

DESIGN OF SPECIAL LIGHT SOURCE FOR BIOLOGICAL APPLICATION

M. Steinbauer, E. Kadlecová

Brno University of Technology, Dept. of Theoretical and Experimental Electrical Engineering,
Kolejní 2906/4, 612 00 Brno, Czech Republic
e-mail: steinbau@feec.vutbr.cz, kadleca@feec.vutbr.cz

Summary This paper presents information about design of special light sources, which is intended for photosynthesis process research, especially for photoinhibition effect. Required properties were continuous spectral characteristic with respect to photosynthetically active wavelength area, possibility of luminous flux regulation and practically zero thermal effect to illuminated object. Owing to new high-performance LED this type of light source was selected. Design of light source consisting of high efficient white LED's, as well as experimental results, are presented.

The special light source was designed and constructed for the research activity on the lichen structure in the Antarctica. This research is made by the Institute of Experimental Biology, Masaryk University, Faculty of Science.

1. INTRODUCTION

Photosynthesis is a physiological phenomenon that converts solar energy into photochemical energy. This physiological phenomenon may be described thermodynamically in terms of changes in energy, entropy and free energy. The energetic of photosynthesis, driven by light, causes a change in entropy that in turn yields a usable source of energy.

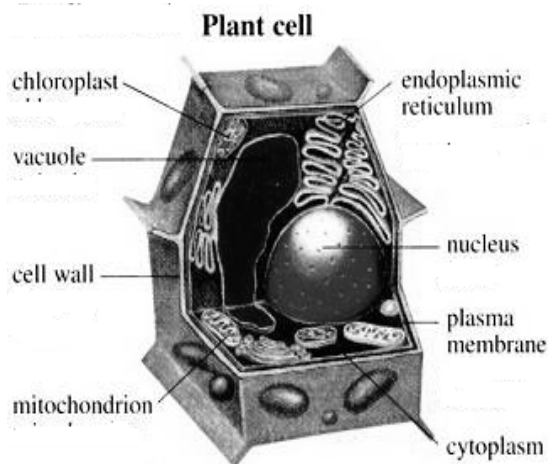


Fig. 1. The illustration of the Plant cell

There is known effects of light intensity (irradiance) and temperature on the rate of photosynthesis. At constant temperature the rate of photosynthesis varies with irradiance, initially increasing as the irradiance increases. However at higher irradiance this relationship no longer holds and the rate of photosynthesis reaches a plateau. The effect on the rate of photosynthesis of varying the temperature at constant irradiance can be seen in image to the left. At high irradiance the rate of photosynthesis increases as the temperature is increased over a limited range. At low irradiance, increasing the temperature has little effect on the rate of photosynthesis.

The research on area of the photosynthesis is made by the Institute of Experimental Biology,

Masaryk University, Faculty of Science within grant No. GA522/06/0979 (2006 - 2008) and is focused on the principles of plant resistance against the effects of high light-induced reactive oxygen species (ROS) in photosynthetic apparatus. Two model plants were selected to study photoinhibition under a variety of light and temperature conditions: lichenized green alga *Trebouxia* and *Arabidopsis thaliana*. Detection of photoinhibition and photodamage will be done by fluorometric and molecular biology methods. Photoprotective mechanisms activated during the early stages of photoinhibition will be evaluated biochemically. Actual level of ROS will be evaluated by specific sensor molecules monitored during and after photoinhibition by the means of fluorescence imaging technique.

2. DESIGN OF LIGHT SOURCE

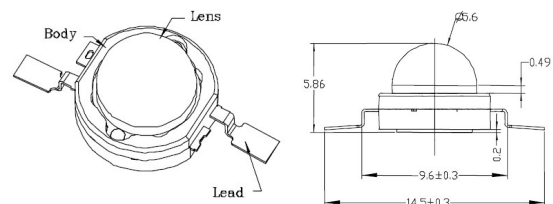


Fig. 2. Geometrical shape of used LEDs

Light source have had to meet following requirements

- continuous spectra in visible area from 400 to 800 nm,
- shape of the spectrum characteristic should be very similar as the daylight,
- the source should radiate in IR area as low as possible,
- defined shape and size of the illuminated surface,
- very high and homogenous intensity of the light on the defined surface.

These requirements are met using power LEDs, which are illustrated on fig. 2. Shape of this LED spectrum is on fig. 3. This LED emitted blue light from junction, but there is luminophore on its top, which change blue light to full white spectrum.

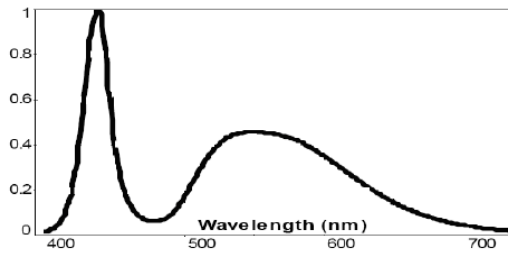


Fig. 3. Relative spectral characteristic of the light source

Power consumption of whole arrangement consisting of 17 LEDs is about 85 W. Whenever wide range of power source voltage was required, pulsed source was chosen.

Designed power supply is voltage driven current source 0 to 10 A operating on 180 kHz with efficiency over 80%, input voltage can be from 12 to 30 V.

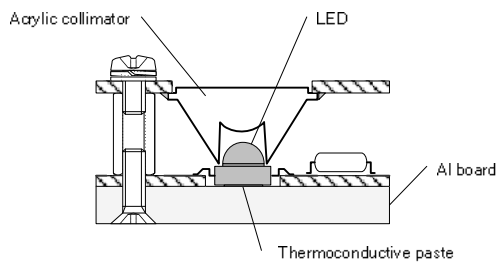


Fig. 4. Detail of LED arrangement on heat sink

High power of LEDs request efficient cooling to thermal dissipation. LEDs are joined to base aluminum board under permanent thrust (can be seen on construction detail fig. 4) and board is fitted by two fan coolers.

3. SIMULATION OF HOMOGENEITY

Matlab modeling of light source arrangement was designed for first verification of the lighting systems design and it is given in the fig. 5. The main advantages of the Matlab simulation are the simplicity of the submission for the initial figures and the high speed of the calculations for the simple assignments. This modeling is suitable for the verification of the results, which are received from other type of the modeling method.

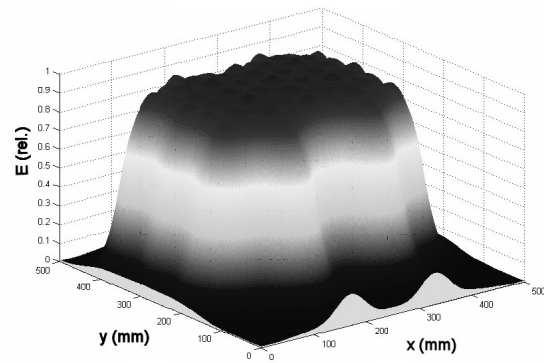


Fig. 5. Simulated relative intensity of illumination for final arrangement of 17 LEDs

4. EXPERIMENTAL VERIFICATION

Verification of designed source was provided on semiautomatic workplace in darkroom laboratory fig. 6. Results of the design verification are given in fig. 7.

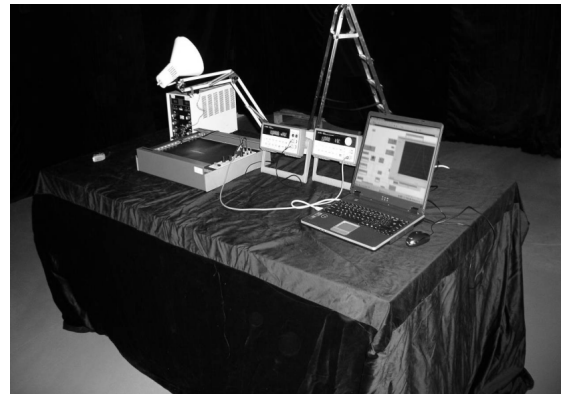


Fig. 6. The research workplace

There are differences between the values obtained by modeling and experimental measurement, ranging to the 20%, depending on the distance. When the light is into the requested distance, the differences are also lower. Experimental measurements were used as second verification.

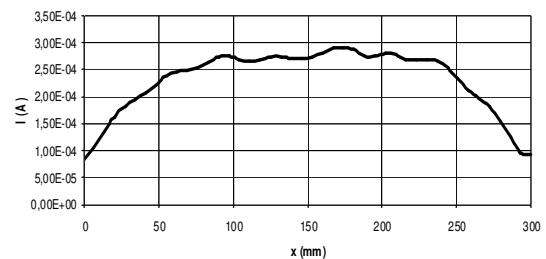


Fig. 7. Measured homogeneity of illumination for optimal distance 19 cm

The characteristic of the light source was calibrated to better regulation of the light power by the voltage input. This characteristic is given in the fig. 8.

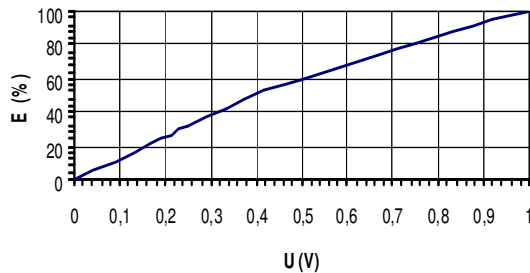


Fig. 8. Regulation characteristic of source

The picture of the control panel is given in the fig. 9. Power of the source can be driven locally as well as remotely by external voltage source 0-10 V.



Fig. 9. Control panel of light source

5. FINAL PARAMETERS OF LIGHT SOURCE

Final arrangement of the special source of light was measured on workplace fig. 6. Parameters of this source are:

- distance from the illuminate area is 18 – 21 cm for the best homogeneity,
- illuminate area is 200×300 mm,
- intensity of the light for the distance 19 cm is $500 \mu\text{Einstein}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$,
- homogeneity of the light is better than 10% into the area 100×200 mm (for the distance 19 cm),
- the lifetime of used LEDs is around 1000 hours for upper-most setting power,

- storage and container temperature -40 - +85°C,
- working temperature is -25 - +30°C,
- power supply range is 12V/9A till 30V/3,5A

The source of light agrees with extreme climatic conditions in the Antarctica and it is constructed with regard to the environmental resistance, thermal shocks, weatherproofness and protection against shaking. To achieve this corresponding climatic class components were chosen, the screws and the components were fixed against the movement, the silver PCB was used, etc.

6. CONCLUSION

Designed prototype of the special source of light reached all requirements. Increasing intensity of the light will be possible, as soon as the LED diodes with higher powers will be available.

Acknowledgement

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