Seven Good Reasons to Consider the TechnoTeam LMK Family of Imaging Light and Color Measuring Devices

1 All CCD and CMOS based LMK systems are measured individually in-house for its spectral responsivity. This gives an accurate measure for the spectral matching of the sensitivity curves of the 2° standard observer define by the CIE. The measurement is done for every configurated lens of the delivered LMK system. The results are stated in the calibration certificate.

2 A high transmission of the CIE matching filters is a parameter for the optimization of each CCD. This allows using much shorter exposure times for capturing low light levels. This specific optimization is made unique for the LMK system.

3 The accuracy of fine spectral matching is almost in the level of other high-accuracy photometers. This allows to minimized the uncertainty due to spectral mismatch even for saturated LED colors.

4 Electronic components are manufactured in-house designed especially for LMK systems.

5 A supplier-independent optimization considering the influence for radiometric signal detection is being possible due to this.

6 Special measurement features like High-Dynamic measurements are supported from hardware point of view in a very unique way.

7 Serveral different measuring options with one system e.g.

- Luminance distributions in measuring images L(x,y)
- Derived lighting-engineering parameters such as illuminance distribution E(x,y) and Luminous intensity distribution (LID) I(x,y)
- Color and chromaticity data
- Human vision based metrology data like glare, visibility and contrast sensitivity, visual perception based ratings

LMK

Architectural/Outdoor lighting

- Luminance - Brightness level light pollution, glare sensation, visual perception
- Color - CRI, color appearance
- Luminous intensity distribution (LID), ray-data, BRTF data
- Non visual effect - blue light hazard, human melatonin suppressionMelatonin suppression

Automotive lighting

- Exterior: head/tail lamps - luminance, color, luminous intensity distribution (LID)
- Interior: ambient and dashboard illumination - visibility, contrasts, visual and color appearance rating
- Display design - visual perception, glare sensation, contrast sensitivity

Automotive interior lighting

- Luminance
- Color – CRI
- Luminous intensity distribution (LID) – ray data
- Non visuals – Blue light hazard

Display industry/metrology

- Luminance - brightness, uniformity, contrast ratio, image sticking, angular performance
- Color – color reproduction, color rendering, color homogeneity
- Pixel defects and crosstalk
- Gamma determination and rating

LMK6

The LMK 6 is the center-piece of the entire LMK product family and equipped with colored full glass filter to adapt the system to the 9 function or a set of full filter glasses to realize the matching for the 2° CIE standard observer.

Its robust construction, compact dimensions and lightweight means that it can be used in almost every process for a wide range of lighting measurement tasks.

In conjunction with the supplied system and measuring software, their areas of application lies in a lot of tasks in which the imaging determination and evaluation of luminances is required.

A large selection of high-quality standard lenses and special imaging systems in combination with an interchangeable lens mount further increase the flexibility of the LMK 6. As a result, the LMK 6 is able to meet a wide range of requirements and to combine a wide variety of measuring devices in one system.

Modulation detection (e.g. flicker)

With the use of a CMOS image sensor arrays, it is not necessary to transfer a complete image during image acquisition. Rather, the CMOS technology makes it possible to partially read the image data. For example, individual image pixels or image lines can be recorded.

With a special modulation measurement the LMK 6 is able to measure the modulation frequency of the light source. Using this information the influence of the modulation frequency to the measurement result can be minimized.

Trigger function

The LMK 6 series has an external and an internal trigger function to communicate with the surrounding. Thus the LMK 6 is able to state the integration time to an external signal. Additionally the image capture can be controlled from an external trigger source. Also an external source can be controlled by the LMK 6 itself. For both cases time delays before and after the image integration are possible. This saves the need of expensive power supplies.

LMK

CALIBRATION PROCESS

An ILMD/ICMD (short IxMD) system consists of a digital camera, optical filters for the spectral matching, (changeable) lenses and additional neutral density filters. The aim is to measure the two-dimensional projection of the luminance / color distribution of a device under test (DUT) with or without a geometrical calibration.

For accurate data evaluation, all non-ideal properties of the system need to be corrected in relation to international agreed standards (e.g. luminance) typically using calibration factors. For this purpose, the software controlling the IxMD, needs a model and model parameters. The estimation of the model parameter is the aim of the individual adjustment of a measuring system. With the additional calibration the success of the adjustment will be checked and stated including the associated measurement uncertainty verified by the measurement of defined index values.

Most of the following measurements to estimate model parameter are made individually for every system and lens. Only viewing measurements are system specific only and can be done once for a system type.

All characterizations described with red index values are performed individually. Some other characterizations described with black index values can be created system specific in most cases.

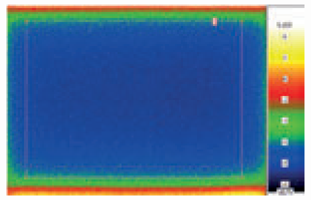
This description is valid for an LMK COLOR camera with a focusable lens and neutral density filters.

The way to a calibrated ILMD/ICMD system

$f_{3,0}$

Dark signal properties

Measurement and characterization of the dark signal properties of a system including dark signal, dark signal non-uniformity and faulty pixels.



Dark signal non-uniformity (of the system without correction) at 5s integration time and 25°C ambient temperature.

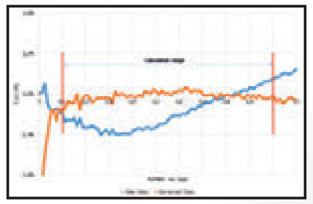
Apply all the dark signal properties for correction and calculate the detection limit (relative or using a common calibration factor).

$f_{3,1}$

Basic camera and sensor data

Measurement of basic camera and sensor data (not related to lenses) using the Photon Transfer Method (PTM) to estimate the system transfer factor k_{Sys}, the basic noise σ_0 and the full well capacity Q_F.

The non-linearity over different integration times with selected luminance values is measured and used for correction later on.

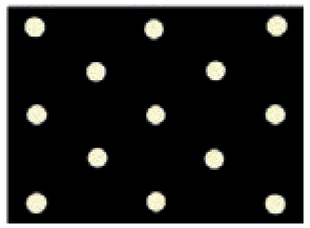


Measurement with and without correction of the non-linearity for a system.

f_{21}, f_{22}

Lens shading

Flat field measurements with large homogenous objects using specialized integrating spheres and raster measurements using small homogenous objects and a rotation stage.

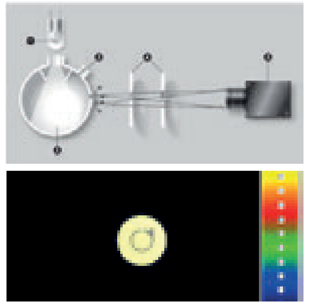


Example: Raster measurement for the characterization of the lens shading to measure the f_{22} uniformity index after using all measured corrections.

f_{Adj}

Adjustment

Measure the calibration factor for every color filter and use the luminance for standard illuminant A as the reference value.



Measurement setup according to DIN5032-10 for the luminance adjustment of an ILMD.

ΔC

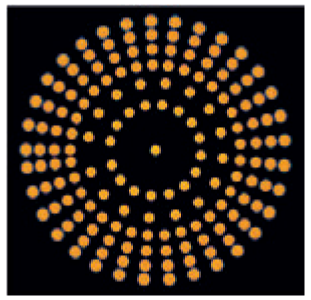
Color calibration

Measure different known light sources (LED based L^3 STANDARDs or other references) and calculate a transformation matrix for the camera color space (4 to 8 filters) to the standard color space of the 2° CIE standard observer.

Multi-Color calibration with different L^3 STANDARDs. Apply the transformation, perform test measurements and calculate color differences ΔC.

Lens and filter distortion correction

Measure the distortion caused by the color filters and/or lenses and calculate correction information.

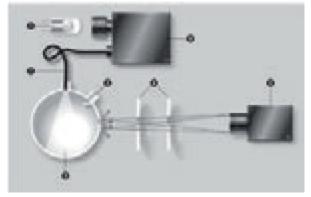


Example of a measurement grid for a sky lens (fisheye lens) to calculate the angular positions for every pixel e.g. necessary for UGR evaluation.

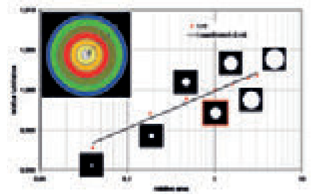
f_1' $f_{6,T}$ f_{12} f_{23} f_{24} f_{25} f_{29}

Further characterization

After finishing all the measurements used for correction multiple characterizations are necessary to check the calibrated system:



Measurement setup according to DIN5032-10 for the spectral responsivity measurement of an ILMD e.g. to state f_1'.



Example measurements results for the Size-Of-Source effect stated with the characteristic value f_{29}

For every measurement the adjustments made by the measurement before are taken into account.

If no other reference is given all tests and characterizations are done according to DIN5032-10:2019 / CIE TC2-59 CD:2019

LMK Display

The characterisation of different display types - small mobile phone displays up to large TV displays or also head-up displays - is an important topic in various R&D applications and the quality management for production accompanying processes.
For example automotive displays and their very strict performance, quality and safety requirements or the measurement of virtual displays (VR/AR, ocular systems) are becoming more and more important.

Imaging Luminance and Color measuring devices (ILMD/ICMD) can be used to analyse a various range of performance and quality benchmarks for the different display types.

The image measuring technology can be used to evaluate uniformity parameters like black-level gradients in a few seconds measurement time. Using special lenses (e.g. hyper-centric lens (Conoscope) or Macroscopic lenses) the user can perform angular luminance and color characterisation for small parts of the display or for single pixel / subpixel structures.

Additionally parameters like the Gamma-curve can be measured with one shot within seconds. In addition, the evaluation of sticking images is possible with the same measuring device.

The **LMK** Luminance/Color system can be equipped with three different lens types for display analysis

- 50mm focusable lens (whole screen analysis like uniformity measurement)
- Conoscopic lens (angular dependent luminance and color measurements)
- Macroscopic lens (single-/subpixel structure analysis e.g. for Pixel-Crosstalk analysis or the evaluation of anti-glare and anti-reflection coatings)

The **LMK** display software package is available for the current **LMK** 5 systems and the future **LMK** 6 generation based on CMOS sensor.

LMK display

LMK 5 [CCD based]

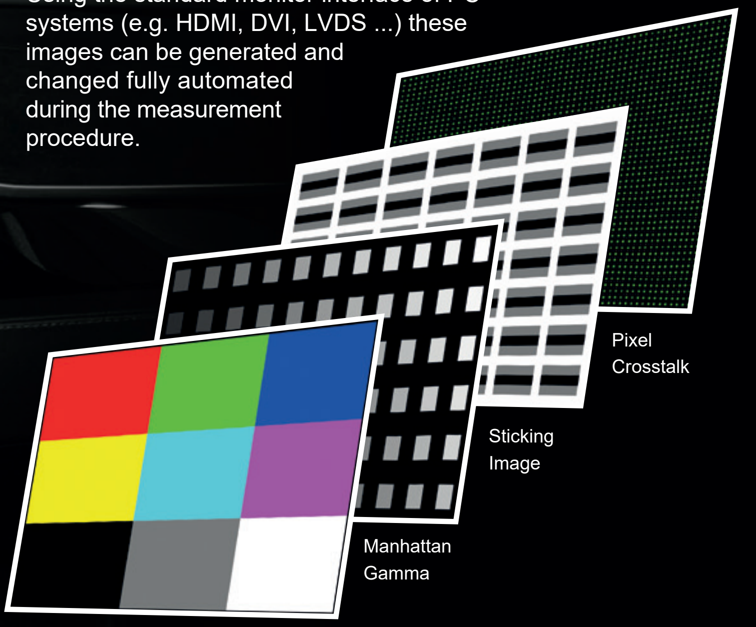
1386 (H) × 1035 (V) (1MP)
2448 (H) x 2050 (V) (5MP)

LMK 6 [CMOS based]

1936 (H) × 1216 (V) (2MP)
2448 (H) x 2048 (V) (5MP)
4100 (H) x 3000 (V) (12MP)

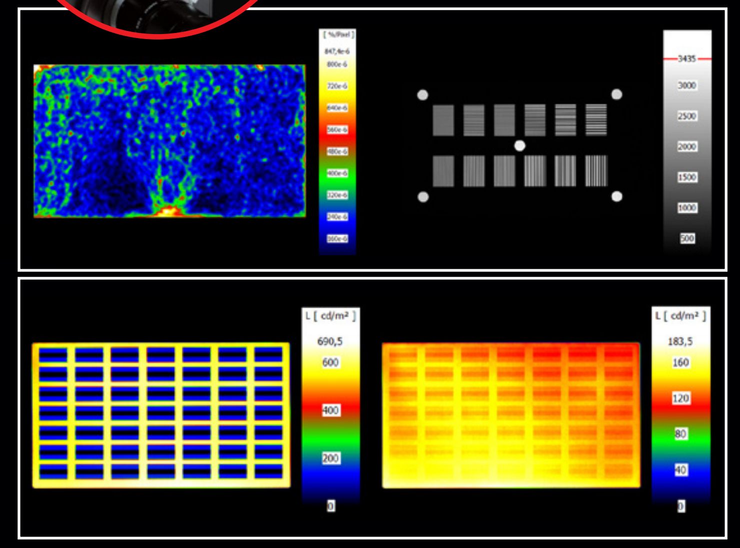
Test Image Generator

Using the standard monitor interface of PC systems (e.g. HDMI, DVI, LVDS ...) these images can be generated and changed fully automated during the measurement procedure.

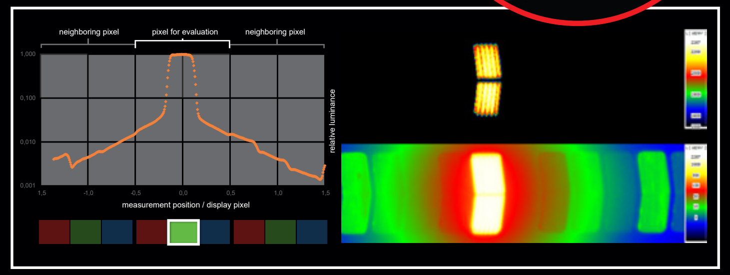


LMK BlackMURA supplies the analysis of display screen quality according to the black-level uniformity. Thus the package is providing an extension to the functions of the **LMK** LabSoft for realising a gradient filter detection of particular non-uniformity on the display screen.

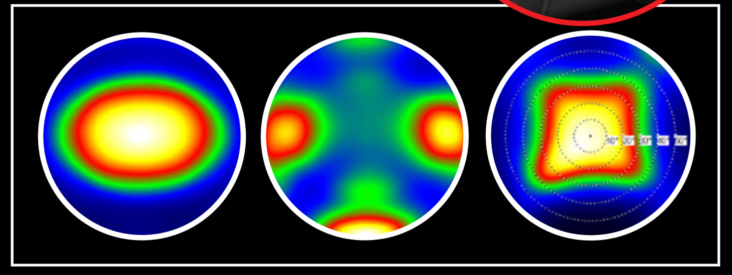
LMK Sticking Image supplies the analysis of display screen quality according to the three-level burn-in method developed by Dr. Lauer.



LMK Pixel Crosstalk method developed by Dr. Fink characterises the loss of image clarity caused by anti-glare coatings. The method uses high-resolution imaging with a Macroscopic lens, giving a distribution and evaluation of scattered light.



LMK CCM (Conoscopic contrast measurement)
The software package allows the user to perform angular contrast determination of displays in an easy way. It provides the capability of conversion to H/V angular coordinates as well as the definition of measurement regions and points in the ϑ,ϕ and ϑ_H, ϑ_V angular coordinate system.



Member of
DFF
German Flat Panel Display Forum

Target applications

- Various topics in the application of display evaluation (human machine interface (HMI) displays, Head-Up display (HUD), AR/VR displays) such as luminance level, color settings, luminance/color uniformity and angular dependence of luminance/color
- Material evaluation (e.g. Brightness enhancement foils, Combiner windows for HUD)
- Evaluation of display screen surfaces (anti reflection / anti glare coatings)

Research & Development (R&D)

- BlackMURA analysis according to DFF Standard „Uniformity Measurement Standard for Displays V1.3“
- Sticking Image determination according to the “three-level burn-in Method” of Dr. Lauer (Visteon) and the "two-level burn-in specification" using a checkerboard burn-in pattern only.
- Pixel Crosstalk analysis according to the method of Dr. Fink (Porsche)
- Angular contrast measurements with the Conoscopic lens

Production control

- Luminance and Color evaluation
- BlackMURA
- Sticking Image (available soon)

LMK display

LID Checker & BV Room

The spatially resolved measurement of luminous intensity distributions by means of the indirect light measurement technique allows the complex evaluation of numerous lighting-engineering devices:

- head- and rear lamps
- Signal lamps
- LED modules
- stage spot lights and reflector lamps

The imaging luminance measuring technology provides the acquisition of both photometric and geometrical data, thus allowing the user to determine important lighting-engineering quantities:

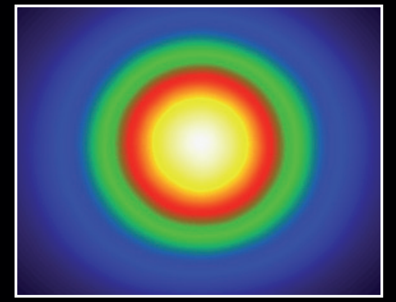
- luminance distribution L(x,y) on an illuminated surface
- derived parameters such as luminous intensity distribution I(ϑ,ϕ) and the illuminance distribution E(x,y) on an illuminated surface by means of the luminance distribution
- color distribution on an illuminated surface getting the chromaticity coordinates x,y
- Contrast
- Chromatic fringe
- Position and luminous intensity values of predefined measurement regions

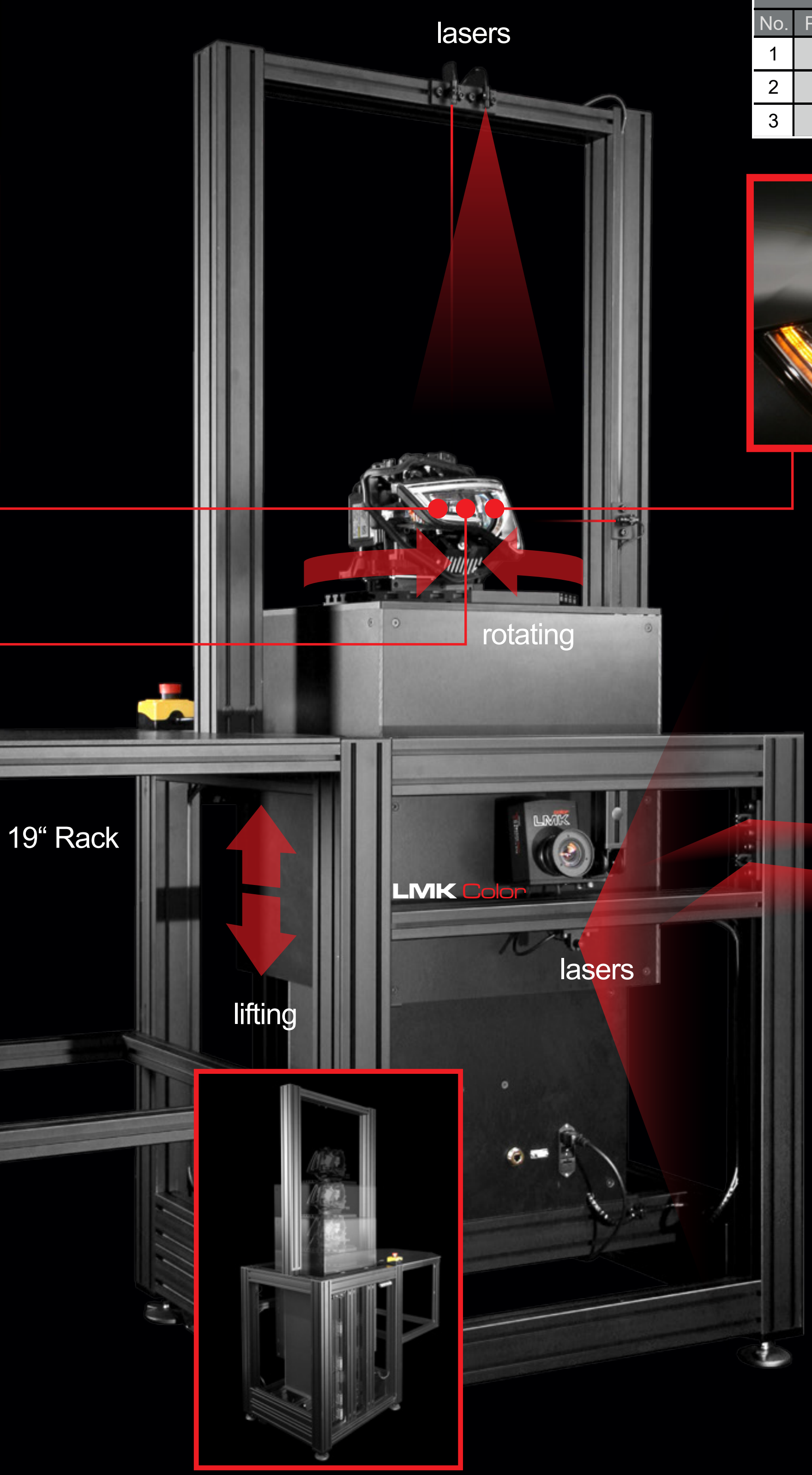
All this information can be determined by using our imaging photometer **LMK** or imaging colorimeter **LMK** Color within seconds. In addition, the integrated software solution **LID** Checker provides automated image processing routines for customer related measuring tasks or the software solution **LMK** LabSoft enables the user to analyse the measuring data manually and flexible.

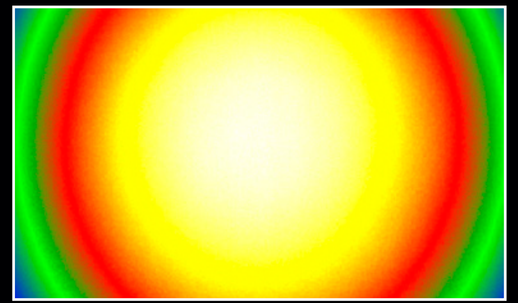
BV Room

Lamp No.	Voltage U[V]	Current I[A]	Power P[W]	Axial luminous intensity I[cd]	Max luminous intensity I[cd]	Tilt angle horiz. [°]	Tilt angle vert. [°]	Half value angle left [°]	Half value anlge right [°]	Sum HVA horiz. [°]	Half value angle up [°]	Half value angle down [°]	Sum HVA vert. [°]
Mean	**5.91**	**6.60**	**38.97**	**11778.0**	**12080.0**	**-0.40**	**0,30**	**-4.35**	**4.40**	**8.75**	**-4.20**	**4.15**	**8.30**
StdDev.	**0.02**	**0.00**	**0.13**	**674.6**	**356.4**	**0.42**	**0,00**	**0.07**	**0.14**	**0.21**	**0.00**	**0.07**	**0.00**
1	5.89	6.60	38.88	12255	12332	-0.1	0,3	-4.3	4.3	8.6	-4.2	4.1	8.3
2	5.92	6.60	39.06	11301	11828	-0.7	0,3	-4.4	4.5	8.9	-4.2	4.2	8.3

In the case of reflector lamps using the **LMK** within the **BV** Room including the **LID** Checker Software provides notable speed advantages, so that it can even be used during the production process.





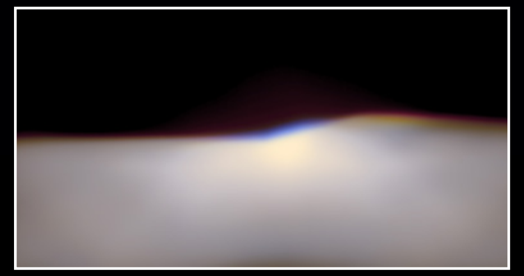


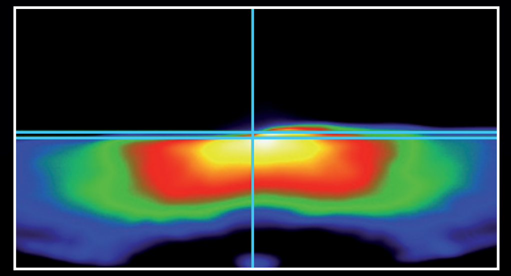
	x[°]	y[°]	Result	Luminous flux[lm]
Ref. Point	0.25	0.1	pass	225

Measuring				Set Val. [cd]		
No.	Position	x[°]	y[°]	Min[cd]	Max[cd]	I[cd]
1	15UH	0	15		260	210
2	10U5L	-5	10	12	260	223
3	10U5R	5	10	12	260	195

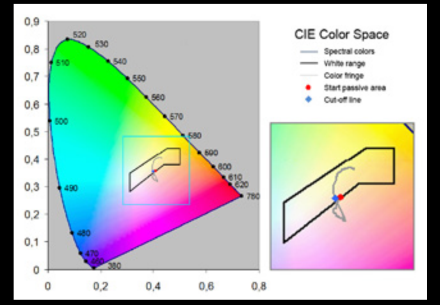
	x[°]	y[°]	Result	Luminous flux[lm]
Elbow Point	-0.42	0.05	pass	378

Measuring				Set Val. [cd]		
No.	Position	x[°]	y[°]	Min[cd]	Max[cd]	I[cd]
1	HV	0	0		500	496
2	B50L	-3.43	0.57		250	244
3	75R	1.15	-0.57	15000		19392





Measuring headlamp with the **LMK** or **LMK** Color is fast. Using **LID** Checker offers wide possibilities to define test specification in accordance to ECE, SAE and more. Therefore, a LID segment for example ±17°; ±8.5° can be captured in appr. 10s including elbow point detection an protocol generation.

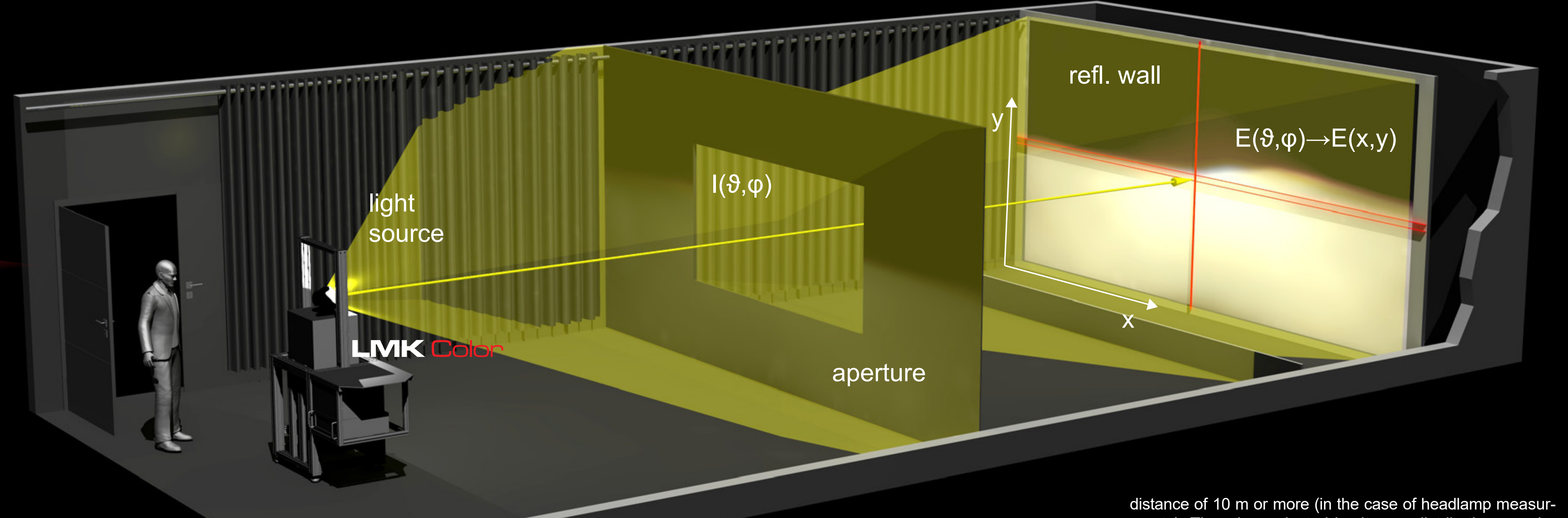


Using the **LID** Checker with the **LMK** Color offers possibilities in the range of chromatic measurement. For example, analysing the chromatic values along a cross section is the basis for detailed cut-off line analysis.

Measuring Table

To realize a stable and reproducible measurement of more and more complex luminous intensity distributions, it is necessary to position the measuring object precisely. Although it is important to compensate different measuring object dimensions, to sufficiently reach the reference point of the measuring setup. To help the customer to achieve these conditions, **Techno**Team provides an own design of a measuring table. Features are:

- Height-adjustable – ±25 cm
- Rotation unit full 360°
- Alignment lasers directed to the measuring object for positioning in the reference point
- Alignment lasers directed to the measuring wall for visual control and optional adjustment of the beam direction
- Optional x-y-table for horizontal adjustment of the measuring object
- Camera mounting
- Slot for 19” devices (power supply, PC, ...)



Measuring Principle

The **BV** Room is a solution for the indirect light measurement. A measuring object positioned on a stable measuring table illuminates a reflective wall with lambertian characteristics, which is placed in a typical measuring distance of 10 m or more (in the case of headlamp measurments). Thus the projected luminance distribution or color distribution can be measured by using the **LMK** or **LMK** Color, which is mounted ideally on the measuring table or anywhere within the room, facing the measuring wall. The geometrical and photometric relations between the light source (in spherical coordinates) and the reflective wall (in camera coordinates) will calibrated, so that the luminous intensity distribution I(ϑ,ϕ) can be calculated automatically from the image of the luminance L(x,y).

Technical Data

Geometrical dimension[1]
Depends on the room size and photometrical limiting distance

Size of the measurement object
any; depends on the photometrical limiting distance and the corresponding size of the measuring room

Interface
Gigabit Ethernet Interface (GigE ®)

Spectral mismatch
V(λ) [f_1' < 3.5%]; X(λ) [f_1* < 4%]
Z(λ) [f_1* < 6.0%]; V'(λ) [f_1* < 6%]

Measuring range[2]
Adaptable by using different integration/ exposure times
100 µs - 15 s → approx. 1 Mcd down to 1 cd
Higher intensities can be measured using optional grey filters

Angular resolution[3]
0.01° to 0.1°

Typical Image field[4]
±17° hor.; by ±8.5° vert. for a 10 m room
±32° hor.; by ±17° vert. for a 3.16 m room
The horizontal image field can increased by using the motor unit of our measuring table.

Calibration uncertainty
Focusable lens ΔL [< 2.5%]

Repeatability
ΔI [< 0.1%]; Δx,y [< 0.0001]

Measuring accuracy[5]
ΔI [< 3%]; Δx,y [< 0.0020]

Uniformity
ΔI [< 3%]

Measurable contrast[6]
Common 1:1000 with measurement conditions according to CIE TC2-59 Draft characteristic f_{25}

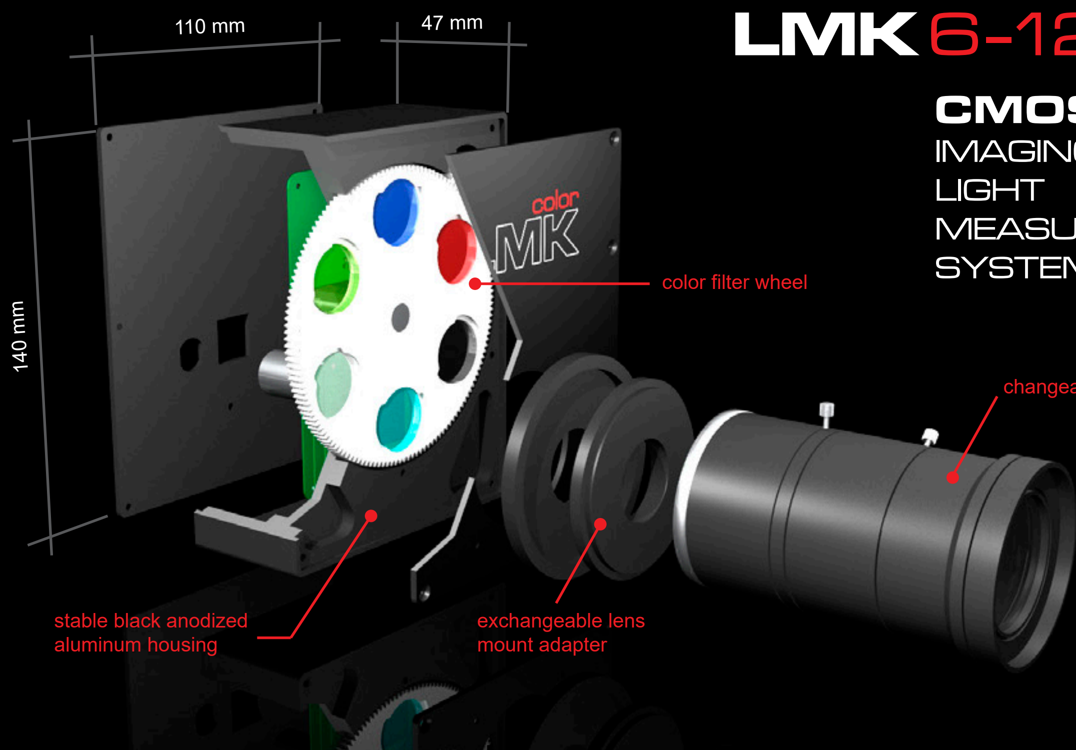
Measurement period
< 1 min for a full field luminance intensity distribution (e.g. ±17° horizontal by ; ±8.5° vertical with resolution of ; 0.01°)

1 For headlamp measurements; for other measurements more compact dimensions are realizable | 2 upper range value according to the integration time | 3 Depending on the measuring task and the angular range | 4 For headlamp measurements; for other measurements greater fields of view are possible | 5 For standard illuminant A with homogenous illuminance | 6 Depending on the light distribution lower or higher contrasts are possible

BV Room

LMK 6-12

CMOS IMAGING LIGHT MEASURING SYSTEMS



SYSTEM

Standard resolution LMK 6-5 color	2464 x 2056 Pixel | Sony-CMOS [IMX 250 (2/3"); 12 Bit digital]
High resolution LMK 6-12 color	4112 x 3008 Pixel | Sony-CMOS [IMX 253 (1,1"); 12 Bit digital]
Measurement time	starting with 1 sec. up to 15 sec. depending on luminance level, adjusted lens and exposure/integration time
Dynamic range	[1:10000000 (~140 dB)]
Data interface	Gigabit Ethernet Interface(GigE®)
Spectral matching	using V(λ)-function matched full glas filter for luminance measures adapted with full glass filters to the X(λ)-, V(λ)- and Z(λ)-function to measure color values further full glass filters for the functions V'(λ)-, S_{mel}(λ) and BLH (blue light hazard) as well as NIR filters are available

METROLOGICAL DATA

Metrological specifications	V(λ) [f´1 < 4 %[1]]; X(λ) [f*1 < 4 %] Z(λ) [f*1 < 6 %]; V´(λ) [f*1 < 6 %]
Measuring quantities	Luminance: L (cd/m^2)
Chromaticity coordinates	x,y
Supported colour spaces	RGB, XYZ, sRGB, EBU-RGB, User, Lxy, Luv, Lu'v', L*u*v*, C*h*s*uv, L*a*b*, C*h*ab, HIS, HSV, HSL, WST
Measuring range (integration time)	100 µsec. ...15 sec.
Measuring range[2] depending on lens aperture value (F) mono	1 msec. ...appr. 1800 cd/m^2 & 3 sec. ... appr. 0.6 cd/m^2 (F = min.) 1 msec. ...appr. 60000 cd/m^2 & 3 sec. ... appr. 20 cd/m^2 (F = max.)
Measuring range depending on lens aperture value (F) color	1 msec. ...appr. 7500 cd/m^2 & 3 sec. ... appr. 2.5 cd/m^2 (F = min.) 1 msec. ...appr. 60000 cd/m^2 & 3 sec. ... appr. 20 cd/m^2 (F = max.)
Measuring range for the preset f-number (F/4)	1 msec. ... ca. 10000 cd/m^2 & 3 sec. ... ca. 3.3 cd/m^2
Calibration uncertainty[3]	fix focused lenses ΔL [< 2 %] focusable lenses ΔL [< 2.5 %]
Repeatability[4]	ΔL [< 0.1 %]
Measuring accuracy	ΔL [< 3 % (for standard illuminant A)]
Uniformity	ΔL [< 2 %]

DIMENSIONS AND WEIGHT

	housing dimensions (HxWxD)	weight (without lens)	available lens
LMK 6 mono	80 mm x 80 mm x 47 mm	600 g	120 g - 800 g
LMK 6-5 color	117 mm x 90 mm x 47 mm	800 g	120 g - 600 g
LMK 6-12 color	140 mm x 110 mm x 47 mm	1300 g	200 g - 800 g

1 Measurements according to DIN 5032 Part 6/CIE Pub. 69 | 2 The given values representig the highest luminance values with the given setting. | 3 Calibration according to DIN 5032 Part 6 using a luminance standard led back from the Physical-Technical Federal Institute | 4 Measurement performed on a stabilized white LED light source L=100 cd/m^2. Mean value over 100 Pixel; repeatability