



Virtual Simulation Measurement of Lamp Intensity Distribution Based on Near Field Goniophotometer

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Abstract. In order to solve the problems of not mastering the experimental process and not knowing the results clearly when using the full space distribution photometer for near-field measurement of lamps, a virtual simulation measurement of lamp intensity distribution based on near field Goniophotometer is proposed. The virtual simulation system builds the experimental platform and simulates the basic process of near-field measurement of lamps by the full-field Goniophotometer. The scheme includes the use of 3D Max and Blender to build models, unity 3D to simulate animation and scene development. According to the light intensity distribution of different types of lamps, the IES file is used to draw the light distribution curve of different lamps. The design results also prove that the system has good operability, interactivity and stability, realizes low-cost, safer and more convenient experiments, and improves the efficiency of lamp experiment of near field Goniophotometer.

Keywords: Unity 3D · Goniophotometer · Light distribution curve · near field measurement

1 Introduction

The Full-field Goniophotometer is an instrument used to measure the photometer spatial distribution characteristics of light sources or lamp. It is widely used in measurement equipment such as lighting product production enterprises, research institutions, testing laboratories, etc. [1–3]. In addition, it has an important status and role in the teaching of lighting and photoelectric instruments. However, due to the lack of equipment and the COVID-19 in traditional teaching and training, students do not fully understand the equipment. At the same time, the near-field measurement of the Full-field Goniophotometer can meet the needs of high-precision measurement at a short distance, and is suitable for the light intensity distribution of lamps and light sources with small luminous surface [4–8]. Therefore, an open network virtual experiment teaching system based on virtual reality technology is proposed to solve the above problems.

With the rapid development of virtual reality technology, the research on virtual laboratory simulation is gradually carried out. First, Poland uses virtual reconfigurable manufacturing systems to improve students' cognition and practice ability; what is more, Norway also uses virtual environment to cultivate navigation professional students at sea deck operation capacity. At the same time, China's Ministry of Education opened the "Demonstrative Virtual Simulation Experiment Teaching Project" for higher education in 2018. The project was published through the ILAB platform. At present, the platform has been included in 2079 professional experimental projects. Virtual reality technology is continuously applied to teaching experiment training, further improve students' learning cognition and practical hands-on ability, and further contribute to occupational overall quality [8–11].

Great achievements have been made in virtual laboratories at home and abroad, but the construction of the virtual simulation laboratory of lighting projects is still in its infancy in China. In 2018, Dalian University of Technology has developed lighting construction and distribution virtual simulation experimental system based on mixed realistic technology. The feasibility of the virtual simulation platform constructed of the Full-field Goniophotometer measuring system began in 2020. There is no research report on other research teams in this area [12–15].

In view of this, this paper intends to carry out the virtual simulation measurement of lamp intensity distribution based on near field Goniophotometer. The measurement of near field Goniophotometer is based on virtual reality technology, which does not take up real laboratory resources and it is a detached from the real scenario. In the virtual lab, it can provide students with a variety of experimental equipment, so that students can more understand the working principle of the instrument, thereby saving the expensive funds required to purchase equipment; and real-time distance education, to solve the special reasons for the school can not provide a safe experimental environment. Virtual simulation measurement of lamp intensity distribution based on near field Goniophotometer is detached from the real scene, and compared to the physical apparatus of the experiment cost is lower, it will not occupy real laboratory resources, better interactivity, and better stimulate the autonomy of student learning.

2 Overall System Design

The near-field measurement system of the Full-field Goniophotometer is a complex virtual operating system. The system structure is designed to take into account the environmental simulation, operational simulation and other aspects. Using unity 3D, 3D max and Blender to build the virtual measurement of the Full-field Goniophotometer is mainly divided into the Full-field Goniophotometer information display and spatial light intensity distribution measurement process simulation, as shown in Fig. 1 below, the system is applied to optical to different lamps or light sources for light intensity distribution and 3D display of its results.

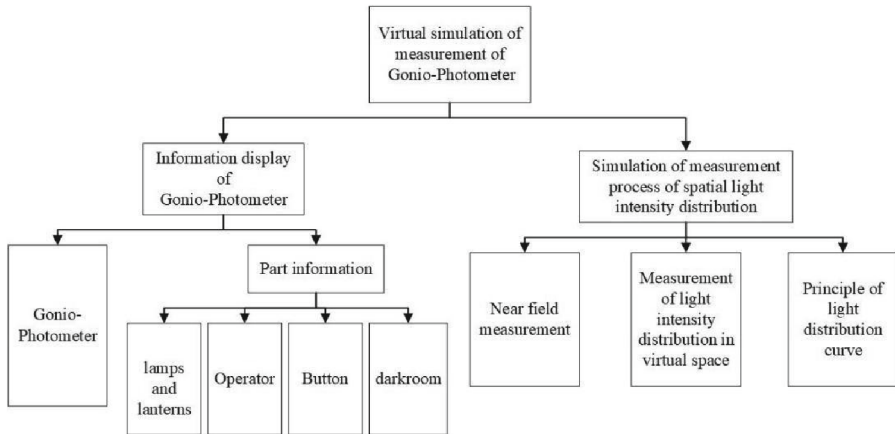


Fig. 1. Block Diagram of the system design

The experimental platform of the virtual near-field measurement simulation system first collates and analyzes the components of the Full-field Goniophotometer, the measurement principle and operation process of the Full-field Goniophotometer, and analyzes the mathematical model required for the system design combined with the experimental data. It is mainly composed of laboratory (darkroom), the Full-field Goniophotometer instrument, lamp model, operating table, button and other components. Among them, the darkroom is a model established by using the three-dimensional modeling software Blender and imported into unity's measurement scene in FBX format as a game object type. The model of the full space distribution meter mainly composed of control cabinet, turntable base, fixed mirror, vertical axis is made in 3D max and imported into Unity 3D to handle the necessary texturing, rendering, baking and animation settings for the model. The model of road lamps is established in blender, and the FBX format file is used as the game object type to import the measurement scene. Add a light source component to the game object's road lamps, and set the intensity of the light source component to 1. At the same time, set the whole space distribution photometer model and lamp model at the specified position inside the darkroom in unity.

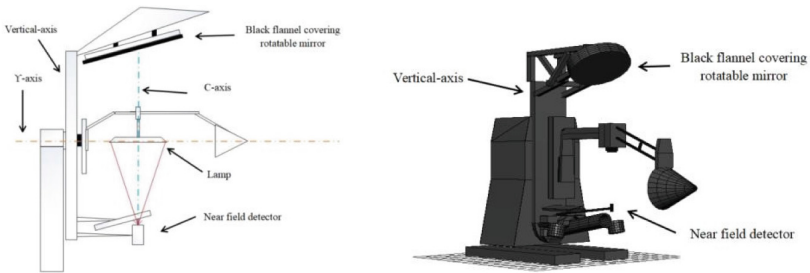
The Unity 3D editing platform edits, adjusts and refines the imported 3D model and then renders a virtual scene of the full-space distribution photometer measurement system using Shader. After entering the virtual experiment platform, the user will enter the predefined full-space distribution photometer lab, and there will be a prearranged virtual experimenter for the user to operate in order to facilitate the user's operation. By operating the virtual experimenter, the user can perform basic movement, jumping, acceleration, perspective movement, and interaction with objects in the surrounding environment such as the lamp model and the photometer. By moving the virtual experimenter, the user can achieve the basic operation function in the virtual laboratory, so as to complete the steps of installing the lamp and getting the lamp parameters. At the same time, the design functions such as lamp measurement with full spatial distribution luminometer are realized by C# script, Finally, the virtual measurement simulation platform of lamps based on near-field Goniophotometer is released.

3 Simulation of Spatial Light Intensity Distribution Measurement

3.1 Near Field Measurement

The virtual near-field measurement is based on a full spatial distribution photometer with virtual near-field made by 3D Max, as shown in Fig. 2(b) below, which mainly consists of a rotating arm (γ axis), a lamp arm, a near-field detector, a luminaire and a rotatable reflector covered by black fleece. The principle of near-field measurement is to cover the rotatable reflector with black fleece so that the light from the measured light source or luminaire is directly received by the near-field detector.

When the measurement is started, the vertical axis starts to rotate around the gamma axis to measure the light intensity of the measured light source or lamp at various angles in a certain plane; At the same time, when the vertical axis rotates for one circle, the lamp can rotate around the C-axis to switch between different measurement planes, as shown in Fig. 2 (a) below.



(a) A schematic diagram of near field measurement

(b) A virtual near field measurement model

Fig. 2. Measurement of the near field

In Unity, the horizontal angle of the vertical axis rotation and the vertical angle of the lamp are put into the rotation script. When the lamp is installed and turned on, click Start Measurement. The vertical axis starts to rotate around the gamma axis. When the rotation angle does not exceed 360° , continue to rotate. When the rotation angle exceeds 360° , reset its angle to 0° . At the same time, the angle of the lamp around the C-axis mechanical arm can be increased by 5° each time in this simulation design, then check whether the angle of the axis of the lamp around axis C exceeds 360° . If not, continue to work and output parameters in real time. If it exceeds, stop output, as shown in Fig. 3 below.

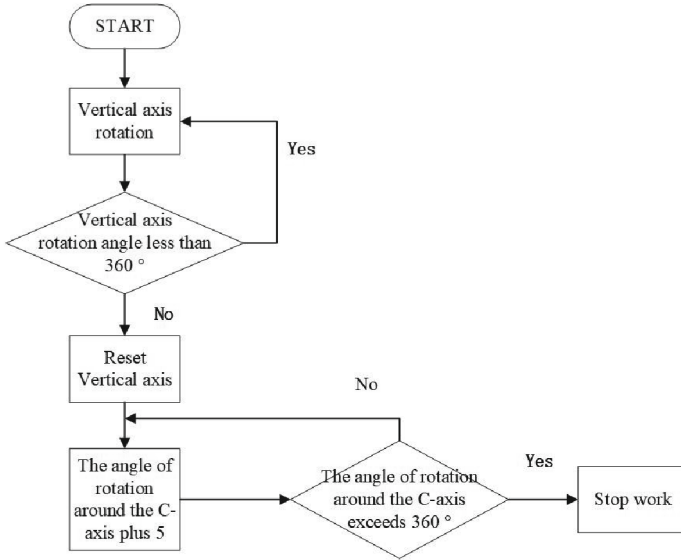


Fig. 3. The rotation principle for near field measurement

3.2 Measurement of Virtual Light Power Distribution

When entering the virtual light power distribution measurement experimental platform, a virtual experimenter will be controlled from a first-person perspective, by manipulating the virtual experimenter to the distribution photometer luminaire measurement experimental platform. Control the virtual experimenter to the distribution luminometer at the nearby installation of lamps, as shown in Fig. 4 (a); then turn on the light switch, as shown in Fig. 4 (b); to the operating table click to start measuring, as shown in Fig. 4 (c), at this time began to run the pre-designed full-space distribution luminometer animation script, the user can intuitively see the full-space distribution luminometer robot arm began to rotate, while relying on the robot arm rotation Angle parameters and has been entered to set the corresponding lamp parameters for comparison, the user can intuitively watch the three-dimensional dynamic formation of the light distribution curve on the operating table; at the end of the experiment, the light distribution curve is no longer drawn, click to end the measurement, as shown in Fig. 4 (d).

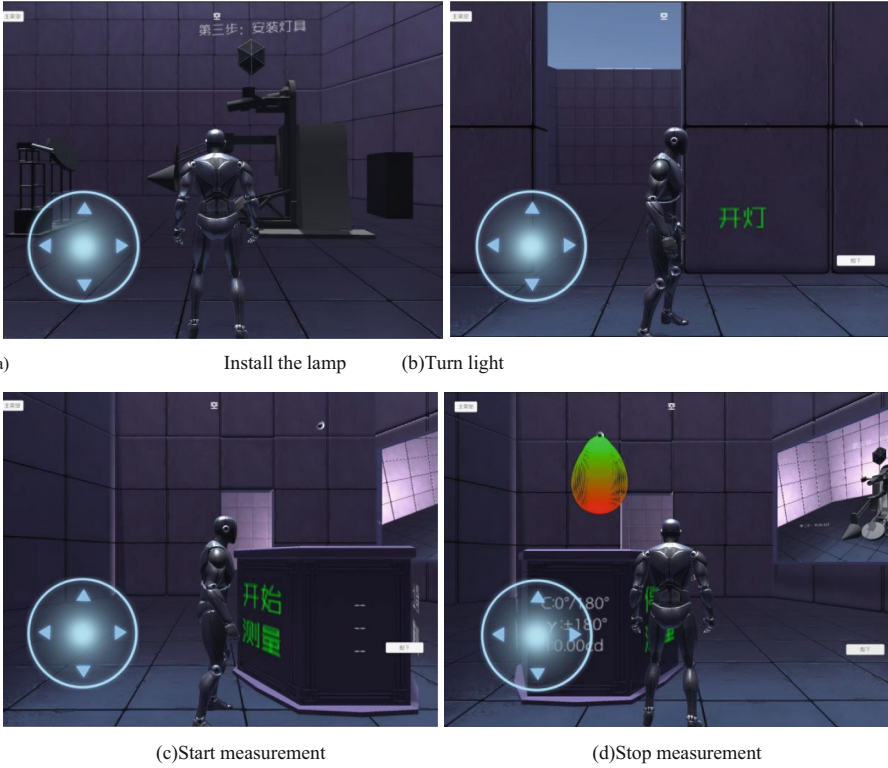


Fig. 4. Virtual light intensity measurement

3.3 Principle of Light Distribution Curve

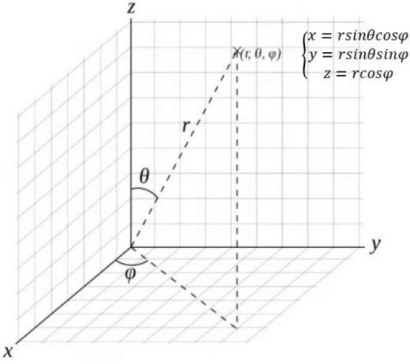
The light intensity distribution curve are used in virtual near-field light intensity distribution measurements to represent the light intensity distribution in all directions in space. There are two types of light distribution curves: the right-angle coordinate system method and the polar coordinate method. Here, the polar coordinate method is chosen to describe the light intensity distribution of the luminaire, which is more intuitive to show the light distribution curve in three dimensions.

In the virtual light distribution curve drawing, the light distribution curve is drawn by calling the IES file. The initial stationary angle of the mechanical arm is 90° , and the vertical axis mechanical arm rotates between 90° to 360° and 0° to 90° . At the same time, due to the spatial light intensity distribution characteristics of Lambert light source, its light intensity between 180° and 360° is zero, so the rotation angle will be detected during the rotation of the vertical axis mechanical arm, and the data between 180° and 360° will not be displayed and output. In addition, when the program detects that the rotation of the vertical axis manipulator has exceeded 360° , it will reset the rotation angle of the vertical axis manipulator to 90° .

The light distribution curve is mainly derived from the three-dimensional coordinate formula of the ball, as shown in Fig. 5 (a), and the φ (PHI) and θ (theta) mainly based on the data processing of the IES file of the lamp, select some data of the IES file of a certain lamp, as shown in Fig. 5 (b). It is mainly composed of horizontal angle, vertical angle and data of the luminaire, etc.

First, assign a value to the horizontal angle according to the horizontal angle in the IES file, and then a different assignment is made to Phi by comparing the size of the horizontal angle with 180° . If it is less than 180° , the horizontal angle in the IES file is assigned to Phi, and because the data in the IES is placed upside down, theta is given to output the value in the IES upside down; if it is greater than 180° , the negative of the horizontal angle in the IES file is assigned to Phi, and theta is given to output the negative of the number in the IES positively. Finally, Phi is then taken as a remainder, so that the angle is controlled between $270^\circ\text{--}360^\circ(0^\circ)\text{--}90^\circ$, thus satisfying the distribution characteristics of the spatial light intensity of the Lambert light source. Next, the angle values of Phi and theta are converted into radian values to obtain φ and θ , and import the data into the spatial light intensity parameter table, as shown in Fig. 5(c) below. Finally, the radius is normalized so that the size of the drawn curve can be controlled, and then the real-time 3D coordinate map of the light distribution curve is obtained through the spherical coordinate system, and the flow chart of the light distribution curve is shown in Fig. 5(d) below.

The light distribution curves of different lamps are also different. If the lamp has a rotational axis of symmetry, the distribution of light intensity in its space can be expressed only through the light intensity distribution curve on one metering surface of the axis. In the measurement of virtual distribution photometer, a lamp with a rotational axis of symmetry is selected [16–19]. Figure 5 (a) is the light distribution curve measured by the instrument, the red line is the initial measured light distribution curve, and the blue line is the final measured light distribution curve, Because they are symmetrical lamps, they are overlapped together. Figure 6 (b) is the C0 surface drawn on the virtual near-field measurement light distribution curve, which is the same as the initial light distribution curve in Fig. 6 (a). Fig. 6(c) and Fig. 6(d) are the C90 and C360 surfaces drawn on the virtual near-field measurement light distribution curve of the lamp respectively, and the drawn light distribution curve is the same as the actual measured light distribution curve.



(a) Spherical coordinate system

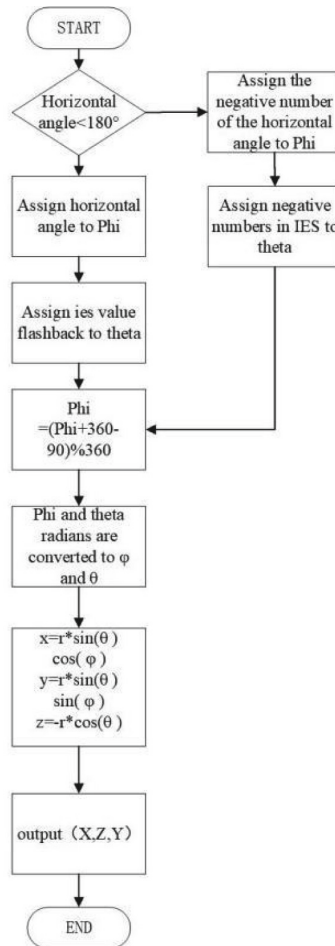
Horizontal angle																																															
0.00	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50	25.00	27.50	30.00	32.50	35.00	37.50	40.00	42.50	45.00	47.50	50.00	52.50	55.00	57.50	60.00	62.50	65.00	67.50	70.00	72.50	75.00	77.50	80.00	82.50	85.00	87.50	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	180.00	
Vertical angle																																															
0.00	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50	25.00	27.50	30.00	32.50	35.00	37.50	40.00	42.50	45.00	47.50	50.00	52.50	55.00	57.50	60.00	62.50	65.00	67.50	70.00	72.50	75.00	77.50	80.00	82.50	85.00	87.50	90.00											
Lamp data																																															
270.00	269.13	268.50	266.75	264.87	262.25	258.88	255.13	250.63	246.25	240.87	235.00	228.62	221.75	214.50	206.75	198.37	190.00	180.87	171.75	162.00	152.12	141.75	131.13	120.25	109.13	97.88	86.37	75.00	63.63	52.25	41.25	30.75	21.88	14.00	8.37	5.38	3.87	3.75	3.63	3.63	3.38	3.13	2.87	2.62	2.50	0.00	
270.00	269.00	268.25	266.75	264.75	262.12	259.13	255.13	251.12	246.50	240.87	235.00	228.62	221.75	214.62	206.75	198.62	190.25	181.38	172.25	162.50	152.50	142.00	131.63	120.63	109.62	98.37	87.00	75.63	64.38	52.87	41.88	31.62	22.75	14.87	9.13	6.13	4.25	3.87	3.75	3.63	3.38	3.13	2.87	2.75	2.62	0.00	

(b) IES file

	A	B	C	D	E	F	G	H
1	RHO	THETA	INTENSITY	THETA RAD	COS	SIN	X	Y
2	int	float	float	float	float	float	float	float
3	1000	0	270	0	1	0	0	270
4	1000	2.5	269.13	0.043633231	0.999048222	0.043619387	11.73928572	268.8738479
5	1000	5	268.5	0.087266463	0.996194698	0.087155743	23.40131693	267.4782764
6	1000	7.5	266.75	0.130899694	0.991444861	0.130526192	34.81786177	264.4679168
7	1000	10	264.87	0.174532925	0.984807753	0.173648178	45.99419282	260.8460295
8	1000	12.5	262.25	0.218166156	0.976296007	0.216439614	56.76128876	256.0336279
9	1000	15	258.88	0.261799388	0.965925826	0.258819045	67.0030744	250.0588779
10	1000	17.5	255.13	0.305432619	0.953716951	0.3007058	76.71907063	243.3218056
11	1000	20	250.63	0.34906585	0.939692621	0.342020143	85.72050852	235.5156115
12	1000	22.5	246.25	0.392699082	0.923879533	0.382683432	94.23579522	227.5053349
13	1000	25	240.87	0.436332313	0.906307787	0.422618262	101.7960607	218.3023567
14	1000	27.5	235	0.479965544	0.887010833	0.461748613	108.5109241	208.4475458
15	1000	30	228.62	0.523598776	0.866025404	0.5	114.31	197.9907278
16	1000	32.5	221.75	0.567232007	0.843391446	0.537299608	119.1461882	187.0220531
17	1000	35	214.5	0.610865238	0.819152044	0.573576436	123.0321456	175.7081135
18	1000	37.5	206.75	0.654498469	0.79335334	0.608761429	125.8614254	164.0258031
19	1000	40	198.37	0.698131701	0.766044443	0.64278761	127.5097781	151.9602362
20	1000	42.5	190	0.741764932	0.737277337	0.675590208	128.3621394	140.082694
21	1000	45	180.87	0.785398163	0.707106781	0.707106781	127.8944035	127.8944035
22	1000	47.5	171.75	0.829031395	0.675590208	0.737277337	126.6273826	116.0326182
23	1000	50	162	0.872664626	0.64278761	0.766044443	124.0991998	104.1315928

(c) Data sheet of spatial light intensity

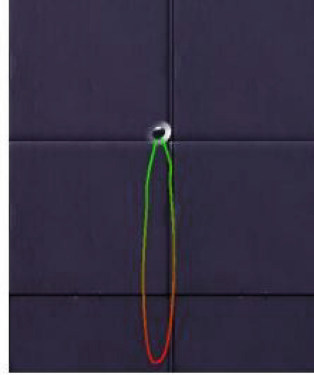
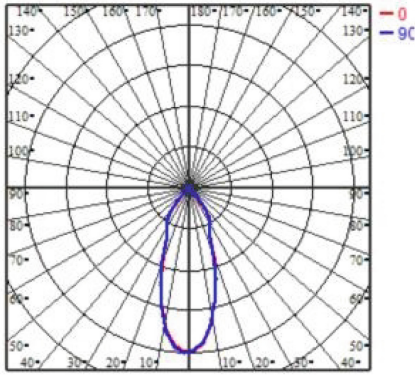
Fig. 5. Principle of light distribution curve



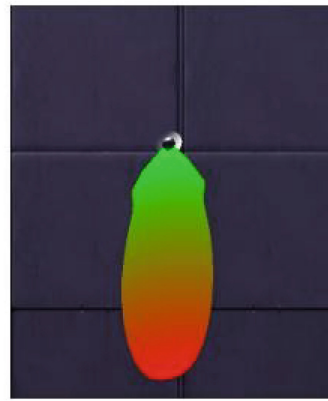
(d) Flow chart of light distribution curve

Fig. 5. (continued)

Light distribution in space is asymmetric, then the spatial distribution of light intensity needs a number of light intensity distribution curve of the measurement plane to indicate, so from a variety of asymmetric lamps and lanterns to choose a typical lamp, as shown in Fig. 7. Figure 7(a) below shows the asymmetric light distribution curve of the lamp measured by the instrument, red indicates the initial light measurement plane and blue indicates the final light measurement plane showing different light distribution curves, Fig. 7(b), 7(c) and Fig. 7(d) below show the C0, C90 and C360 surfaces of the lamp in the virtual near-field measurement light distribution curve, respectively, each light measurement plane showing different light distribution curves.

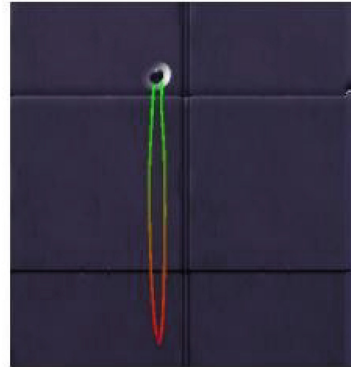
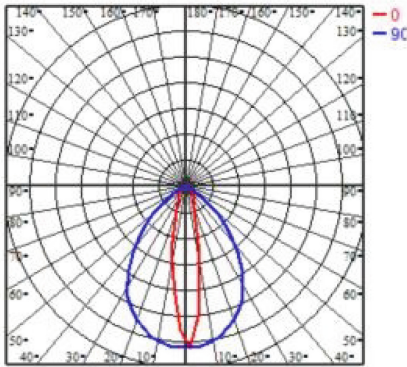


(a) The light distribution curve of the lamps (b) Virtual light distribution curve at C0°



(c) Virtual light distribution curve at C90° (d) Virtual light distribution curve at C360°

Fig. 6. The light distribution curve of symmetrical lamps



(a) The light distribution curve of the lamps (b) Virtual light distribution curve at $C0^\circ$



(c) Virtual light distribution curve at $C90^\circ$ (d) Virtual light distribution curve at $C360^\circ$

Fig. 7. The light distribution curve of asymmetrical lamps

4 Conclusion

The system combines virtual reality technology and light intensity near-field measurement of full-space distribution photometer lamps, and completes a virtual simulation system for near-field measurement of full-space distribution photometer lamps through unity 3D. The system is a study of light intensity measurement, combining 3Dmax, Blender and C#, and realizes the simulation of full-space distribution photometer and the construction of dark room and the drawing of light distribution curve. This system makes the project closer to the actual experiment through program simulation, and provides a good training platform for those who learn remotely.

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