Examination of spectral distribution of radiation emitted by halogen and xenon lamps

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Most often, solar radiation simulators are built with a certain lamp type - halogen, xenon, metal halogen or, less frequently, sulphur lamps. The knowledge of radiation spectra of these lamps is a prerequisite to correctly design a solar radiation simulator. On many occasions, two lamps used simultaneously provide better adjustment of the simulator's radiation to solar radiation. This is especially beneficial in case of simulators dedicated to selected solar radiation receivers with specific sensitivity range, e.g. photovoltaic panels or solar collectors. The article presents the test bed and results of examination of summary spectral distributions of xenon and halogen lamp. Proper mixing of radiation of these lamps allows better adjustment of the simulator's radiation to the needs of a specific receiver of real solar radiation.

KEYWORDS: spectral distributions of xenon and halogen lamp, spectrometer measurement, combined radiation

1. Introduction

The fundamental task of a simulator dedicated to a specific group of receivers is the reproduce of solar radiation in spectral range relevant for this group of receivers. Typical solar radiation receivers (solar collectors, photovoltaic panels, examine samples of materials, plants or chemical reactants) exhibit specific spectral sensitivity. Consequently, it is important to achieve a possibly high spectral convergence of solar radiation and radiation achieved in a simulator, in specific wavelength range. Spectral characteristics of the most commonly used solar radiation receivers falls in 100 - 2000 nm range. The current solar radiation simulators are almost always based on a single type of radiation source - a halogen lamp (that satisfies a standard) or a xenon lamp. The paper presents the results of tests of combined radiation of a halogen lamp and a xenon lamp.

2. Halogen and xenon lamps

Continuous radiation spectrum is typical for both halogen lamps and xenon lamps. The halogen lamp color temperature may be 3000 or 3200K [4, 10]. Figures 1 and 2 show examples of distributions of a selected halogen lamp and a xenon lamp [9, 10].

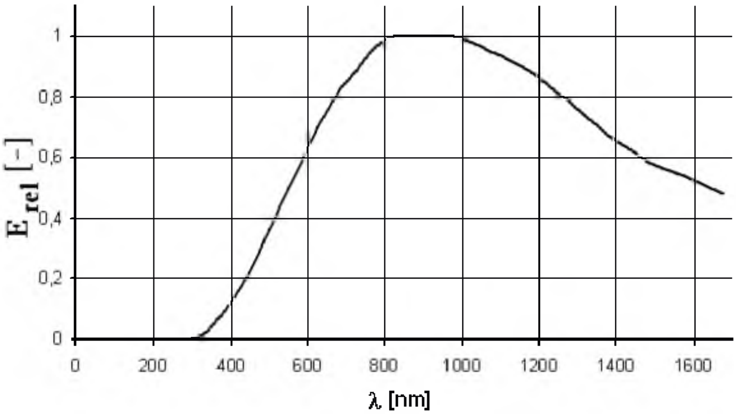

Fig. 1. Relative spectral distribution of a 1000W halogen lamp [10]

Halogen lamps are typically used for illuminating interiors and buildings, as vehicle lamps and for decorative purposes.

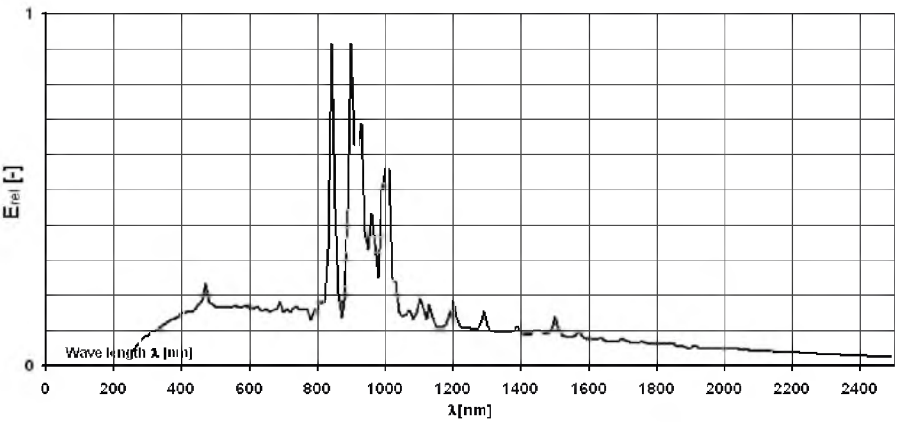

Fig. 2. Relative spectral distribution of an example of a 1600W XBO OFR xenon lamp [9]

Xenon lamps have continuous radiation spectrum from 250 to 2450 nm and an average life of 2400 hrs. Their color temperature is similar to that of daylight, 6000 K, and they have a high color rendering index Ra>95. Xenon lamps power ranges from 50 to 12,000 W. Regardless of the type of lamp and its power, the light color is constant. Xenon lamps are used for conventional film screening, digital film screening and video image screening, illuminating architectural objects, in vehicle lamps and for purposes of obtaining light effects and simulating solar light. [2, 4, 9, 10] In literature [4], xenon lamps are also recognized as discharge lamps.

Due to high luminance, emission of ultraviolet radiation, high internal pressure, both when the lamp is cold and hot, high power xenon lamps should only operated in closed, specially designed luminaires.

3. Test stand

The test stand for measuring spectral distributions of resultant (summary) radiation of halogen and xenon lamps (Fig. 3) has been made in the laboratory of the Division of Metrology and Optoelectronics of the Institute of Electrical Engineering and Electronics at the Faculty of Electrical Engineering of the Poznań University of Technology. The test stand consists of: the examined halogen and xenon lamps placed in a special fixture or luminaire, an integrating sphere and spectrometers (Ocean Optics Maya, whose measurement range is 200 – 1100 nm, and Hamamatsu TGNIR, with measurement range 900 - 1700 nm [11, 12]), with optic fiber cables, a PC with relevant software and power supply units.

Fig. 3. View of the test stand with a halogen lamp in a special fitting, a xenon lamp in a special luminaire and the integrating sphere

Fig. 4. HLX 64656 275W / 24V halogen lamp made by OSRAM [9]

OSRAM HLX 64646 275W/24V lamp was used as a model source of light. The scaling was done in the measurement system, with the help of an integrating sphere connected to the spectrometers with measuring optic fiber cable, a PC with software for spectrometers and a power supply. The spectral characteristics of the used optic fiber cables were adjusted for the spectrometers' measurement ranges.

4. Methodology of measurement of resultant spectra

The spectral distributions of the combined radiation of halogen and xenon lamps were determined in the system described in [6]. The spectral intensity of radiation (spectral irradiance) $E_S(\lambda)$ of the examined sources of radiation were derived from the formula:

$$E_s(\lambda) = E_{s\alpha}(\lambda) \cos \alpha = \\ = I_{PH}(\lambda) \cdot W(\lambda) \cos \alpha = [I_{PHD}(\lambda) - I_D(\lambda)] \cdot W(\lambda) \cos \alpha \qquad (1)$$

where: $I_{PHD}(\lambda)$ – signal with radiation sources switched on ("bright current" + "dark current"), $I_D(\lambda)$ – signal with radiation sources switched off ("dark current"), $W(\lambda)$ – coefficient of calibration of test stand, specified as:

$$W(\lambda) = \frac{E_{SR}(\lambda) \cdot \left(\frac{r_R}{r_2}\right)^2 \cdot \left(\frac{T_{IR}}{T_I}\right)}{I_{PHR}(\lambda)} \qquad (2)$$

where:

$E_{SR}(\lambda)$ – spectral intensity of optical radiation (spectral irradiance) of the model source of radiation at distance r_R

r_R, r_2 – distance of model source of radiation to the front face of the measuring sensor when determining characteristics $E_{SR}(\lambda)$ and when calibrating the spectrometer's measurement lines (r_2),
T_{IR} – time of integration of spectrometer during measurement $I_{PHDR} = f(\lambda)$ and $I_{DR} = f(\lambda)$,
T_I – time of integration of spectrometer during measurement $I_{PHD} = f(\lambda)$ and $I_D = f(\lambda)$,
$I_{PHR}(l) = (I_{PHDR}(\lambda) - I_{DR}(\lambda))$ – corrected signal for the model source of radiation.

Angle α is related to the location and dimensions of examined sources of radiation (Fig. 5). For this test bed the angle was $25^0 29'$.

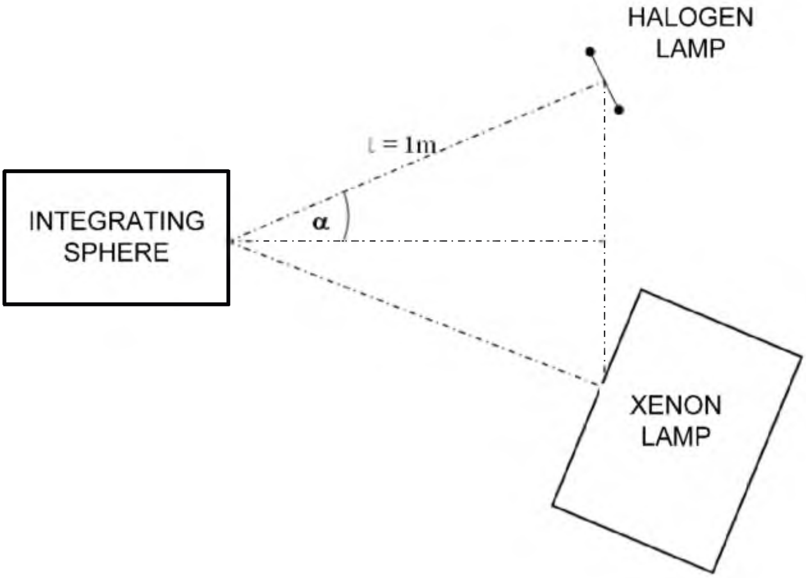

Fig. 5. Layout of test stand presented in Fig. 3, with indicated angle α

The spectra of the following lamps were examined: a xenon lamp (OSRAM XBO 1000W/HSC OFR) and halogen lamps (PHILIPS EcoHalo 350W/230V 2900K, OSRAM 650W/230V 3200K, OSRAM 800W/230V 3200K, OSRAM 1000W/230V 3200K, OSRAM 1000W/230V 3000K), in 9 different sets:

- 1000W xenon lamp and 350W halogen lamp,
- 1000W xenon lamp and 800W halogen lamp,
- 1000W xenon lamp and 1000W halogen lamp (T_b 3200K),
- 1000W xenon lamp and 1000W halogen lamp (T_b 3000K),
- 800W xenon lamp and 800W halogen lamp,
- 700W xenon lamp and 650W halogen lamp,
- 700W and 1000W xenon lamp (T_b 3200K),
- 700W xenon lamp and 1000W halogen lamp (T_b 3000K),
- 1000W xenon lamp and 650W halogen lamp.

5. The resultant spectral distributions of the radiation of halogen and xenon lamps

Fig. 6 and 7 show examples of summary spectral distributions of radiation. In both cases a 1 kW xenon lamp with a 350W and a 1000W halogen lamp was used. The obtained spectral distributions of radiation from two sources (a halogen lamp and a xenon lamp) allow, for a specific receiver, to better adjust the radiation of a two-source simulator to solar radiation, than it would be possible in single source simulators [1].

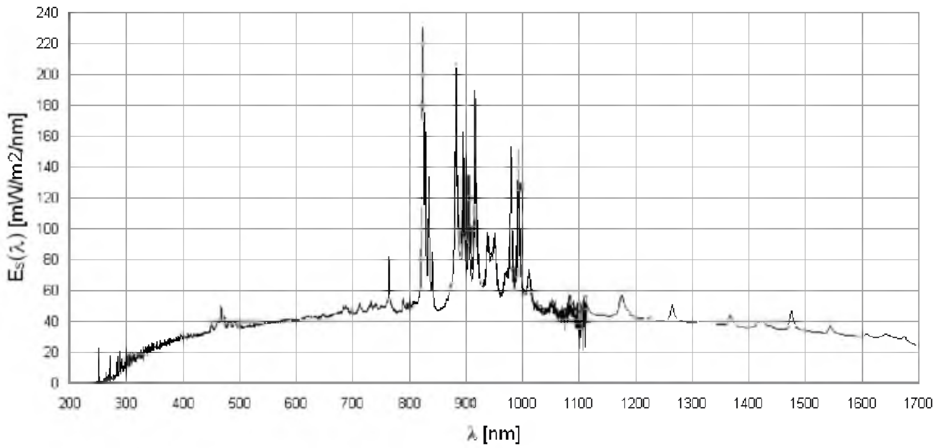

Fig. 6. Experimental summary (resultant) spectral distribution of radiation of a 350W halogen lamp and a 1000W xenon lamp

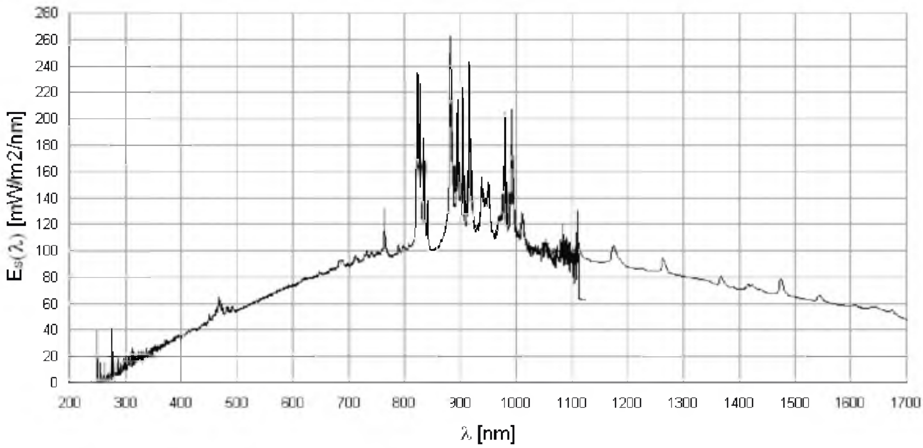

Fig. 7. Experimental summary (resultant) spectral distribution of radiation of a 1000W (Tb 3200 K) halogen lamp and a 1000W xenon lamp

6. Conclusions

The article presents results of measurement of spectral distribution of optical radiation emitted by an assembly (a set) of two lamps, a halogen one and a xenon one. The examined set of lamps may be a source of radiation in a solar radiation simulator designed for evaluating the operation of receivers such as photovoltaic panels or solar connectors. The range of specified characteristics was adapted to spectral sensitivity of selected receivers. Summary spectral characteristics were determined for combinations of lamps of various power. It was found that it is possible to determine summary (resultant) spectral characteristics of a simulator with two types of radiation sources on the basis of spectral distributions of individual lamps.

Acknowledgements

KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

UNIA EUROPEJSKA
EUROPEJSKI
FUNDUSZ SPOŁECZNY

Joanna Ratajczak is a scholarship holder within the project "Scholarship support for PH.D. students specializing in majors strategic for Wielkopolska's development", Sub-measure 8.2.2 Human Capital Operational Programme, co-financed by European Union under the European Social Fund.

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