Introduction of LMK Position

LMK Position

The LMK Position system from TechnoTeam Bildverarbeitung GmbH combines robot-guided machine vision with high-precision luminance and color measurements by combining the LMK series with the high-precision robotic systems from DENSO Robotics. The LMK Position system is an excellent way to perform efficient and effective measurements for complex or time-consuming alignment tasks where speed and precision requirements are of the essence [1-2].

LMK Position: High-precision geometrical reproducibility at high-speed
High flexibility in a compact setup

Figure 1: TechnoTeam's solution for complex alignment: Fast and easy-to-use vision-based robotic

In this application note, we focus on the possibilities of the LMK Position to speed up and enable standardized measurements such as BlackMURA, or individually tailored measurements of complex 3D-free-form displays as shown in Figure 1.

Fully automated high-precision alignment

Traditional manual alignment techniques have worked for quite a while. However, especially in the automotive area, more and more complex tasks become time-consuming or nearly impossible if they should be reproducible. Reasons are

- Highly individualized 3D shapes and designs
- Complex individual mechanical mounting mechanics (especially for prototype panels)

There is no need to design complex mechanical money and time-consuming mounting options only to perform a test measurement.

TechnoTeam overcame these issues by simply using one property of displays, namely controlling the presented content. The LMK Position uses simple test images to perform any alignment task regardless of the initial orientation between the LMK and the device under test (DUT). There is no need to design complex mechanical money and time-consuming mounting options for each iteration of a prototype or small series only to perform a specific test measurement. Just get the display near the LMK Position and align the LMK either automatically or by using the hand panel as required. When done automatically, the 6-axis system combined with LMK-based image processing will minimize all spatial and angular deviations. After that, the system can optimize the focus with any lens and triangulate the distance and you have a perfectly documented setup for your measurements.

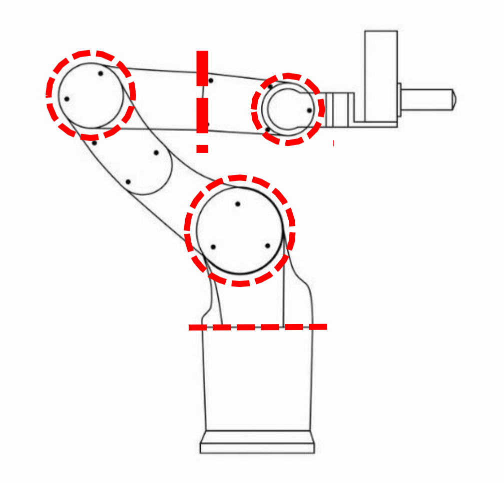

Figure 2: 6-axis of the LMK Position

Table 1: Properties of alignment possibilities

Alignment Strategy for BlackMURA	**Distance measurement**	**BlackMURA field angle test**	**Setup speed**	**Specialized mounting**	**Alignment to sensor center / optical axis**	**Focus optimi-zation**
Manual alignment	By extra sensor or by hand	Very high efforts required. Very error-prone	Minutes to hours	Usually required	Switching is time-consuming	no
Alignment with motorized setup	Needs to be calibrated	Automatization possible. Initial alignment error may propagate	Depends	Usually required	Depends	Depends
Alignment with LMK Position	Automated in a few seconds (1-Click) [3]	Automated for any grey scale (1-Click)	Few Seconds (1-Click)	Not necessarily required	Easily switch between both (1-Click)	Yes (1-Click)

BlackMURA alignment, testing, and measuring in seconds

The BlackMURA specification of the German OEM workgroup displays [1] describes not only specific evaluation algorithms to calculate the display uniformity. Most of the standard describes an advanced alignment procedure between the luminance camera and the display to maximize reproducibility. This includes:

- Alignment such that each tilt angle is less than 0.5 and to a spatial deviation of less than one pixel
- Measurement field angle validation
- Reproducible Moiré free defocus

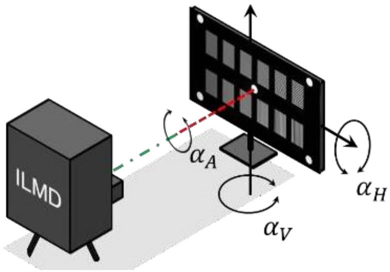

Figure 3: Alignment pattern [1]

Figure 4: Workflow of alignment according to [1] with LMK Position

Figure 3 visualizes a dedicated alignment pattern for that purpose. It can be used directly with the LMK Position. The complete alignment procedure consists of the steps shown in Figure 4

After ensuring the camera observes the complete display with the alignment pattern, start the automatic procedure (Figure 5). Then, everything is done automatically in an iterative algorithm until all angular and spatial deviations are minimized to the desired precision. Finally, the field angle tests according to [1] can be carried out to test the influence of angular effects during the spatial uniformity measurement (1-click). After that, a BlackMURA measurement can be performed.

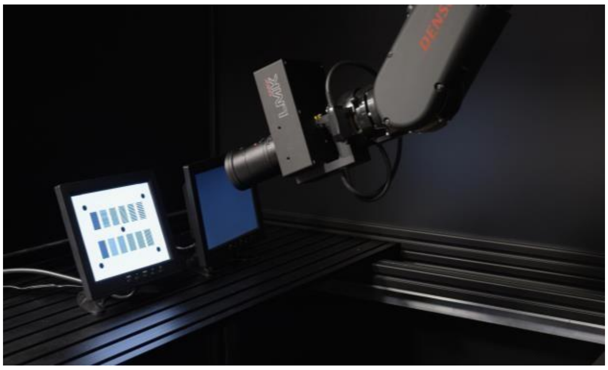

Figure 5: Alignment according to [1] with the LMK Position

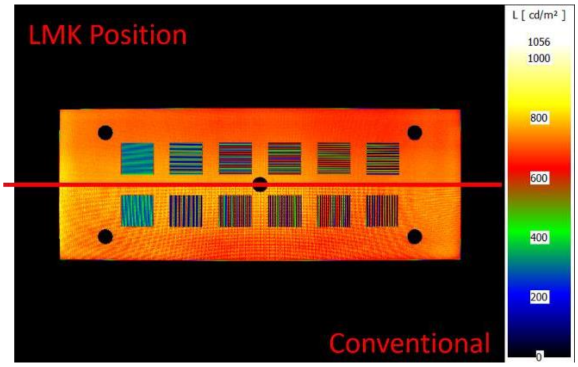

Figure 6: Pixel structure avoidance method

Reduce the BlackMURA setup and alignment verification time to a few seconds regardless of your mounting options

Automated correction of angular effects in spatial uniformity measurement

Usually, spatial uniformity measurements require a long focal length lens with a high measurement distance to avoid angular and spatial uniformity mixing. However, this is not needed with the LMK Position.

The LMK Position offers a measurement-based correction method that corrects spatial uniformity for angular contributions. This allows much more compact measurement setups. This method can also be used to correct standard setups using long focal lengths to further increase the precision of the spatial uniformity measurement or the angular effect of displays with active privacy function.

Optionally: Avoid large distance setups via the LMK Position field angle correction algorithm

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Figure 7 and Figure 8 show the results of a uniformity measurement of a 13-inch laptop display with and without applying the correction using a 16 mm lens. The results in Figure 9 are similar to a long-distance measurement using a 50 mm lens.

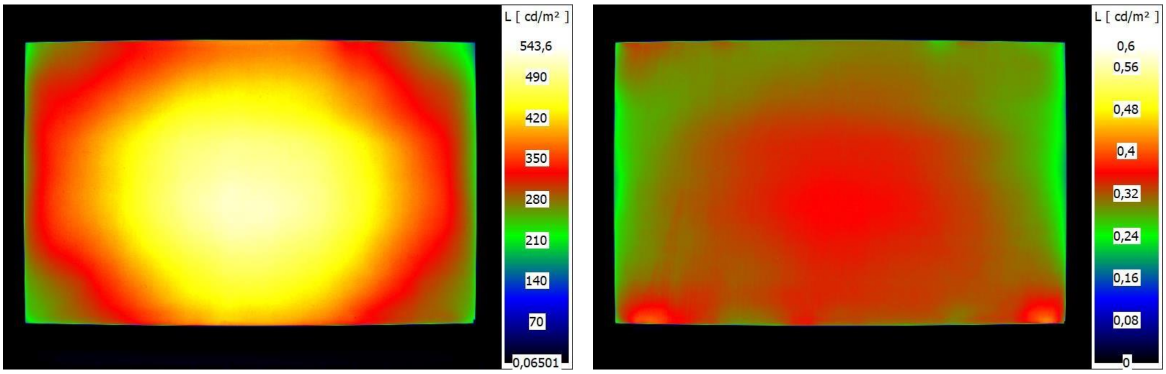

Figure 7: Short-Distance Uniformity measurement without correction (Left: full white, Right: full black)

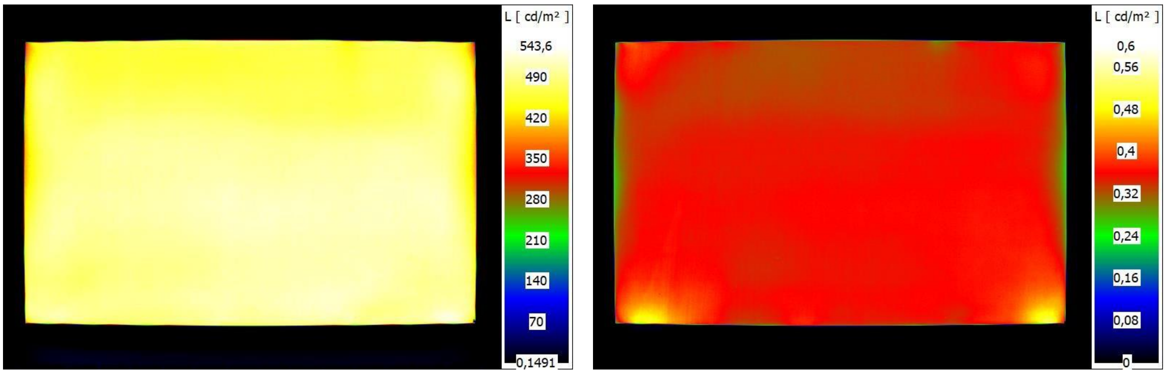

Figure 8: Short-Distance Uniformity measurement without correction (Left: full white, Right: full back)

Alignment at curved and freeform-shaped displays

While the alignment of a flat panel with conventional techniques is only time-consuming, the alignment of a 3D-shaped freeform display can become extremely complicated because the surface normal changes across the curvature, as shown in Figure 10.

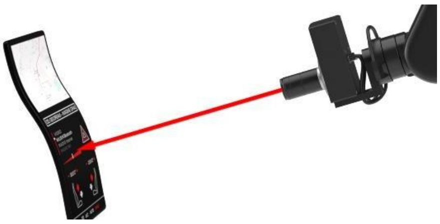

Figure 9: Alignment task for an S-shaped display

The advanced 3D scan (1-click) and 3D alignment (1-click) make any alignment possible regardless of the shape of the display

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The LMK Position can perform a 3D-Position scan of any rectangular circle raster shown on the DUT [2]. Then, the software triangulates a 3D position of each circle and triangulates the complete 3D display surface. The procedure is shown in Figure 11.

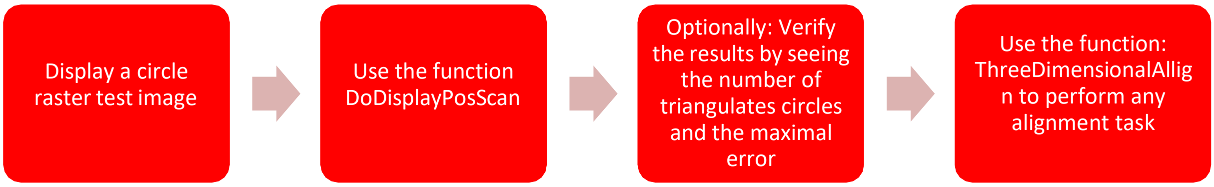


Figure 10: Workflow of alignment for an arbitrarily shaped display and any lens

Next, the LMK Position automatically creates a 3D model based on all circle centroids and a 2-dimensional display coordinate system as shown in Figure 12 (1-click).

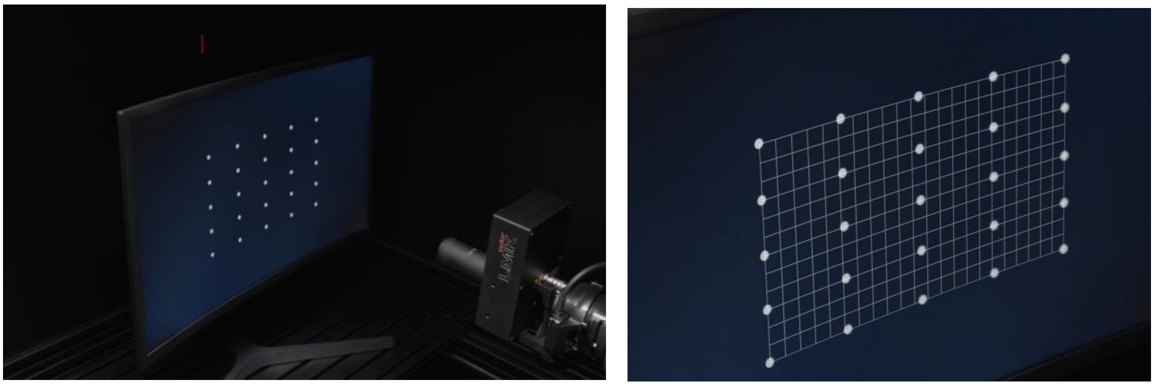


Figure 11: Circle Raster for scan and found coordinate system used for the alignment task (surface normal not drawn)

After that, the 3D alignment (1-click) can align relatively to each surface point of the display with a user-defined distance, and a user-defined angle relative to that particular points surface normal in either spherical or horizontal/vertical coordinates. That way, even complex angular measurement tasks at freeform-shaped displays become fast, easy, and reproducible. Examples are contrast and vantage point measurements.

Viewing Angle and Conoscopic Contrast measurements

A conoscopic lens is a special type of wide-angle lens, which allows measuring a large angular distribution from a small surface point. It is typically used to perform a one-shot measurement for contrast measurements. The most complex part is the angular alignment because any misalignment will translate 1:1 to a misalignment in the contrast over angle measurement.

With the LMK Position, you can use the 3D-scan and alignment directly with the conoscopic lens, minimize the influence of human errors, and maximize reproducibility, and directly avoid the influence of disturbing pixel structures, as shown in Figure 12.

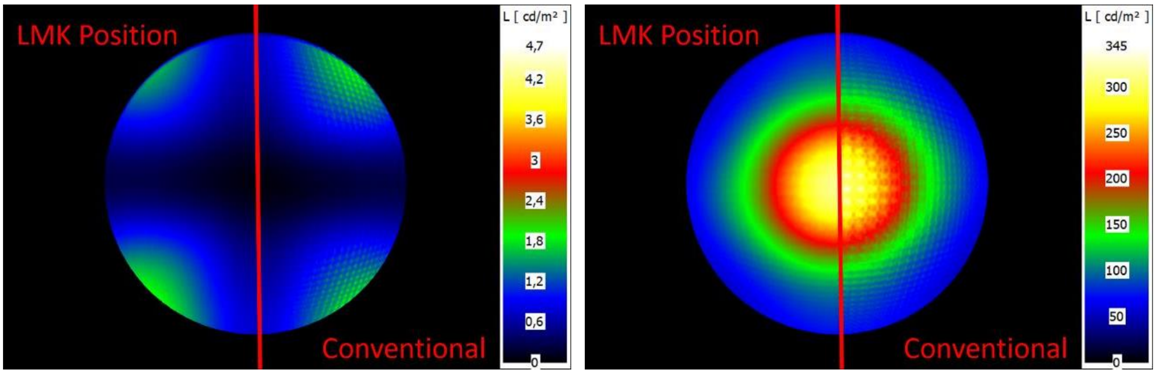
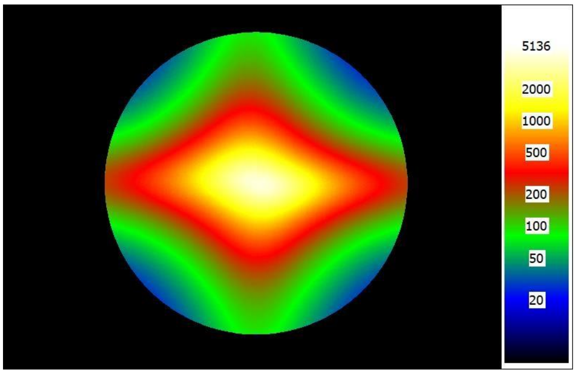


Figure 12: Conoscopic measurements of full black (left) and full white (right) with/without structure avoidance algorithm



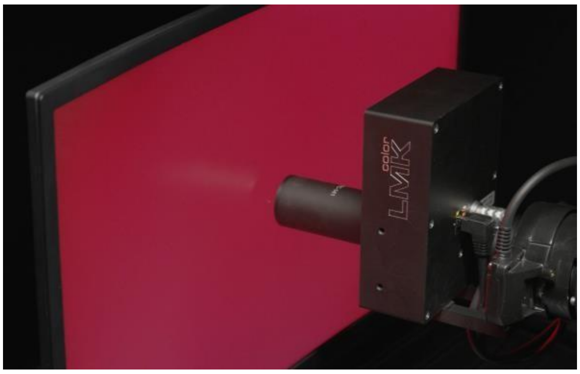


Figure 13: Calculated contrast

Figure 14: Highly precise alignment after a 3D-scan

Vantage Point measurements for any display

While spatial uniformity measurements are used to measure the objective uniformity of a display, the perceived uniformity is always a combination of spatial, angular, and Mura effects. The only way to measure the perceived uniformity is to perform a vantage point measurement. In the case of automotive displays, this is the driver's or passenger's viewpoint position relative to the display.

Again, the most significant part of the measurement is alignment. With the LMK Position, you only need one 3D scan and one click for the alignment with the distance and angular parameters for each desired position. Examples of measurement results are provided in [2].

Minimize human error, maximize reproducibility and time efficiency for complex and error-prone alignment tasks

Tailored application and automatization via SDK Interface

Besides dedicated GUIs for the described measurement tasks from above, the LMK Position package includes an ActiveX-based SDK (Software Development Kit), which allows the use of a variety of functions tailored to individual applications. It can be used with programming languages like VBA, Python, C#, Matlab, or LabView to create simple programs for any measurement tasks. Together with the ActiveX Interface of the LabSoft, tailored programs, including movement and alignment procedures, are easy to generate.

The following Matlab code shows a complete system initialization and alignment procedure followed by a 3D scan and a 3D alignment to perform a vantage point alignment of an arbitrary (e.g., 3D-free-form) display.

```
%% Init the LMK, LabSoft and LMKPosition

LMKPosition=actxserver('TTDisplayMeasurementRTKAx.TTDisplayMeasurementRTK');
LMKPosition.Init('C:\TechnoTeam\LMKPosition\temp')
COMLMK4=actxserver('lmk4.LmkAxServer.1');

LMKInstance=COMLMK4.iOpen;
ok=COMLMK4.iSetNewCamera('C:\TechnoTeam\LabSoft\Camera\TTE4250\oB222745f25');
ok=LMKPosition.InitRobot('C:\TechnoTeam\LMKPosition\NewVS060.ini');

%% Switch on the Robot

LMKPosition.RobotSwitchOn

%% Perform a complete 3DScan

[ok,LatticeX,LatticeY]=LMKPosition.DetermineLatticeConstant2(0,0,-1)
[Ok,Wert_1]=LMKPosition.DetermineOptimalVertMoveSteps(LatticeY,0)
[Ok,Wert_2]=LMKPosition.DetermineOptimalHoriMoveSteps(LatticeX,0)
[Ok]=LMKPosition.DoDisplayPosScan(6*Wert_2,Wert_2*0.9,6*Wert_1,Wert_1*0.9)

%% Check results

[ok,String]=LMKPosition.GetApplicationValue('DPS_NumberOffFound3DPoints','0');
disp(['FoundPoints:’ String])

[ok,String]=LMKPosition.GetApplicationValue('DPS_MaxRMSOffFound3DPoints','0');
disp(['MaxError: ' String])

[Ok,XSize,YSize]=LMKPosition.GetDisplaySize(0,0);

%% Perform vantage point alignment

%Drive the LMK perpendicular to the center with 50 mm distance
LMKPosition.ThreeDimensionalAllign(XSize/2, YSize/2, 50, 0, 0, 4);

%Drive the LMK to a vantage point (e.g. horizontal and vertical angles 45°) and 600
mm viewing distance based on the center of the display
LMKPosition.ThreeDimensionalAllign(XSize/2, YSize/2, 600,-45 , -45, 4)
```

Together with the LabSoft SDK, the LMK Position SDK allows you to create highly automatized and individually tailored repeatable and reproducible measurement applications

Side-by-Side spectroradiometer integration

Optionally, LMK Position can be equipped with a spectroradiometer alongside the LMK. You can use the LMK-based position alignment functionality and select the spectroradiometer in our software. Then the spectroradiometer will be moved exactly at the camera position. A high-precision geometrical calibration ensures that the optical axis of the spectroradiometer matches that of the camera. You can then perform spectroradiometer measurements as standalone measurement tasks or to calibrate the LMK exactly to the spectrum of your DUT.

In contrast to spectroradiometers integrated inside the camera, the side-by-side integration with LMK Position will not increase stray light inside the camera or introduce a polarization dependency. The photometric/spectral measurement precision/uncertainty of both devices is not affected by the other device or the integration itself.

Figure 15: LMK Position with spectrometer option: After the camera alignment, LMK Position can be switched to spectrometer mode to place the JETI specbos optical axis and entrance pupil to that of the LMK

Individual usage of robot, LMK and LMK Position

A key aspect of LMK Position, also related to its flexibility, is that each component can be used independently. TechnoTeams mechanics and calibration allow dismantling the system to use the LMK or the robot individually and later set it up as LMK Position again. This is unique compared to other automation systems, where at least the mechanical system loses value if the sensor components are removed. In the case of LMK Position, you still have your LMK and a state-of-the-art 6-axis industrial robot.

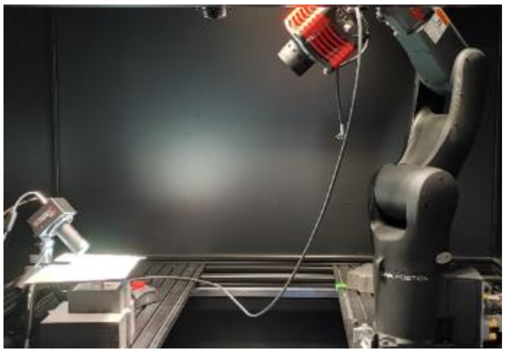


Figure 16: Full flexibility: Setup of a reflection measurement with a fixed LMK and a robots that moves the light source

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Spectroradiometrically enhanced LMK measurements are possible without sacrificing quality as no additional optical components inside the camera lead to light scattering or change polarization.

Specification, compatibility and options of standard systems

Maximum arm reach	875 mm
Axes	6
Motors/Position detection	Absolute encoder; AC servomotors for all joints, Brakes for all joints
Motion Range	J1: ±170; J2: +135 -100; J3: +153 -136; J4: ±270; J5: ±120; J6: ±360
Position repeatability (at the center of an end-effector mounting face)	±0.03 mm
Weight LMP Position + ALU Profile Rack (Robot, Controller, Cables)	< 150 kg
Alu Profile Rack outer dimensions (LxWxH)	780 mm x 780 mm x 950 mm (Robot installation height: 970 mm)
Compatible cameras	LMK5-5, LMK6-5, LMK6-12, LMK6-30*
Available lenses	All standard manual focus lenses, autofocus lenses; conoscope, macro lenses, NED lenses
Installation environment of the LMK Position	Temperature: 0 to 40 ℃ Humidity: 20 to 90% RH Vibration 4.9 m/s² (0.5 G)
Optional equipment	7th axis (linear) mounted below the robot (below J1) Specbos 1211-LAN VIS-NIR spectroradiometer, Industrial operation PC (19'' rack)