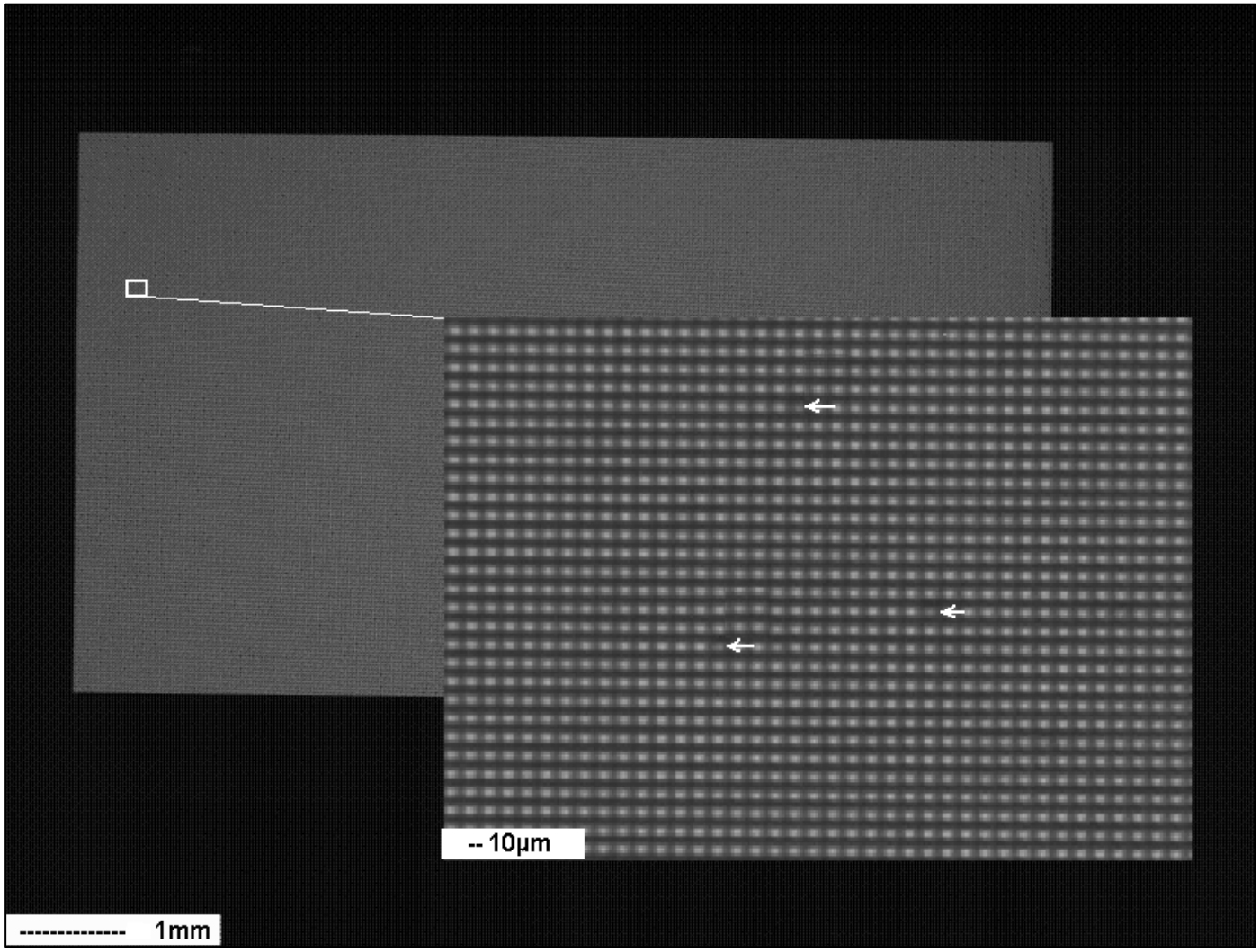
- **Spatial resolution is not limited by the optics**
- **Quasi flat field without distortion**

High resolution & large field : XScope optics



Measurement on 50 cycles/mm grating using 50M pixels CCD

High resolution & large field : XScope optics



Measurement of the green pixels of an 870x500 microOLED (10x10µm pixels)

High resolution & large field : XScope optics

Common specifications		XScope	Options
Imaging lens	*Magnification* *Field of view*	*4.5* *10.9x8.2mm*	*Standard* *Standard*
Sensor configuration	*Monochrome CCD grade 1* *Pixel size* *Spatial resolution*	*8176x6132 or 50.1M pixels* *6x6µm* *~1.5µm*	*Standard*
Luminance	*One filter*	*Y*	*Standard*
Color	*5 filters adjusted to the CCD response on automated wheel*	*2 for X, 2 for Y and 1 for Z*	*Optional*
Densities	*On automated wheel*	*ND0.6, ND1.2, ND1.8 and ND2.4*	*Optional*
Luminance range	*Without density* *With density*	*0.001 to 500Cd/m²* *up to 125,000Cd/m² with ND filters*	*Standard* *Optional*
Accuracy	*Luminance* *Chromaticity (x,y) RMS*	*±3% for any color stimulus* **(*1)** *±0.003 for A type illuminant* **(*1)** *±0.005 for any color stimulus* **(*1)**	*Standard* *Optional* *Optional*
Repeatability	*Luminance* *Chromaticity*	*±0.5% for full resolution* **(*2)** *0.001 or full resolution* **(*2)**	*Standard* *Optional*
Measurement time	*Luminance* *Color*	*< 2s* **(*3)** *<10s* **(*3)**	*Standard* *Optional*
Interface	*camera* *filter wheels*	camera link USB 2.0	*Standard* *Optional*

Main XScope specifications

More than luminance & color

Luminance & Color

Isense

UMaster

Polarization state

UMasterPZ

Spectral radiance

UMasterMS

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