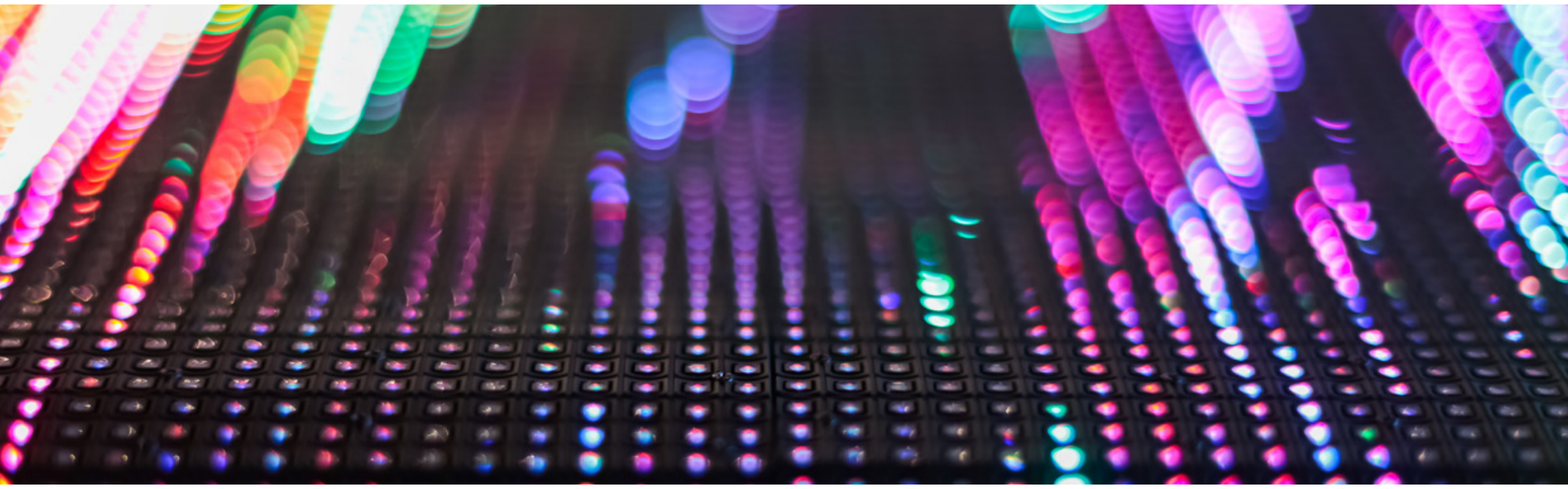
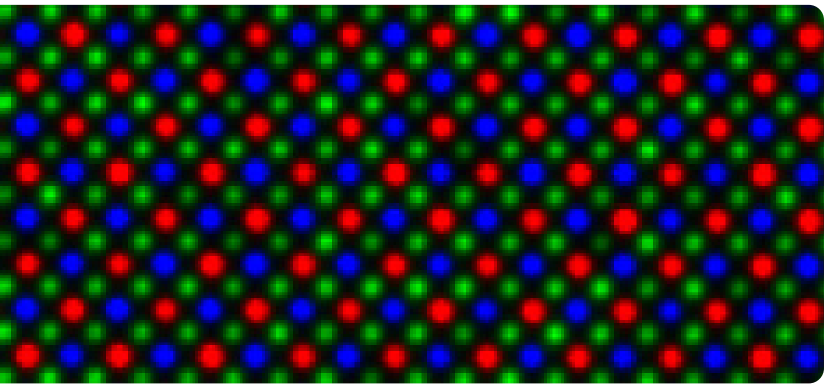
SYSTEMS
& SOLUTIONS

MicroLED / MicroOLED Measurement Portfolio & Solutions





For
Display
Wafer &
Module

Instrument Systems
KONICA MINOLTA Group

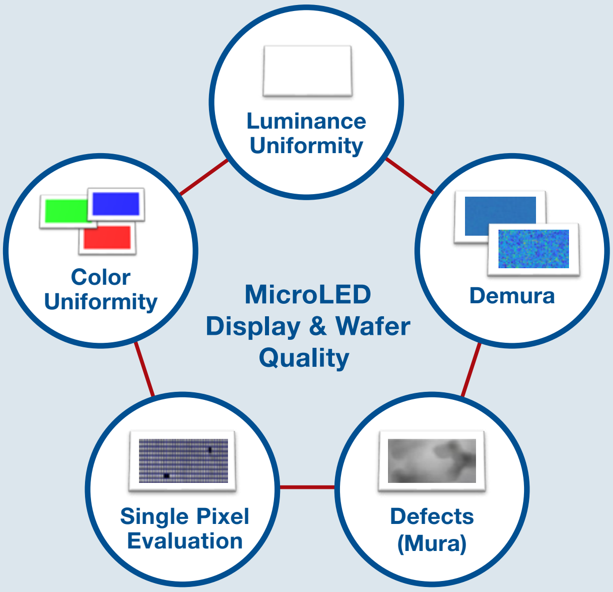
01 \\ Introduction

MicroLED display technology is rapidly advancing toward high-volume manufacturing, delivering unmatched brightness, contrast, efficiency, and lifetime for applications ranging from AR/VR and automotive to premium consumer displays. As pixel sizes shrink and densities increase, manufacturing success depends on accurate optical test and metrology at every stage—from wafer to final display.

In production, speed and accuracy must go hand in hand. Measurement systems must keep pace with demanding takt times while providing the photometric and colorimetric accuracy required for reliable pass/fail decisions. Even small measurement errors can lead to false rejects, yield loss, or escaped defects that impact display quality.

Instrument Systems advanced optical metrology solutions enable high-throughput testing with exceptional accuracy and repeatability, supporting inline process control, optimized binning, and higher overall yield. In MicroLED manufacturing, fast and accurate measurement is not just quality control—it is a key driver of productivity, profitability, and scalable production.

MicroLED evaluation criteria



Within the Instrument Systems portfolio, various solutions are available to support these MicroLED display and wafer measurement tasks. The following test systems are covered in this brochure:

- **LumiTop Imaging Colorimeter**: High-resolution imaging measurement of luminance and color for MicroLED displays, enabling fast, traceable 2D analysis of uniformity and defects
- **Software Suite for µLED specific applications:**
  - Single Pixel Evaluation
  - Automated Live calibration
  - User calibration (MyCal / LiveCal)
- **TOP 150 & TOP 200 Spotmeters**: Enable precise, traceable spot measurements of small, high-brightness emitters like µLED pixels.
- **DMS Goniometer**: Comprehensive angular and spatial characterization of light-emitting devices from wafer to display under controlled measurement conditions
- **RTS Optical Inspection System**: A fully automated system for fast, non-destructive full-wafer MicroLED testing with high-precision optical measurement.

02 \\ MicroLED / MicroOLED Measurement Challenges

MicroLED displays combine ultra-small pixel sizes with narrow emission spectra and pixel-level wavelength variations. Accurate measurement therefore requires both high spatial resolution and spectrally resolved data.

These effects can lead to measurement uncertainties, impacting binning accuracy, yield, and overall display quality.

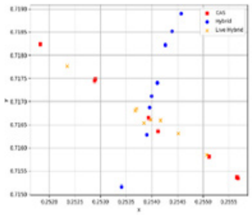
At the same time, millions of emitters must be evaluated efficiently across wafers (by photoluminescence, PL) and displays (by electroluminescence, EL). Conventional approaches typically trade off between spectral accuracy and measurement speed, limiting their suitability for high-density µLED testing.

Instrument Systems addresses these challenges through a combined imaging and spectrally referenced measurement approach. These capabilities enable accurate, high-resolution, and scalable testing from lab to production.

Core measurement capabilities

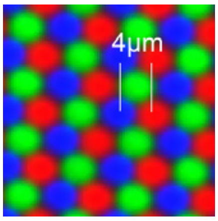
High accuracy through spectral correction

- Spectrally referenced imaging using CAS
- Dynamic calibration (MyCal / LiveCal)



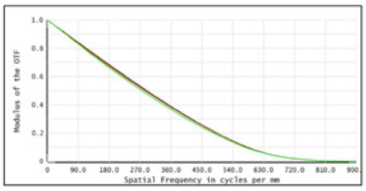
µm-level spatial resolution

- High-resolution imaging with microscope optics
- Pixel-level luminance and chromaticity mapping



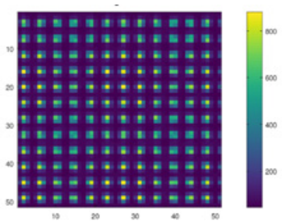
MTF (Modulation Transfer Function)

- MTF-optimized optical system design
- Accurate spatial and contrast reproduction



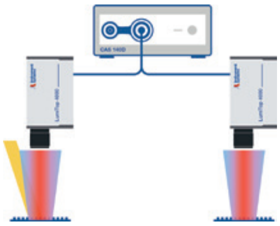
Reliable sampling of dense arrays

- Optimized sensor resolution and sampling
- No pixel loss or sampling artefacts



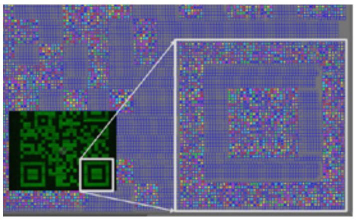
High-speed one-shot measurement

- Parallel image acquisition of entire arrays
- GPU-accelerated data processing



Wafer-to-display consistency

- Unified PL and EL measurement approach
- Comparable results across process stages



03 \\ LumiTop Imaging Colorimeter

The LumiTop imaging colorimeter implements the core measurement capabilities required for MicroLED testing. By combining high-resolution imaging with a spectrally referenced measurement approach, it enables accurate, fast, and scalable characterization of µLED displays and wafers.

Measurement principle

The LumiTop design combines a camera with a high-end array spectroradiometer, which acts as a live reference to ensure true color measurement. The camera image and reference spectrum are captured in a single acquisition, enabling instant fine correction of measured color values.

Customized for lab and production demands

LumiTop, LumiTop X, and LumiTop M series are designed to meet diverse laboratory and production requirements with a wide range of customization options:

- High-dynamic, low-noise CMOS RGB cameras (12–150 MP), expandable up to **600 MP** via pixel shift
- Up to **81 dB** dynamic range for precise low- and high-luminance measurement
- Internal or external neutral density filters to extend measurement range for extremely bright light sources
- Industry-grade objective lenses for microdisplays, flat panels, wafers, and near-eye displays

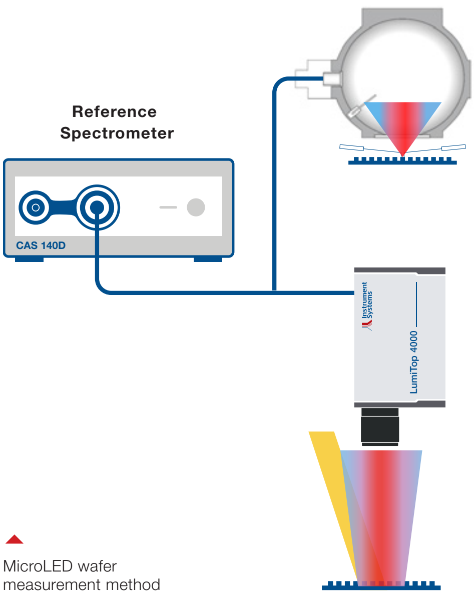
Key features

- One-shot image acquisition for high-speed measurement
- Spectrally referenced imaging using CAS spectroradiometer
- Live automated and customized calibration (LiveCal/MyCal) for DUT spectral variations
- No narrow-bandwidth limitations compared to filter-based systems
- Multiple color matching functions for application-specific color evaluation
- High stability and robustness (no moving parts)
- Traceable measurement from lab to production

Precision, speed and flexibility

The LumiTop imaging colorimeter delivers exceptional speed combined with absolute photometric accuracy for µLED and µOLED displays and wafers.

Specially developed microscope and macro lenses enable reliable production testing across a wide range of display types — from microdisplays used in AR/VR headsets and smart glasses to watch displays. Interchangeable microscope lenses allow seamless adaptation to different device-under-test (DUT) sizes, while the optical design is optimized for both display and wafer inspection.

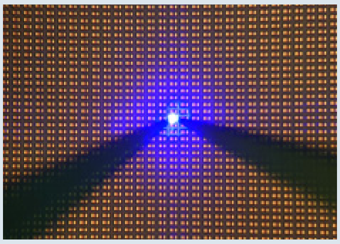


MicroLED wafer measurement method

Conventional method

Sequential contacting of individual LEDs

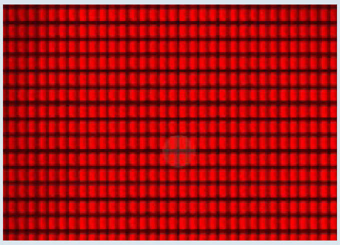
- Electroluminescence measured via an integrating sphere
- Proven method for LED lighting testing



ILMD approach

2D measurement of PL or EL across a wafer

- With LumiTop – comparable results at much higher speed
- Proven one-shot method for display testing



LumiTop solutions for microLED testing

LumiTop 4000	
Sensor	12 MP CMOS (4096 × 3000 px)
Pixel size	3.45 × 3.45 µm
Measurement range	0.06 – 800,000 cd/m^2
ND filter	OD0.3 – OD6 (on demand)
Min. meas. time	0.7 s
Speciality	Hardware trigger

Lens options		
Lens	**FoV**	**Resolution**
100 mm (@×1)	14 × 10 mm	3.45 µm/px
×2	7.0 × 5.0 mm	1.73 µm/px
×5	2.8 × 2.0 mm	0.68 µm/px
×10	1.4 × 1.0 mm	0.34 µm/px

LumiTop 5300	
Sensor	24MP CMOS (5312 × 4600 px)
Pixel size	2.74 × 2.74 µm
Measurement range	0.06 – 800,000 cd/m^2
ND filter	OD0.3 – OD6 (on demand)
Min. meas. time	0.7 s
Speciality	Small pixel size

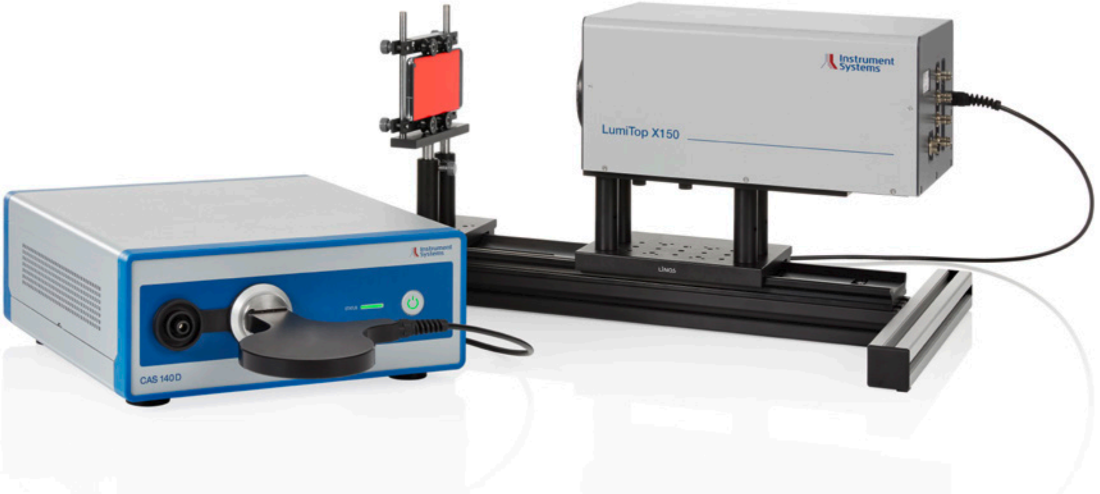
Lens options		
Lens	**FoV**	**Resolution**
100 mm (@×1)	14 × 12 mm	2.74 µm/px
×2	7.3 × 6.3 mm	1.37 µm/px
×5	2.9 × 2.5 mm	0.55 µm/px
×10	1.4 × 1.2 mm	0.27 µm/px

LumiTop X150	
Sensor	14,192 x 10,640 (151 megapixels)
Pixel size	3.76 × 3.76 µm
Measurement range	0.003 cd/m^2 – 50,000 cd/m^2
Dynamic range	80.8 dB

Field of view at selected magnification		
Magnification β	**FOV size**	**Resolution**
β = 1.35 – 1.54	max. 40 mm x 30 mm	2.5 – 2.8 µm/px
	min. 35 mm x 26 mm	
β = 0.28 – 0.38	max. 193 mm x 145 mm	10 – 14 µm/px
	min. 137 mm x 103 mm	
β = 0.16 – 0.24	max. 331 mm x 248 mm	16 – 24 µm/px
	min. 226 mm x 170 mm	
β = 0.05 – 0.2	max. 847 mm x 635 mm	19 – 75 µm/px
	min. 276 mm x 207 mm	

LumiTop M150 – latest generation	
Sensor	14,192 x 10,640 (151 megapixels)
Pixel size	3.76 × 3.76 µm
Measurement range	0.04 cd/m^2 – 2.2 x 10^7 cd/m^2
Dynamic range	80.8 dB

Field of view at selected magnification		
Magnification β	**FOV size**	**Resolution**
β = 11.25	4.74 mm x 3.56 mm	0.35 µm/px
β = 4.5	11.8 mm x 8.9 mm	0.85 µm/px



04 \\ LumiSuite Software: From Measurement to Insight

The LumiSuite software package provides an intuitive environment for µLED display and wafer analysis, enabling easy integration and operation.

SmartAnalysis is specifically designed for µLED and OLED applications, supporting advanced evaluation methods such as single-pixel analysis and optimized color calibration.

The **Single Pixel Evaluation (SPE)** tool detects emitters, typically µLEDs or OLEDs, within an image and evaluates their intensities and color properties.

MyCal and **LiveCal** enable application-specific and real-time calibration for accurate color measurement.

Key features

- User-friendly graphical interface (GUI) for intuitive workflow guidance
- SmartAnalysis structured in a clear 3-step process, from data acquisition to pixel-level analysis
- Comprehensive analysis tools for display and wafer characterization

SmartAnalysis

Data acquisition

- Luminance
- Color uniformity
- High-accuracy spectral measurement using LumiTop as a spotmeter

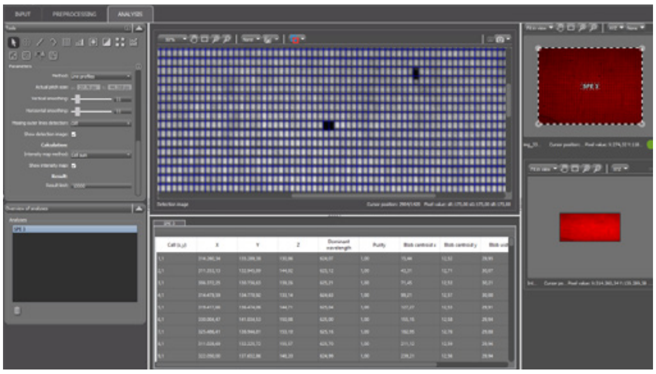
Image processing

- Automated (LiveCal) or user calibration (MyCal)
- Color correction
- Binning
- Smoothing
- Moire filtering
- Multipoint correction

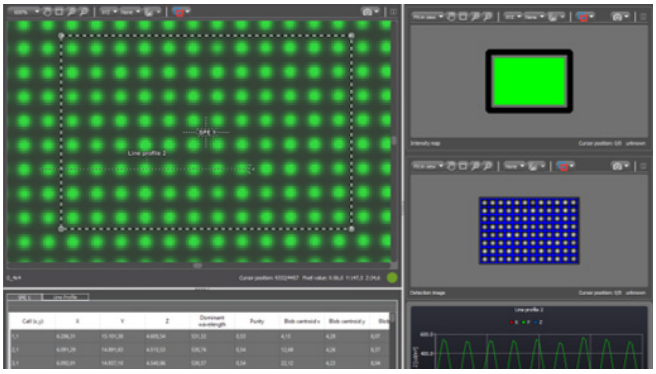
Image analysis

- Luminance
- Chromaticity
- Dominant wavelength
- Emitter size and position
- Chromatic aberration
- Contrast ratio
- Michelson contrast
- Slanted edge analysis
- Defect pixel/region analysis
- Single pixel evaluation (SPE)

Single Pixel Evaluation (SPE) Results



Photoluminescence (PL) µLED wafer



Electroluminescence (EL) µLED display

MyCal

Ultimate calibration accuracy for µLED and OLED measurement

Achieve a new level of measurement precision with the advanced **MyCal calibration** technology.

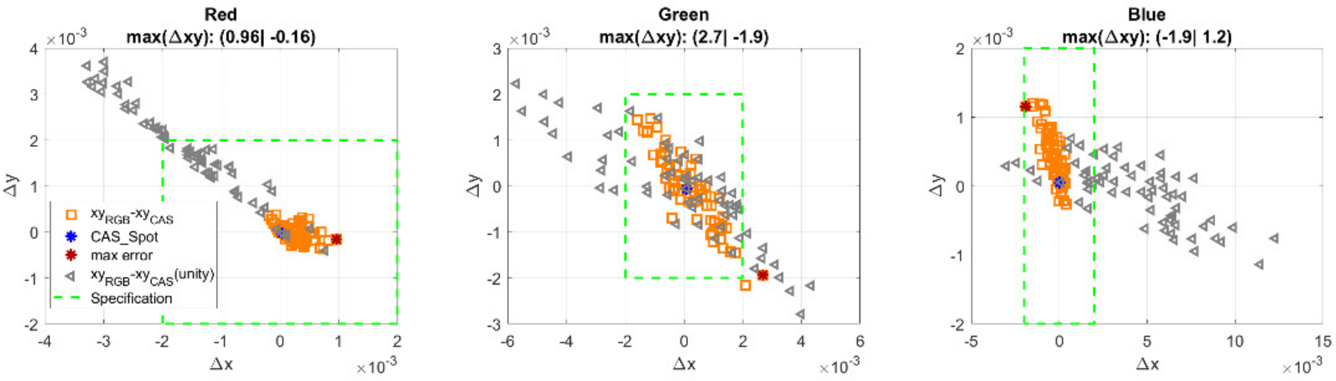
MyCal enables fully customized color calibrations for LumiTop systems, leveraging the high accuracy of CAS spectrometer data. These user-defined calibrations can be precisely tailored to real samples, significantly improving color and luminance accuracy — especially for spectrally complex and non-uniform displays such as µLED and OLED.

LiveCal

Intelligent real-time adaptive calibration

Further increase calibration efficiency with the fully automated **Live Hybrid** acquisition mode. This innovative approach generates DUT-specific color calibrations in real-time, using the actual spectral characteristics of the measured sample.

- Dynamic calibration based on live measurement data
- Enhanced XYZ image accuracy through fine correction using CAS spectrometer reference data
- Optimized for next-generation display technologies



Faster processes, higher confidence, higher yield

Custom calibrations can be stored either temporarily or permanently on the LumiTop device and applied seamlessly during measurements — replacing standard factory calibration when needed.

- Achieve superior measurement accuracy with application-specific calibration
- Reduces calibration time and accelerates production takt time
- Ensure consistent, traceable, and reliable results across all measurements

With MyCal, calibration becomes a measurable performance advantage for µLED / OLED display and wafer inspection.

The figure illustrates the color measurement uncertainties in xy coordinates for a µLED array with spectral peak variations of up to 5 nm.

Measurements performed with LumiTop using automatic live spectral calibration (orange squares) demonstrate outstanding accuracy, with deviations as low as 0.5 to 2 color points, depending on the color.

In contrast, a colorimeter without spectral calibration (grey triangles) shows significantly higher deviations — reaching more than 10 color points.

05 \\ TOP 150/200/300 Spotmeters

Key features

- Perfectly round and sharply defined measuring spot for precise isolation of µLED pixels and small emitters
- Convenient focusing via integrated viewfinder camera
- Wide range of lenses for flexible spot sizes and measurement distances
- Software-controlled selection of multiple measuring spot sizes
- Flexible fiber connection with patented mode mixer

High-precision spot measurement for µLED characterization

Accurate characterization of µLED devices requires precise measurement of extremely small, high-brightness emitters.

A well-defined and stable measurement spot, combined with reliable light coupling, is essential to ensure reproducible and traceable results.

In combination with the spectrometer, the TOP Telescopic Optical Probe Series enable highly accurate spot measurements of radiance, luminance, and chromaticity. It is ideally suited for µLED displays, high-density emitter arrays and virtual images based on µLED ligh sources.

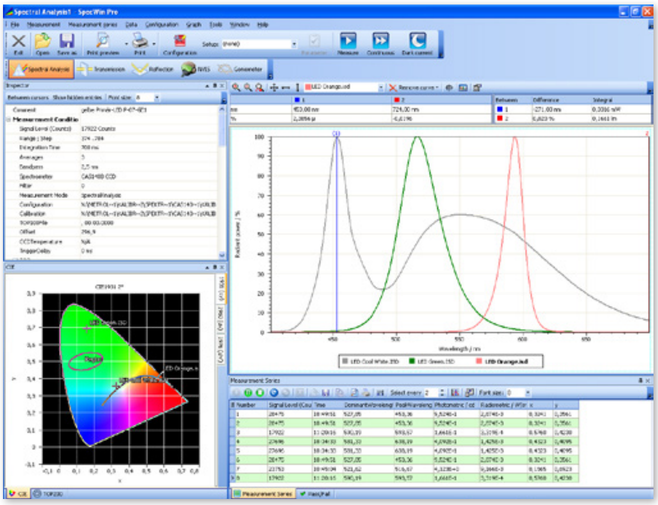
A multimode fiber guides the collected light from the TOP to the spectrometer. The patented mode mixer ensures uniform light transmission into the fiber, enabling reproducible measurement results even when the fiber position changes.

The TOP can be operated with all spectroradiometers of the CAS 140D Series as well as with the DTS Display Test System, using SpecWin Pro software. Remote control is provided via a USB interface.

Why it matters for µLED

Precise spot definition and stable signal transmission are critical for accurate measurement of µLED devices.

The TOPs ensure reliable characterization of even narrow bandwidth and very bright emitters — supporting consistent, traceable results in both laboratory and production environments.



Analysis of an LED with SpecWin Pro software

06 \\ DMS Goniometer

The DMS system enables precise characterization of light-emitting devices from wafer to display through automated angular and spatial measurements under controlled conditions.

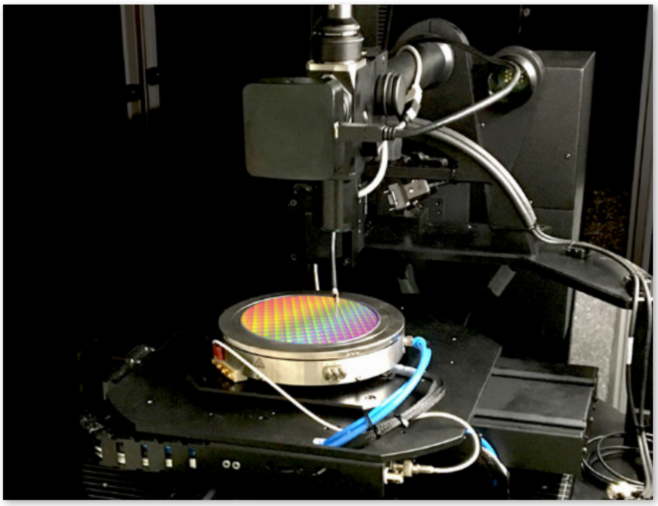
MicroLED testing applications

DMS systems are ideally suited for MicroLED characterization at wafer and display level. Precise control of viewing direction enables detailed analysis of angular emission, while spectral measurements support evaluation of wavelength shifts and color performance.

Combined with controlled DUT driving, temperature, and ambient conditions, DMS ensures accurate and repeatable MicroLED testing.

Key features

- Automated angular and spatial measurements
- Full control of viewing direction and measurement conditions
- Spectral and photometric analysis via spectrometer and photometer
- Flexible configuration for wafer and display testing
- Accurate and repeatable measurement results



Wafer testing

- Angular distribution of luminous intensity
- Wavelength shift over viewing angle
- NA adaptation for high angular resolution
- Motorized probing for DUT driving
- Temperature-controlled measurements

07 \\ RTS – Full-Wafer MicroLED Testing Solution

The RTS system is designed for optical inspection of µLED wafers. It combines Rapitech's automated wafer handling technology with high-precision measurement solutions from Instrument Systems to form a high-efficiency, high-precision inspection system.

RTS provides fast, non-destructive, and high-sensitivity testing, enabling effective evaluation of emission characteristics and uniformity of wafers, and supporting process optimization and yield improvement.

Non-destructive, high-sensitivity measurement

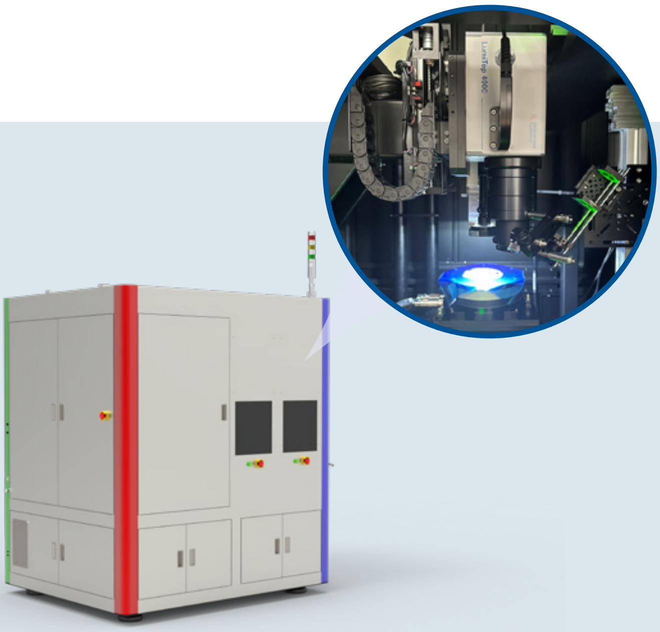
RTS utilizes a non-contact, low-power excitation method, allowing direct testing of µLED wafers without cutting or coating, reducing sample loss. The measurement process does not damage the material structure and is suitable for quality control in both R&D and production. Compared to conventional EL point measurement, which may cause irreversible damage, RTS maintains sample integrity while providing stable measurement results. Equipped with a CAS high-accuracy spectrometer and a low-luminance LumiTop imaging colorimeter, the system detects weak light signals down to 0.009 cd/m^2 and measures wavelength, luminance, and color. All measurement data are traceable to Instrument Systems' metrology laboratory.

Fast, efficient full-wafer testing

RTS can complete full scanning of a 6-inch wafer within minutes, meeting efficiency and stability requirements for mass production. Combined with LumiSuite SDK and algorithm-assisted analysis, it automatically identifies defect regions and generates distribution maps of wavelength, luminance, and color, improving inspection and analysis efficiency. RTS integrates spectrometer and camera on a single platform based on the LumiTop concept, enabling simultaneous multi-parameter measurement and correlation with display module results. The modular design supports different excitation wavelengths, filters, and detection modules, and is suitable for microLED, quantum dots, and other optoelectronic materials.

Data visualization and cost efficiency

RTS generates optical distribution maps and supports output formats such as CSV, Excel, and images for further analysis and reporting. The non-destructive approach extends sample and component lifetime, reduces equipment and maintenance costs, and supports yield improvement.



Key features

- Fully automated wafer testing with automatic loading, alignment, and testing
- High-precision, traceable optical measurement using spectrometers and imaging colorimeters
- Wide luminance range (0.009 to 120,000,000 cd/m^2) with high-sensitivity detection
- Fast full-wafer scanning (< 5 min for 6-inch wafers) with algorithm-based defect inspection and wafer mapping
- LiveCal real-time calibration for stable, repeatable measurement results

09 \\ Technical Specifications

TOP 150 & TOP 200 Spotmeters

Model	TOP 200	TOP 150
Spectral range	Determined by the lens (see ordering information)	
View-finder camera	2560 x 1920 pixel, RGB	752 x 480 pixel, RGB
Aperture diameter	0.125 / 0.25 / 0.5 / 0.8 mm	customer specific
Dimensions basic unit (L x H x W)	141.5 mm x 136 mm x 98.3 mm	131.5 mm x 113 mm x 89.3 mm
Weight	2.2 kg	1.5 kg
Power supply	100 VAC to 240 VAC, 50/60 Hz	4.75 to 5.25 V via USB 2.0
PC connection	USB 2.0	
Operating temperature range	+10 °C to +35 °C	
Relative humidity	< 70 % non-condensing	
Base plate	¼-20 UNC, 4 x M6	

TOP 300 AR/VR Spotmeter

Optical properties	
Entrance pupil diameter (Others upon request)	2.5 mm / 3.0 mm / 3.6 mm / 4.5 mm (One entrance pupil can be configured)
Focus distance (Others upon request)	1000 mm / 1333 mm / 1500 mm (One focus distance can be configured)
Optical probe Field of View	±1.2°
View finder Field of View	±3.5°
Fiber length	Approx. 3 m
Bending radius fiber	200 mm
View finder resolution (H x W)	2592 px x 1944 px
Nominal resolution	5 MP
Type view finder	Mono

DMS Goniometer

Component / Feature	DMS 201	DMS 505	DMS 803	DMS 903	DMS 904
Mechanics					
Scan range theta inclination	0° to 90° 1), 4)	0° to 90° 1)	0° to 90° 1)	0° to 80°	0° to 80°
Scan range phi rotation	-	0° to 360°	0° to 360°	0° to 360°	0° to 360°
Reflective Illumination angle	0° to 90° 1), 4)	0° to 90° 1), 4)	0° to 90° 1)	0° to 70°	0° to 70°
Min. step Theta/Phi/ Refl. Illumn.	1° 4)/ - / 1° 4)	0.1°	0.1°	0.01°	0.01°
Positioning accuracy Theta/ Phi/Refl. Illumn	1°	0.1°	0.1°	0.1°	0.1°
Resolution Theta/Phi/ Refl. Illumn	-	0.01°	0.01°	0.01°	0.01°
Scan range X/Y translation	-	±10 mm 4)	±50 mm	X: ±300 mm; Y: ±225 mm	X: ±300 mm; Y: ±225 mm
Scan range X+	-	-	-	-	±700 mm
Scan range Z	300 mm 4)	114 mm	250 mm	280 mm	320 mm
Min. step X/Y/Z	-	0.1 mm	0.1 mm	0.1 mm	0.1 mm
Positioning accuracy X/Y/Z	-	Z: 0.05 mm	X/Y: 0.005 mm; Z: 0.05 mm	0.05 mm	0.05 mm
Resolution X/Y/Z	-	Z: 0.005 mm	X/Y: 0.001 mm; Z: 0.005 mm	0.01 mm	0.01 mm
Sphere of confusion (all axis)	-	100 µm	100 µm	300 µm	300 µm

DMS Goniometer

Component / Feature	DMS 201	DMS 505	DMS 803	DMS 903	DMS 904
DUT dimensions					
Max. diagonal	600 mm (23")	600 mm (23")	600 mm (23")	1600 mm x 1300 mm (81")	1800 mm x 1200 mm (85”)
Max. diagonal for motorized x-y scanning	-	-	459 mm (18")	1000 mm x 800 mm (50")	1200 mm x 700 mm (54”)
Orientation of DUT surface	horizontal	horizontal	horizontal	horizontal	horizontal
Dimensions					
DMS mechanics (L x W x H)	790 mm x 500 mm x 580 mm	1500 mm x 1080 mm x 2030 mm	1500 mm x 1080 mm x 2030 mm	1895 mm x 1465 mm x 1855 mm	2250 mm x 1350 mm x 1950 mm
Electronics rack	19" table rack	715 mm x 555 mm x 1025 mm	715 mm x 555 mm x 1025 mm	715 mm x 555 mm x 1250 mm	715 mm x 555 mm x 1250 mm
Thermostream temp. control	1000 mm x 725 mm x 1240 mm	1000 mm x 725 mm x 1240 mm	1000 mm x 725 mm x 1240 mm	1000 mm x 725 mm x 1240 mm	1000 mm x 725 mm x 1240 mm
Weight					
DMS mechanics	35 kg	405 kg	405 kg	700 kg	800 kg
Electronics rack	10 kg	105 kg	105 kg	120 kg	120 kg
Thermostream temp. control	230 kg	230 kg	230 kg	230 kg	230 kg

RTS MicroLED Wafer-Level Optical Inspection System

System Configuration	
Single Wafer Measurement Time	< 5 min 1)
Number of Dies per Measurement	100,000 2), 3)
Minimum Detectable Die Size	15 µm × 20 µm 3)
Spectrometer Peak Wavelength (WD) Accuracy	0.5 nm
Wafer Sizes	4", 6", 8"
Measurement Parameters	LOP, WLD, WLC, WLP, x, y, u, v, u', v'
Chromaticity Accuracy (x, y)	±0.002
Optics	100 mm Lens, 2X, 5X, 10X 3)
Data Output	CSV, Excel, Image (PNG/TIFF)
Environmental Requirements	
Cleanroom Class	Clean room (Class ~ 10000)
Temperature	15 °C – 35 °C
Humidity	<85 % RH with no condensation
System Specifications	
Dimensions	On request
Weight	On request
Power Supply	100 – 240 VAC, 50/60 Hz

1) Based on 6" wafer, die size 35 µm × 60 µm, pitch 15 µm, measurement area 7 × 7 mm
2) Based on die size 15 µm × 20 µm, pitch 10 µm, measurement area 7 × 7 mm
3) Using 100 mm lens without magnification; smaller sizes possible with Micro Lens

Instrument Systems GmbH and Rapitech Enterprise Co., Ltd. reserve the right to make technical changes. Errors and omissions excepted.
Subject to general terms and conditions.