

Design of A New Type of Full-Spectrum Solar Simulator

Linhua Zhang¹, Yuan Wang²

¹ShanDong University of Architecture and engineering, Jinan, China

²The EAC of Xi'an JiaoTong University, Xi'an, China

Abstract: A new type of full-spectrum solar simulator was designed through testing the light source. It is showed in the experiment that the mismatch error of the spectrum distribution from dysprosium lamp reaches the A level of "A general standard for the solar simulator" (GB/T12637-90) in partial wave length and reaches B level in the range from 250nm to 2500nm. A solar simulator has been constructed taking the dysprosium lights as the light source. Within the effective radiation surface of $2\text{m} \times 1.5\text{m}$ from the centre of configuration, the ununiformity of radiation and unsteadiness exceed the C level to reach the B level, but did not arrive at the A level. And the radiation intensity reaches 1000W/m^2 as expected.

Keywords: solar radiation; solar spectrum; simulation

1. INTRODUCTION

The sun influences environment factors in the earth, such as temperature, humidity, wind and so on. The solar simulation is a technology that makes use of artificial light source to simulate the radiation characteristic of sunlight. The simulated technology of solar radiation is widely used in many field, for example, aviation, space flight, weapon, agriculture, automobile, material and so on.

The choice of light source and the design of system are two critical points to solar simulators. Considering economically and technically the aim of research and for meeting technical requirements, It is required to find economical and practical artificial light source to achieve the lower expenditure in investment and operation.

According to the above principles and the characteristics of solar radiation in research area, the designed technical indicator of solar simulator requires that as the simulator is 2m high, the ground radiation intensity reaches 1000W/m^2 and the technical indicators such as the ununiformity and unsteadiness of radiation and spectrum mismatch error reaches the national standard (GB/T12637-90). In addition, the simulator can be adjusted in height.

2. THE EXPERIMENTAL RESEARCH ON THE LIGHT SOURCE OF SOLAR SIMULATOR

Dysprosium lamp, which is used in this research, is a new type of gaseous discharge light source with high efficiency, high colour rendering property and long lifetime. It is appropriate to use dysprosium lamp to simulate the sun's ray on the surface of globe. Because it make use of the filled dysprosium iodide, thallous iodide and mercury etc to, given off the peculiar and intensive spectrum, which is similar to solar spectrum. So we have had a test to the

spectrum of new dysprosium lamp within wider wavelength (250~2500nm). This kind of dysprosium lamp owns parabolic reflector, which makes the lights approximate to parallel rays and provides convenience to the design of solar simulator. The main instruments in the test are WDF-1 reflex monochromator, plum'bun sulphide photoresponse (Pbs) and amplifying receptor and photomultiplier

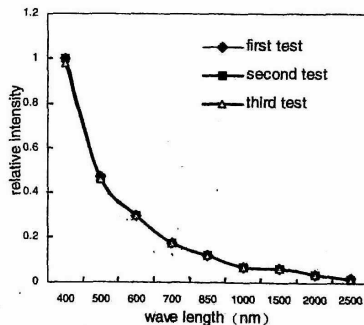


Fig.1 The relative energy distribution in visible and infrared field of dysprosium lamp

receptor, etc.

2.1 Measurement of the relative spectrum energy distribution of dysprosium lamp within the portion of visible light and infrared

According to the supplied standard bandwidth and band quantities, we tested the dysprosium lamp with incidence width of crevice is 1.3mm. The result is shown in Fig.1, in which the curve indicates the correction with quartzes standard lamp. It can be seen that the three repeated metrics' outcomes insolated extremely well, which shows that the

dysprosium lamp have good steadiness and lesser metrical stochastic error.

2.2 Measurement of the relative spectrum energy distribution of dysprosium lamp within the portion of ultraviolet radiation and visible light

In testing the portion of ultraviolet radiation, we took the photo multiplier tube which increase with optical signal 106 times as a receptor due to the receptor of plum'bun sulphide photoresponse is not utilized. Fig.2 shows the curve of dysprosium lamp's relative energy distribution according to the supplied standard bandwidth and band quantities within the portion of ultraviolet radiation and visible light.

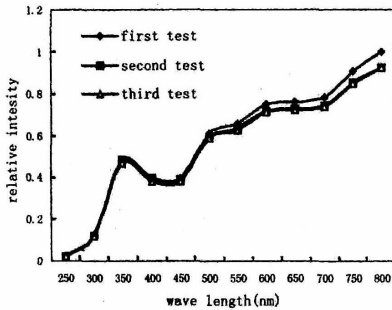


Fig.2 the relative energy distribution in portion of ultraviolet and visible light

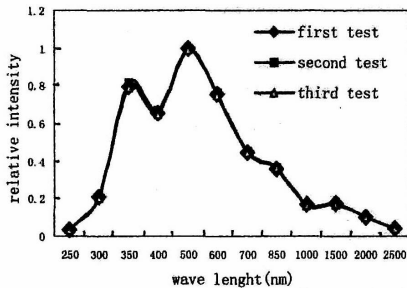


Fig3 the relative energy distribution in full spectrum of dysprosium lamp

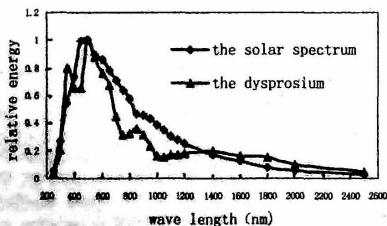


Fig.4 Comparison of the relative energy of dysprosium lamp to the sun's

In the measure, the standard value of standard lamp is corrected by the idiocratic curve of photomultiplier tube within 250~350nm due to the supplied standard value of standard lamp just reaches 300nm, and Fig.2 is the curves are corrected.

Having combined the results that come from two kinds of receptors, then we obtained the relative energy distribution in the range of 250~2500nm. As showed in Fig.3. The influence of the apparatus to the results is extremely little for all the metrical results have been corrected by the standard lamp.

Comparing the curve of dysprosium lamp's relative spectrum energy distribution with that of AM1.5 solar spectrum, as shown in Fig.4. We can get that the distributed tendencies match up to each other. But the dysprosium lamp has little lower energy on the portion of visible light and higher energy in the portion of infrared. The more exact comment is discussed in the following content.

2.3 Evaluation of the dysprosium lamp's spectrum distribution mismatch error

"A general standard for the solar simulator" prescribes that within certain distant wavelength how much percent the energy account for in the radiant energy of valid wave band on the condition of AM1.5. The technical indexes are seen in chart 1 and table 2.

Comparing the proportion that the energy of dysprosium lamp in each distance of wavelength account for in the total energy in the range of 400~1100nm with the radiation intensity distribution on the condition of AM1.5, and then we can make a list that have three repeated experimental outcomes in table 3. It is seen that the dysprosium lamp's spectrum distribution mismatch error reaches the A level within a certain wavelength and reaches the B level in the total wavelength.

Table 1 the level of solar simulator (%)

Level Technical index Technical requirement	A	B	C
The uniformity of radiation	$\leq \pm 2$	$\leq \pm 5$	$\leq \pm 10$
The unsteadiness of radiation	$\leq \pm 1$	$\leq \pm 2$	$\leq \pm 5$
Spectrum mismatch error (deviation of percent ratio in Table 2)	$\leq \pm 20$	$\leq \pm 35$	$\leq \pm 50$

3.DESIGNING THE SOLAR SIMULATOR

Table 2 the relative distribution of standard spectrum irradiance

The distance of wavelength (μm)	Account for the percent of the total radiation intensity within the valid wave band (%)	
	The condition of AM0 (the effective wave band $0.3\sim 1.1\mu\text{m}$)	The condition of AM1.5 (the effective wave band $0.4\sim 1.1\mu\text{m}$)
0.3~0.4	9.4	—
0.4~0.5	18.5	18.5
0.5~0.6	18.6	20.1
0.6~0.7	15.8	18.3
0.7~0.8	12.8	14.8
0.8~0.9	10.2	12.2
0.9~1.1	14.7	16.1

Table 3 the comparison of dysprosium lamp's relative energy distribution

The distance of wavelength (nm)	The distribution of radiation intensity on the condition of AM1.5 (%)	The proportion that the energy of dysprosium lamp in each distance of wavelength account for the total energy in the range of 400~1700nm (%)			The average relative error (%)
		The first test	The second test	The third test	
400~500	18.5	24.1	24.1	24.0	30.1
500~600	20.1	25.6	25.5	25.5	27.0

Making use of the above dysprosium lamp as light source, we designed the simulator. The apparatus mainly contained the configuration of the lamps array, fixture and adjustment of lamps' shelves.

There were 188 reflecting dysprosium lamps (DDF400) which is 400W in the simulator. Considering the uniformity of illumination, the lamps were disposed as a plum blossom and the distance of two lamps was 295mm, as shown in Fig.5. The size of lamps' shelves is $4500\times 3880\text{mm}$, the total power of light source is 75kW, that is, the average is 4.19kW/m^2 . The simulator has a large size, there are many lamp's and each lamp has independent ballast and trigger, so we have to choose quadrate steel

tubes with enough intensity as the lamp shelves. The cables are laid in the tubes in order to prevent them from damaging by sunlight through vitreous housetop. The simulator was connected with pulling jack set in four corners to move up and down in vertical, that is to say the highness of simulator can be adjusted. On the other hand, this kind of design makes the simulator inclined to change the angle of incidence of the light source to content the requirement of special experiment. In addition, the solar simulator must be well earthed for security.

4. THE EXPERIMENTAL RESEARCH ON THE TECHNICAL CAPABILITY OF SOLAR SIMULATOR

4.1 Testing the radiation intensity of solar simulator

The metrical apparatus is automatic weather station (AZWS03) whose radiation intensity of SR5 solar radiation transducer have a range from 0 to 2000W/m^2 . The metrical precision reaches $\pm 5\%$, and reaches secondary standard of ISO9060d.

As shown in Fig.6, the vertical ground projection of the lamp array in simulator was compartmentalized into quadrate grids. We obtained the value of radiation intensity of each test point when the distance is separately 1.75m, 2.0m and 2.5m from the lamps' light surface to the ground. It is seen from the results that the radiation intensity has reached the designed goals of 1000W/m^2 in the areas of $2\text{m}\times 1.5\text{m}$ from the centre of the lamp array.

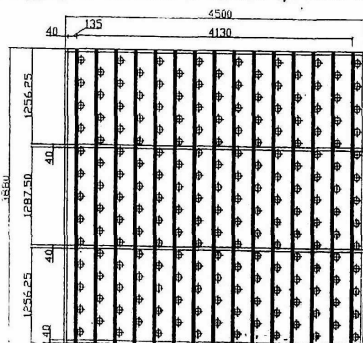


Fig.5 the ichnography of solar simulator's lamp array configuration

4.2 Checking the ununiformity of radiation of solar simulator

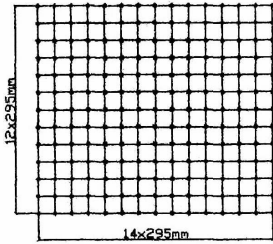


Fig.6 the tested points' array

In the whole radiation surface, only a portion of the radiation intensity distributes equally, which is called effective radiation surface. In the total range of effective radiation surface, we can use the ununiformity of radiation to describe the maximum relative error of radiation intensity which is varying with position, the formula is:

$$\pm \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}} \times 100\% \quad (1)$$

Where:

$E_{\max}$ is the maximum radiation intensity get in total range of effective radiation surface, W/m^2

$E_{\min}$ is the minimum radiation intensity get in total range of effective radiation surface, W/m^2

According to the experimental data, referring to the standard chart 1, the ununiformity of radiation is 4.91%, 4.27% and 4.85% respectively when the lamps are above the ground as 1.75m, 2m and 2.5m high. And the solar simulator has exceeded the C level of the standard, reaches the B level but has not reach the A level yet.

4.3 Checking the unsteadiness of radiation of solar simulator

We can use the unsteadiness of radiation to describe the maximum relative error of the radiation intensity which is in the discretional given position of the effective radiation surface, within the given time interval, and varying with time. Its formula is:

$$\pm \frac{E'_{\max} - E'_{\min}}{E'_{\max} + E'_{\min}} \times 100\% \quad (2)$$

Where:

$E'_{\max}$ is the maximum radiation intensity get in given position of the effective radiation surface, W/m^2

$E'_{\min}$ is the minimum radiation intensity get in given position of the effective radiation surface, W/m^2

There were three characteristic positions chosen as the positions to test the unsteadiness within the effective radiation surface, which were the centre of the effective radiation surface, a discretional point on the edge of the effective radiation surface and a discretional point between the centre and the edge of

the effective radiation surface. Then we tested the unsteadiness of radiation at 2m high above the ground when only made two groups of lamps on (there are four groups in all). The outcomes are shown in Fig.7, Fig.8 and Fig.9.

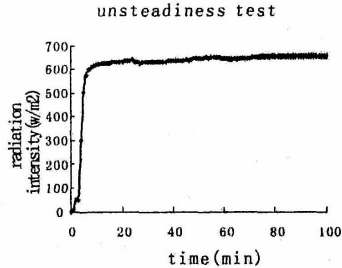


Fig.7 the radiation intensity in the centre

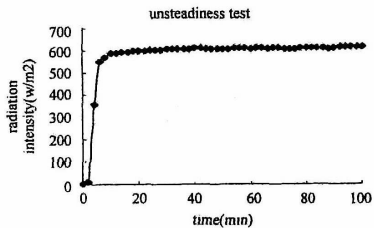


Fig.8 the radiation intensity on the edge

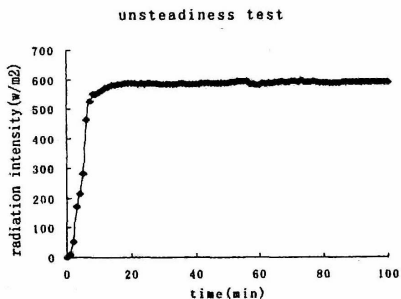


Fig.9 the change of the radiation intensity between the centre and the edge

The initial time after the lamps being electrified is not considered because there is some time for the dysprosium lamps to get steady from being electrified. For ensuring veracity, the unsteadiness of radiation of solar simulator was tested uniformly in the time interval from 20min to 100min after the lamps being electrified. According to the formula (2), the unsteadiness of radiation should be 1.69%, 1.33% and 0.79% respectively at three various points. The

unsteadiness is less than 2% at different point, so the solar simulator, on the index of the unsteadiness of radiation, has exceeded the C level of the standard, reaches the B level but has not reach the A level yet.

5. CONCLUSION

Testing the light source and designing a new type of full-spectrum solar simulator's were described in the article. The mismatch error of the spectrum distribution from dysprosium lamp reaches the A level of "A general standard for the solar simulator" (GB/T12637-90) in partial wave length and reaches B level in the range from 250nm to 2500nm. A solar simulator has been constructed taking the dysprosium lights as the light source. Within the effective radiation surface of $2\text{m} \times 1.5\text{m}$ in the centre of configuration, the ununiformity of radiation and unsteadiness have exceeded the C level and reach the B level, but have not arrive at the A level. The radiation intensity reaches 1000W/m^2 as expected.

ACKNOWLEDGMENTS

This study is jointly supported by the National Natural Science Foundation (No. 10272089) and the National Key R&D Programs in the 10th Five-Year Plan Period (No. 2004BA901A21).

REFERENCES

- [1] Wang.J., Huang.B.Ch., Wan.D.C Technology of Environmental simulation [M]. Beijing : National defence industry publishing company, 1996
- [2] Yu.F. New Type Solar Simulated System [J]. Solar Energy, 1995(1): 7.
- [3] Li.G, Dai.J Sh,Yuan.Y.Sh. The Methodological Research of the Endurance of Reinforced Concrete [J]. Journal of Huaihai Institute of Technology 2002, 10: 21-23.
- [4] Zhang.X.Zh, Wang.J. The Simulated Laboratory of the Air Conditioning Environmental in Automobile [J]. Automobile Technology, 2002, 10:21-23.
- [5] Japanese High Energy Efficiency & Clean Energy Technologies [J]. Photovoltaic Power., Dec2001/Jan2002, Vol. 1 Issue 6, p10.
- [6] US Army Test and Evaluation Command International Test Operations Procedure. Solar Radiation Tests. AD/A133889. 1989.
- [7] Lorin D Klein. Unique Test Capabilities of the Eglin AFB McKinley Climatic Laboratory. The Journal of Environmental Science, 1987(6).
- [8] The National Standard of the People's Republic of China GB/T12637-1990. A general standard for the solar simulator, Beijing. The standard publishing company in china