TechnoOptis

AR/VR Evaluation Example

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TechnoOptis Co., Ltd.

Introduction

The market for wearable devices, including AR (Augmented Reality), VR (Virtual Reality), and MR (Mixed Reality), is rapidly growing. AR technology overlays digital information onto the real world and VR technology allows users to experience virtual worlds. MR combines virtual and real-world elements by overlaying virtual objects onto the real world up to the device. As the wearable device market continues to expand, it becomes increasingly important to assess the optical properties of HMD(Head Mounted Displays) and AR glasses.

Usually, evaluations of flat panel display measures such as luminance, chromaticity, and uniformity. On the other hand, new technology near-eye displays (NED) in AR/VR/MR systems magnify images across the entire field of view, making display defects more visible, therefore new display evaluation methods for AR/VR/MR technologies are necessary.

Below are examples of evaluation cases for AR/VR development, design, and production.

1. Panel Evaluation for Integration into AR/VR/MR Devices

■1-1.Evaluation of luminance, Chromaticity, and Uniformity for RGBW : IEC63145-20-10 (5.4)

The evaluation process typically involves displaying full screens of red, green, blue, and white to assess luminance, chromaticity, and uniformity.

Measurements are usually taken from the panel's normal direction (0°) in a dark room. Figure 1 provides an illustration of the measurement image.

Mura (uneven brightness) across the panel between the center and periphery can cause discomfort for users of Head-Mounted Displays (HMD), so minimizing mura is crucial. Particularly for panels used in AR/VR/MR devices, the panel is magnified by the lenses in the HMD, which can accentuate any mura.

Measurement method for those display, at first measure luminance at various points, and confirming uniformity which calculated from the highest and lowest values. Higher uniformity values indicate superior luminance uniformity across the panel. Furthermore, measuring chromaticity, and calculating color differences. For instance, the 2D spectroradiometer SR-5100 can measure luminance values, which can then be pseudo colored to visualize uniformity status, enabling numerical management (Fig.2). Spectral data analysis can identify any discrepancies in the measurement by determining which wavelength ranges are affected.

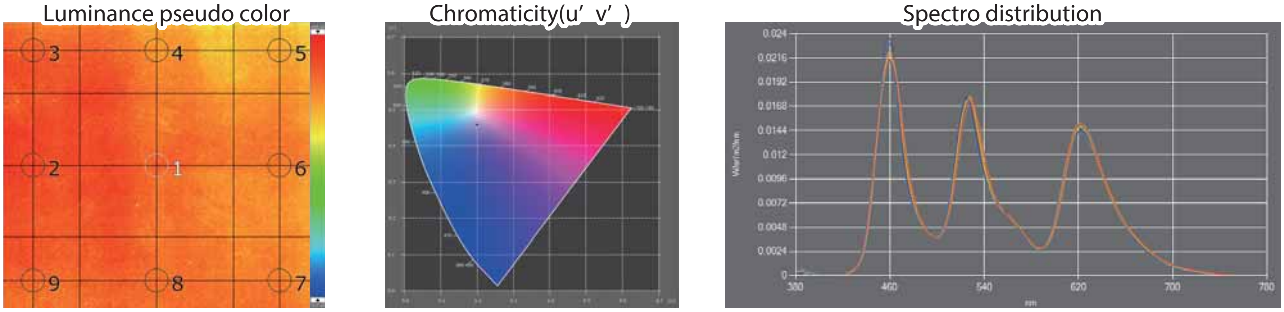
The Luminance & Chromaticity Analyzer UA-20 is instrument which can easily measure uniformity. It is also compact size making it ideal for use on production lines. It comes with an SDK as standard, allowing for data acquisition as needed.

2 DSpectroradi-ometer SR-5100

Luminance ＆ Chromaticity Uniformity Analyzer UA-20

Fig.1Example image of Luminance, Chromaticity, and Uniformity Measurement

Luminance pseudo color　Chromaticity(u'　v'　)　Spectro distribution



Data Sheet

データシート

統計　測定値　分光放射輝度

☑	スポットNo	X座標	Y座標	三刺激値X 平均値	三刺激値Y(輝度) 平均値	三刺激値Z 平均値	色度x 平均値	色度y 平均値	色度u' 平均値	色度v' 平均値	色温度 平均値	偏差 平均値	主波長 平均値	刺激純度 平均値
☑	1	324	302	589.915056	611.623047	708.399023	0.30887	0.32023	0.19847	0.46298	6804.20	0.0006	421.33	0.0271
☑	2	64	302	598.667523	618.338665	713.776034	0.31006	0.32025	0.19931	0.46317	6732.36	0.0000	-563.10	0.0290
☑	3	64	60	600.161076	614.035753	726.148836	0.30931	0.31646	0.20023	0.46094	6818.86	-0.0016	-562.16	0.0422
☑	4	324	60	587.050638	602.371022	721.797921	0.30716	0.31518	0.19920	0.45990	6969.04	-0.0011	-565.85	0.0433
☑	5	583	60	582.972578	598.001412	711.009076	0.30813	0.31607	0.19955	0.46055	6896.80	-0.0012	-564.60	0.0416
☑	6	583	302	587.544770	607.277551	709.121279	0.30859	0.31896	0.19876	0.46223	6834.64	0.0001	-566.06	0.0313
☑	7	583	544	582.640326	606.806136	690.599940	0.30991	0.32276	0.19824	0.46453	6716.69	0.0014	430.71	0.0194
☑	8	324	544	583.932042	609.561545	703.258899	0.30786	0.32137	0.19732	0.46346	6852.11	0.0017	466.60	0.0268
☑	9	64	544	589.967288	611.513646	709.907745	0.30866	0.31993	0.19844	0.46279	6819.92	0.0006	429.38	0.0281

Fig.2 Example of Luminance, Chromaticity, and Uniformity Measurement Results with SR-5100

In addition to evaluating displays, it can also assess the luminance, chromaticity, and uniformity of backlight modules. It can also evaluate the spectral transmittance of goggle lenses and other optical components.
To calculate the spectral transmittance of goggle lenses, divide the spectral radiance transmitted through the lens by the spectral radiance of the light source (Fig. 3). During measurement, it is important to maintain a consistent distance between the light source and the spectroradiometer.
Additionally, using the 2D spectroradiometer SR-5100 enables the display of spectral transmittance data through image comparison and the presentation of transmittance luminance profiles through sectional view.

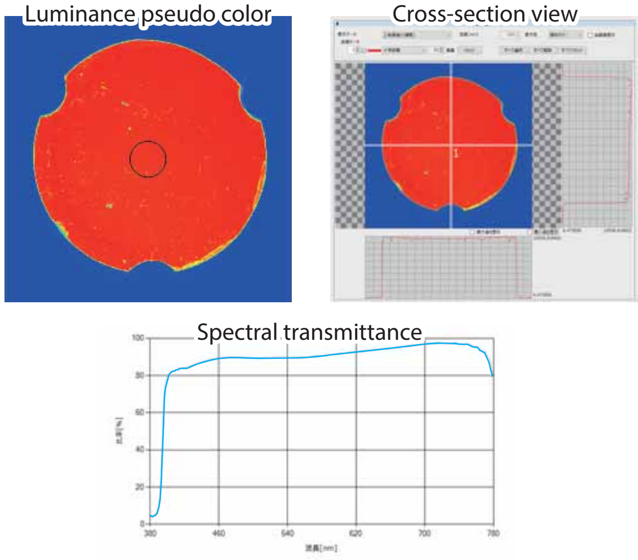


Fig.3 Example of spectral transmittance measurement results for goggle lens.

2. Evaluation of HMD

HMD displays images with a wide field of view, covering the entire horizontal field of vision of the human eye. Instruments used to measure luminance for HMD should be nationally traceable. The 2D spectroradiometer SR-5100HM is a nationally traceable instrument that enables HMD measurement when equipped with a C-mount lens (Fig.4). Additionally, the 2D spectroradiometer SR-5100 can precisely measure each spot through spectrophotometry measurement.

Fig.4 SR-5100HM + C-mount lens

■2-1. Nine point average value of Luminance(L),chromaticity(u', v') : IEC63145-20-10 (5.3)

Figure 5 displays an example of measuring 9 selected points on the HMD that shows a 5x5 checkerboard pattern (IEC63145-20-10). Measurements can be taken for the average values of luminance (L) and chromaticity (u', v') at the measurement points. And also, it can measure single color display of R, G, B, and W.

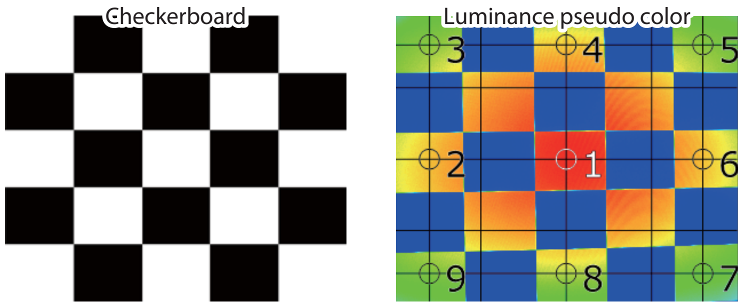


Fig.5 Example image of measurement result with checkerboard patten (White center)

■2-2. Luminance non-uniformity (NU),Chromaticity non-uniformity ($(\Delta u'v')_{max}$),Contrast ratio (CR) : IEC63145-20-10 (6.3, 6.5, 6.6)

Based on the measurement results of the 9 points from Fig. 5, it calculates several parameters including luminance uniformity (LU), luminance non-uniformity (NU), chromaticity uniformity ($\Delta u'v'$), chromaticity non-uniformity ($(\Delta u'v')_{max}$), contrast ratio (CR), mean contrast ratio (CR_a), and contrast non-uniformity (NU_{CR}). To obtain the CR value, measurements of both the white center checkerboard (Fig. 5) and the black center inversion pattern (Fig. 6) are required.

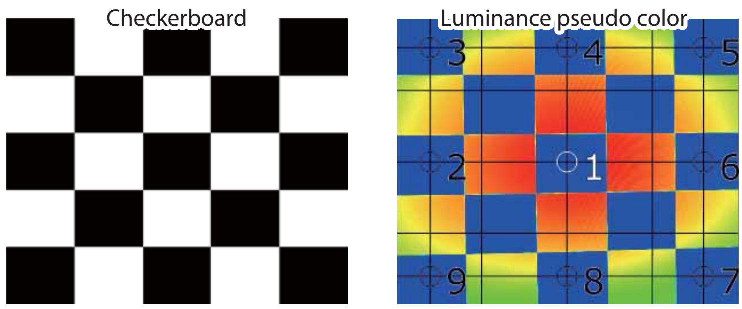


Fig.6 Example image of measurement result with checkerboard pattern (Black center)

2D spectroradiometer SR-5100HM micro lens type can be attached additional wide-angle lens that match the field of view each AR/VR device. We measured 2 type of AR/VR devices (Fig7). And (Fig8) indicate gray scale of luminance image of measurement results of SR-5100HM with additional lens. IN addition, Spectroscopic measurement allow to display spectral distribution for the nine measurement points of each AR/VR devices (Fig9). NU, Δu′ v′ and CR are calculated as follows:

$$NU=\frac{(Y_{max} - Y_{ave})}{Y_{ave}}$$

$$(\Delta u' v')_{max}=\sqrt{(u_j'-u_i')^2+(v_j'-v_i')^2}$$

$$CR=\frac{Y_{white}}{Y_{black}}$$

	AR #1	AR #2	VR #1	VR #2
Display	Micro OLED	Si-OLED	LCD	OLED
Resolution(per-eye)	1920 x 1080	1920 x 1080	2448 x 2448	1400 x 1600
Field of View	46°(Diagonal)	34°(Diagonal)	116°(H), 90°(V)	93°(H), (93°(V)

Fig.7 The four AR/VR display devices.

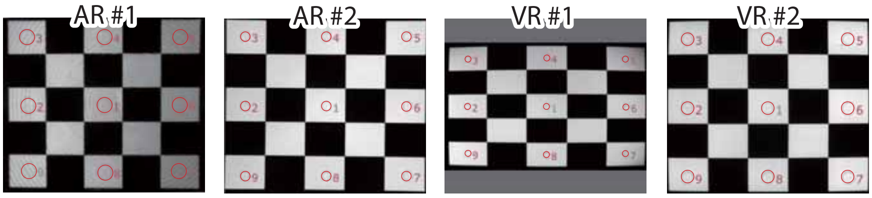


Fig.8 Gray scale of luminance image

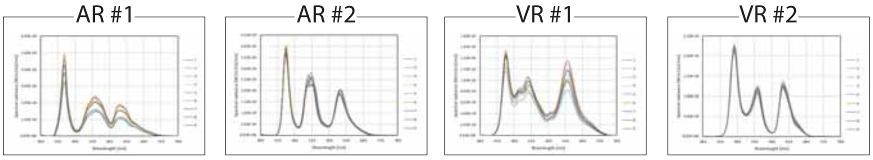


Fig.9 Spectral distribution for the nine points

2-3.Contrast Modulation Transfer Function (CM/MTF) : IEC63145-22-10 (6.4)

Brightness and color contrast modulation is a technique used to enhance the visibility and sharpness of VR images by adjusting the contrast. The Contrast Modulation Transfer Function (CM/MTF) is measured by displaying line pair patterns, and evaluation results are used to improve and optimize contrast modulation technology. An example of a line pair pattern and measurement result image (Fig.10). CM/MTF characteristics are evaluated using maximum and minimum values, and using the cross-sectional view can evaluate cross-section of line pair. Contrast modulation (CM/MTF) can be calculated as follows:

$$CM=\frac{Y_{max}-Y_{min}}{Y_{max}+Y_{min}}$$

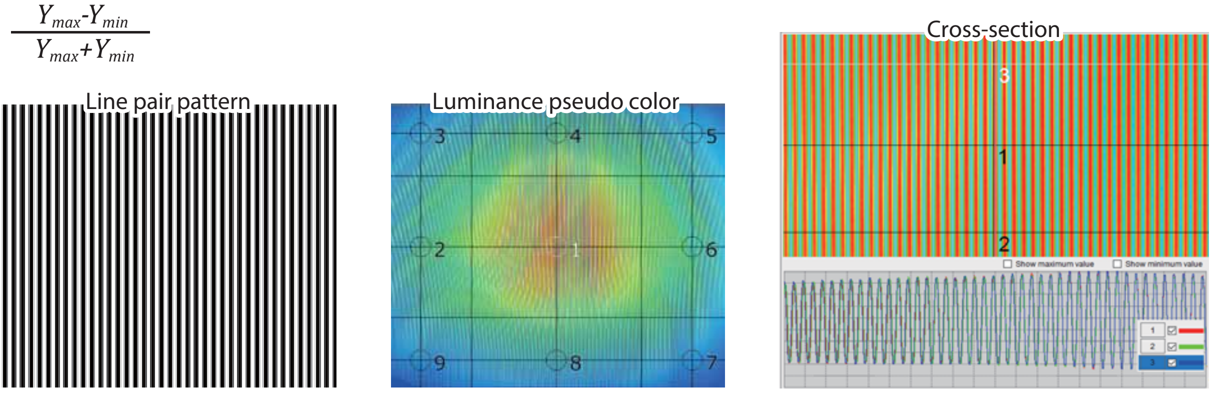


Fig.10 Example image of line pair pattern and measurement result

2-4. Evaluation of ghost

Checkerboard patterns or a white area in the center 4% are used to evaluate ghost caused by differences in luminance around the periphery. An example of evaluation using a 9x9 checkerboard pattern is shown for reference. (Fig.11)

Ghosts that cannot be detected by cameras can be identified using the luminance grayscale function. Furthermore, the amount of ghost can be quantified using cross-sectional views. When using two-dimensional instruments to perform evaluations in IEC63145-20-10, it is common to correlate the results with those obtained from spot-type instruments, as the evaluations in IEC63145-20-10 are specified for spot-type instruments.

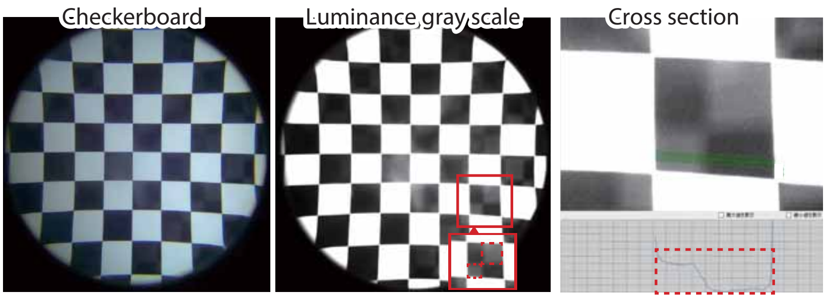


Fig.11 Example image of measurement result with checkerboard pattern

3. Evaluation of AR grasses

AR glasses (Fig.12) display images in the user's field of view. To measure parameters such as luminance, instruments with national traceability are necessary. The 2D spectroradiometer SR-5100HM, equipped with national traceability, can measure AR glasses when fitted with a C-mount lens.

Fig.12 Example image of AR grasses

Using the 2D spectroradiometer SR-5100 for spectral measurements enables precise measurement of each spot. An example is provided in which white is displayed on AR glasses, and measurements are taken at five points (Fig.13). The average values of parameters such as luminance (L) and chromaticity (u' ,v') can be measured. Additionally, measurements are conducted using a 10x10 checkerboard pattern (Fig.14) or single-color displays of R, G, B, W.

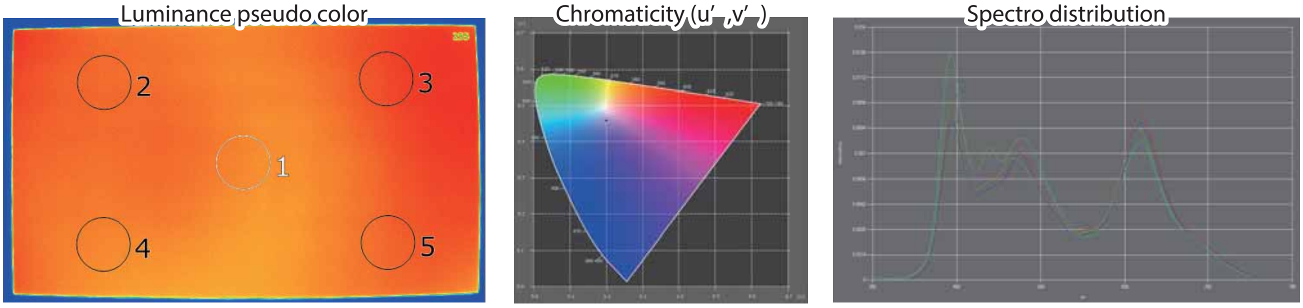


Fig.13 Example image of measurement result of uniformity with white display

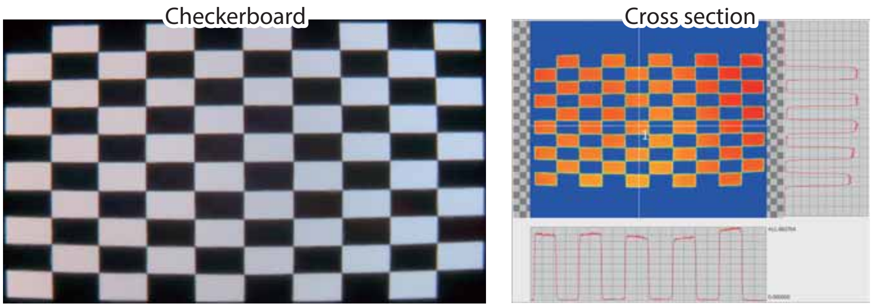


Fig.14 Example image of measurement result with checkerboard pattern

An example is provided where each tone is displayed, and measurements are taken at 5 points (Fig. 15). This allows for measuring differences in uniformity among tones and obtaining average values of parameters such as luminance (L) and chromaticity (u', v'). Additionally, measurements are conducted using a 5x5 checkerboard pattern or single-color displays of R, G, B, W.

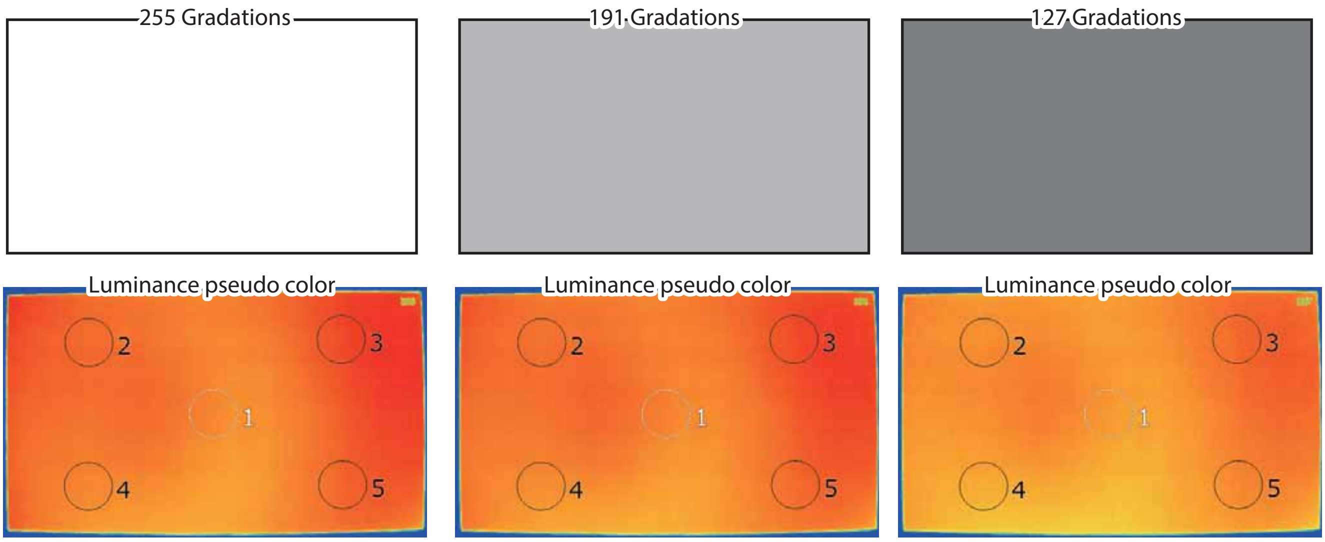


Fig.15 Example image of uniformity measurement for tone display

4. Evaluation of AR/VR using Laser Light

Backlight for current LCD using white LED cannot express wide color range. To expand the color range, laser light and OLED are increasingly being used. As a result, the development of devices that utilize lasers as light sources for AR/VR is underway. This has led to changing requirements for measurement instruments. Due to the narrowband spectral characteristics of lasers and OLED panels, it is difficult to accurately measure them with existing color luminance meters that use XYZ detectors.

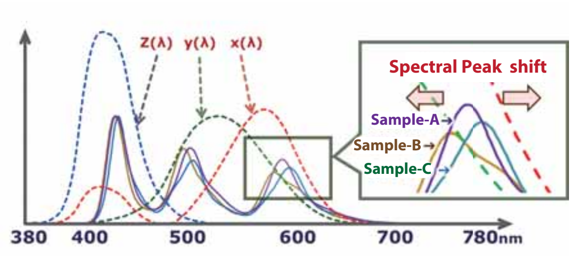


Fig.16 Example of measurement discrepancy

XYZ detectors have spectral sensitivity differences, which can make it difficult to distinguish whether differences in measurement values are due to fluctuations in the spectral characteristics of the measured sample or differences in detector spectral sensitivity. For instance, when measuring red light with a peak wavelength around 600nm, XY detectors are utilized. Changes in these wavelengths affect the balance between X and Y, leading to significant errors in chromaticity measurements (Fig. 16). In such cases, measurements with a spectroradiometer are necessary.

5. Standard

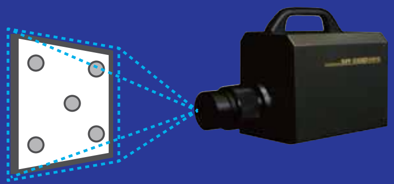
IEC 63145-20-10 : Fundamental measurement methods - Optical properties
IEC 63145-21-20 : Specific measurement methods for VR image quality - Screen door effect
IEC 63145-22-10 : Specific measurement methods for AR type - Optical properties
IEC 63145-22-20 : Specific measurement methods for AR type - Image quality

6. Term

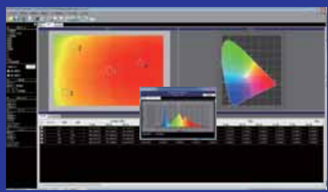
PPI(pixels per inch) : The unit that indicates the number of pixels per inch of resolution.
PPD(pixels per degree) : The unit that indicates the resolution in pixels per 1degree of viewing angle.
FOV(Field of View) : Field of view displayed on the screen.
IPD(Inter Pupilary Distance) : It indicates the distance between the pupils of the right and left eyes, showing their separation.
MTF(Modulation transfer function) : It is an evaluation index that represents the resolution of the optical system.
EP(Entrance pupil) : The image of the aperture formed by the optical system on the object side from the aperture stop.
EPD(Entrance Pupil Diameter) : The diameter of the image of the aperture stop formed by the lens in front of the aperture stop.

For the R&D

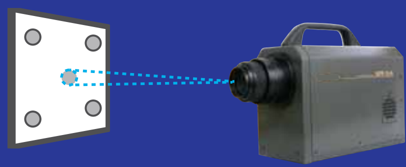
2D Spectroradiometer **SR-5100**



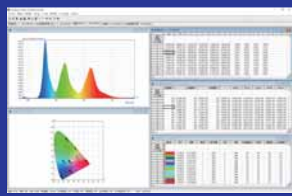
■Spectral imaging measurement
- 5 million points spectral measurement
- Luminance / chromaticity
- Uniformity



Spectroradiomter **SR-5A**



■Spectral spot measurement
- 1point luminance and chromaticity
- Luminance / chromaticity
- Uniformity (Movement is necessary)

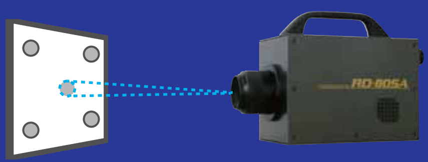


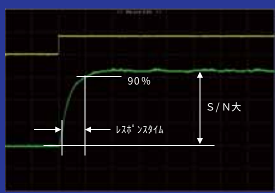
Example of SR-5100HM ＋ C-mount adapter + Wide lens

W×H×Diagonal(°)	EPD(mm)
117.7×86.7×146.2	2.5*
34.6×25.9×43.2	8.6
82.4×66.9×106.1	1.8

*Occasionally, there may be deviations.

Luminance colorimeter **RD-80SA**





■spot measurement
- 1point luminance and chromaticity
- Uniformity (Movement is necessary)
- Analog Output Response Speed: 80μs less

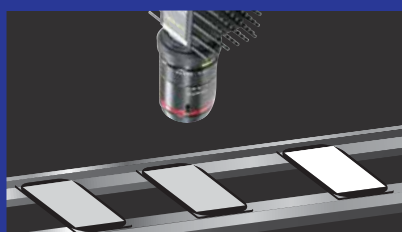
For production lines manufacturing modules

Luminance & Chromaticity Uniformity Analyzer
UA-20C

Luminance Uniformity Analyzer
UA-20Y

■Imaging measurement
- 24.5million points
- Luminance / Chromaticity(UA-20C)
- Luminance(UA-20Y)
- Uniformity

Example image of illumination inspection
for module manufacturing equipment



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