Manuscript received March 12, 2018; revised October, 2018. DOI: 10.24425/123545

Influence of Selected Parameters on Radiant Intensity Measurement Results - Light Meter and a CCD Camera Comparison

Joanna Parzych

***Abstract*—This work concerns measurements of the radiant intensity emitted by LEDs. The influence of selected factors and parameters on the final measurement result are discussed. The research was conducted using two type of detectors: light meter and CCD camera, to compare the degree of influence of these parameters depending on the measurement instrument used.**

***Keywords*—CCD sensor, LED, light meter**

I. Introduction

THE number of fields of LEDs application still is increasing, therefore obtaining detailed information about their optical and electric parameters is significant. In the measurement of the optical parameters, spectrometric, radiometric and photometric methods are used. The choice of a given technique is determined by, among others the kind of light source, the purpose of research or costs. Each method has its advantages and disadvantages. From spectrometric measurements, information about the entire spectrum of the source can be obtained, but it is more time-consuming than photometric. In turn, photometric measurements require the correction of the photometric head, because the maximum of spectral responsivity does not fall on the length of wave of the radiation emitted by white or blue LED [1], [2].

Regardless of the chosen measurement method, various external factors and parameters of the measurement system itself affect the results of measurements. In the case of measurement parameters for radiation sent by light-emitting diodes, they include: distance between the detector and the LED, location of the LED in relation to the detector (angle between the geometrical and optical axes of the LED and the surface of the detector) and parameters of the detector itself. The amount of radiation transmitted by the diode, which reaches the photosensitive surface of the detector, depends on them. Determining the significance of these and other factors disrupting the measurement is essential from the point of view of the precision and correctness of examinations [1]–[3].

This work is focusing on indirect measurements of radiant intensity of the radiation emitted by LEDs. In order to check the impact of the above-mentioned factors on the result, measurements of the radiant intensity using a luxmeter and a CCD camera were carried out. The direct result of the measurement in the case of the luxmeter is illuminance E_υ, and for the CCD camera the average brightness N_{avg}. For both types of measurements, which were conducted, input signals are the same (radiation emitted by LED), but output signals are different, because of transformation in measuring process: quantity in photometric units for light meter and in relative units for CCD camera. Changes in the values of both measured quantities are proportional to changes in radiation intensity [1], [4]. Illuminance is related with radiation intensity linear relationship (1), and the average brightness is the power dependence (2):

$$I = E_\upsilon r^2, \tag{1}$$

$$I = k_1 \cdot e^{k_2 \cdot N_{\text{avg}}}, \tag{2}$$

where r is distance between the detector and the light source and k_1, k_2 are coefficients of proportionality. With regard to different sorts of units, in which there are expressed quantities obtained from light meter measurements and from the registration with the CCD camera, a percentage relative value of the standard uncertainty of type A was introduced in order to compare the scattering of results of both quantities, as can be seen in (3) and (4):

$$u_{\text{A\%}} = \frac{u_A}{E_\upsilon} \cdot 100\%, \tag{3}$$

$$u_{\text{A\%}} = \frac{u_A}{N_{\text{avg}}} \cdot 100\%. \tag{4}$$

II. Measurement System

Indirect measurements of the value of radiant intensity emitted by an LED were conducted using a light meter and CCD camera (Figs. 1 and 2). For both measurement methods the same conditions were preserved according to CIE recommendations: the distance between the lens of the diode and the detector was equal to 100 mm, the surface of the detector was perpendicular to the geometrical axes of the LED, geometrical axes of the detector and the diode were covered and screens were used to isolate the system from the influence of light sources in the surroundings other than the ones examined [1], [2], [5]. In measurements the following measuring instruments were used:

- light meter L-100 with head of type GL-100,
- CCD camera Sony DFW-X710,
- power-driven source,

This work is supported by by Grant/Award Number 04-42/DSPB/0389.

Autor is with the Institute of Electrical Engineering and Electronics, Poznan University of Technology, Poznań, Poland, (e-mail: joanna.parzych@put.poznan.pl).

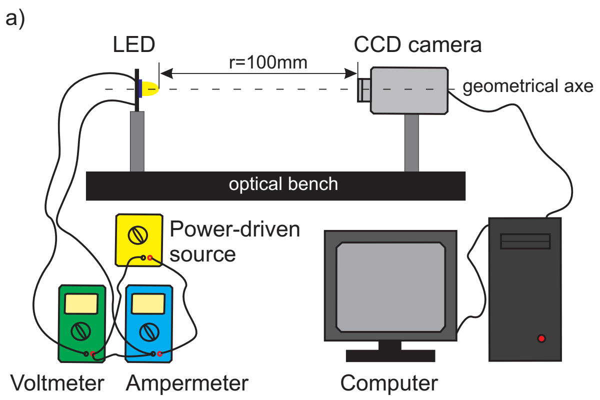

Fig. 1. Structure of the measuring stand for registration with the CCD camera [4]

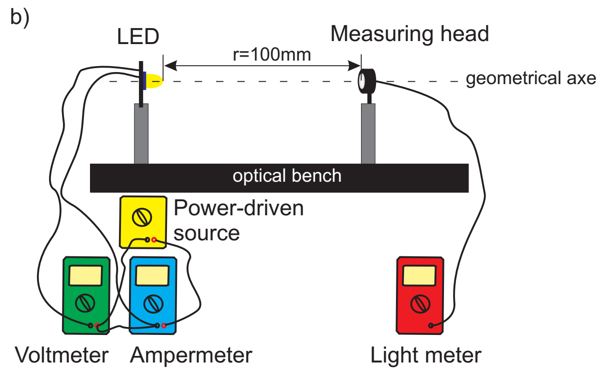

Fig. 2. Structure of the measuring stand for the measurement light meter [4]

- multimeter BRYMEN BM859CF,
- multimeter Metex 4660A.

The measurements were carried out for six selected types of LED, which were diodes that emitted radiation in the colours:

- white or warm white: LED LL-504WC-W2-3QD (LED5WW), LED OSM5DL5111A-VW (LED5W), LED S300TWW4G-S-2800K (LED3W),
- red: LED OS5RPM5A31A-QR (LED5R),
- green: LED OSPG5131A-ST (LED5G)
- and blue: LED OSUB5131A-PQ (LED5B).

For diodes of green and blue LED additional measurements were conducted at the distance $r = 316\,\mathrm{mm}$ with regard to large N_{avg} values close to saturation (close to the maximal value N_{avg} equal to 254). Each measuring series consisted of 31 measurements, during which the setting was changed for:

- the distance between the detector and the LED,
- location of the diode with regard to the detector (with regard to angle between geometrical axes of the LED and the detector),
- sharpness of the CCD camera and value of external illumination (backgrounds).

The measurements were taken for the distances $r = 100\,\mathrm{mm}$ and $r = 316\,\mathrm{mm}$ at the supply current of the diode I_F equal to $5\,\mathrm{mA}$, $10\,\mathrm{mA}$, $15\,\mathrm{mA}$ and $20\,\mathrm{mA}$, for the angle α from the range from 0 to 30 degrees, at external illumination $0.005\,\mathrm{lx}$, $5\,\mathrm{lx}$, $20\,\mathrm{lx}$, $100\,\mathrm{lx}$ and for four selected settings of the sharpness of the CCD camera.

A. *Influence of Setting of the Distance*

During measurements the distance r between the LED and the detector was the only parameter for which the value was changed. Before every consecutive measurement the value of distance r was set anew in order to check what scattering of results causes the inaccuracy of the distances setting. The measurements were carried out for four selected values of the supply current of the diode: 5 mA, 10 mA, 15 mA and 20 mA. It is possible to notice that the value $u_{A\%}$ is smaller for measurements performed by the light meter (Figs. 3- 5). For results achieved with the CCD camera the uncertainty $u_{A\%}$ assumes values from the range (0.001 0.3) % - apart from two cases, when it assumes values higher than 1.5%, and for results obtained from the light meter the uncertainty $u_{A\%}$ assumes values from the range (0.02 0.31) %. Lower range of changes of the value in the case of light meter measurements means that light meter measurement is more stable, however the difference between the $u_{A\%}$ values is slight. But the opposite situation (higher values of the uncertainty $u_{A\%}$ for the light meter) in case of the blue diode LED5B at the distance r = 100 mm on CCD camera images a saturation effect occurs (Fig. 4). At the distance $r = 316\,\mathrm{mm}$ there is no saturation effect (Fig. 5), so the scattering of results is greater. Moreover in most light meter measurement cases the percentage value of the relative standard uncertainty $u_{A\%}$ grows along with an increase in the value of the supply current of the LED diode, and for registered results with the CCD camera a opposite tendency is observed.

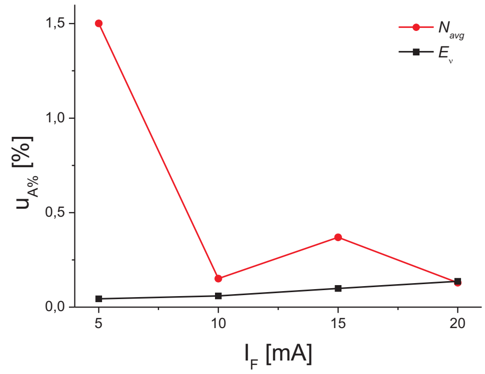

Fig. 3. Relative standard uncertainty $u_{A\%}$ in the function of the supply current of the LED at r = 100 mm for blue diode LED5WW.

B. *Influence of Background*

The measurements were carried out for four selected illuminance values: $0.005\,\mathrm{lx}$, $5\,\mathrm{lx}$, $20\,\mathrm{lx}$, $100\,\mathrm{lx}$ in order to check the influence of the external illuminance (backgrounds) for the result of the registration with the CCD camera. For small values of external illuminance with $0.005\,\mathrm{lx}$ and $5\,\mathrm{lx}$ slight differences in values N_{avg} appeared. At higher values $20\,\mathrm{lx}$

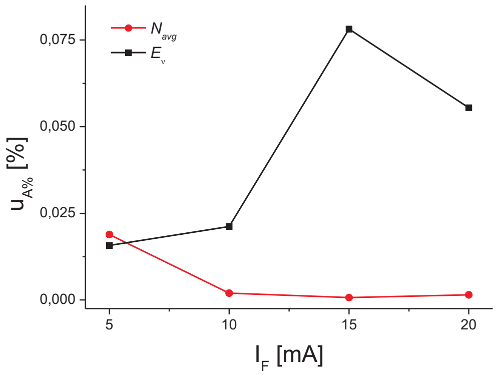

Fig. 4. Relative standard uncertainty $u_{\mathrm{A}\%}$ in the function of the supply current of the LED at r = 100 mm for blue diode LED5B.

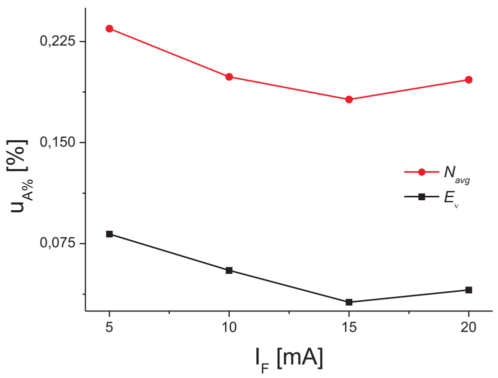

Fig. 5. Relative standard uncertainty $u_{\mathrm{A}\%}$ in the function of the supply current of the LED at r = 316 mm for blue diode LED5B.

and 100 lx the changes of the value N_{avg} are greater, however only in the case of two diodes: red and green (at $r = 316\,\mathrm{mm}$) do the values diverge significantly from the remaining results (Figs. 6 - 7). In the figures, the values of external illuminance were indicated appropriately: 0.005 lx - with green colour, 5 lx - with the blue colour, 20 lx - with the red colour and 100 lx - with black colour.

C. Influence of Setting of the Angle

The measurements were carried out for different values of the angle α between the geometrical axes of the diode and the detector in order to check to what degree the change of the angle affects the result of the light meter measurement and the result of the registration with the CCD camera. Values of the standard uncertainty of type A $u_{\mathrm{A}\%}$ expressed in the percent for both detectors are similar and don't exceed 0.6% (for light meter $u_{\mathrm{A}\%}$ = (0.01 0.5) %, and for the CCD camera $u_{\mathrm{A}\%}$ = (0.005 0.6) %). However on the graphs showing the relation of N_{avg} and E_{υ} from the angle α (Figs. 8 - 12) it seems, that characteristics E_{υ} = f(α) have a steeper course than characteristics N_{avg} = f(α), it means that results achieved using the CCD camera are less susceptible to changes of the angle α in the range from 0 to 10 degrees, and for the

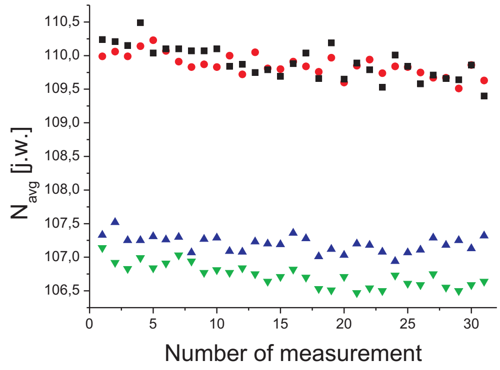

Fig. 6. Average brightness N_{avg} for selected values of the external illuminance for I_F = 20 mA at r = 100 mm for for warm white diode LED3W.

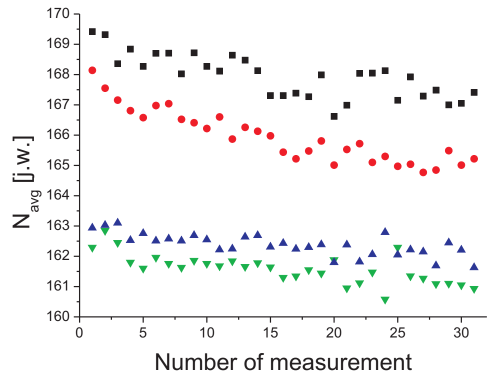

Fig. 7. Average brightness N_{avg} for selected values of the external illuminance for I_F = 20 mA at r = 100 mm for red diode LED5R.

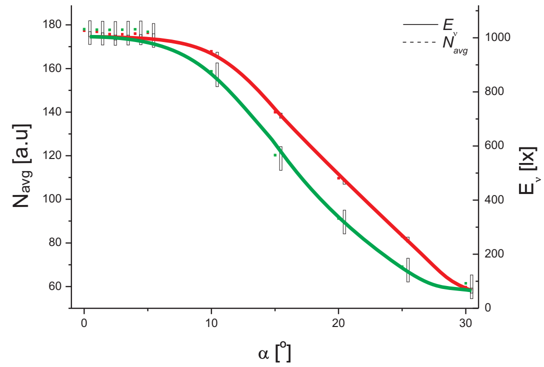

Fig. 8. Illuminance E_{υ} and the average brightness N_{avg} in the function of the angle α at $r = 100\,\mathrm{m}$ and I_F = 20 mA for the white diode LED5WW.

white diode LED5W, which has a half low half-angle from remaining examined diodes, in the range from 0 to 3 degrees (Fig. 9).

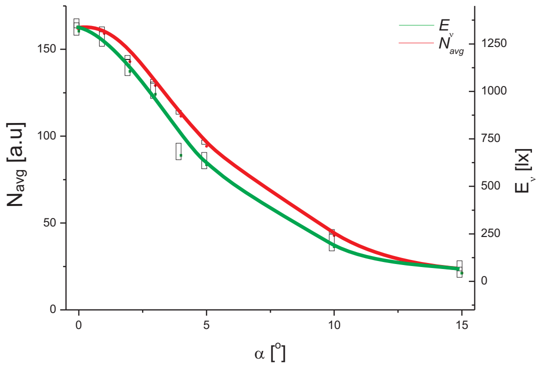

Fig. 9. Illuminance E_υ and the average brightness N_{avg} in the function of the angle α at $r = 100\,\mathrm{m}$ and I_F = 20 mA for the white diode LED5W.

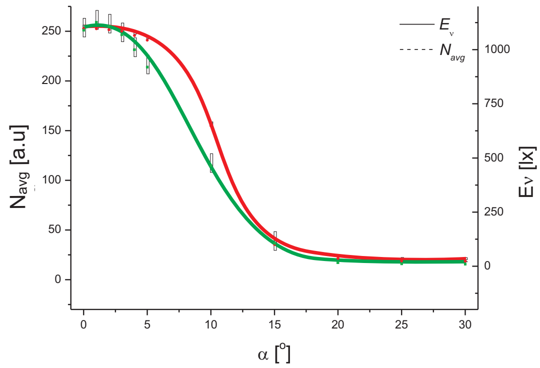

Fig. 12. Illuminance E_υ and the average brightness N_{avg} in the function of the angle α at $r = 316\,\mathrm{m}$ and I_F = 20 mA for the white diode LED5G.

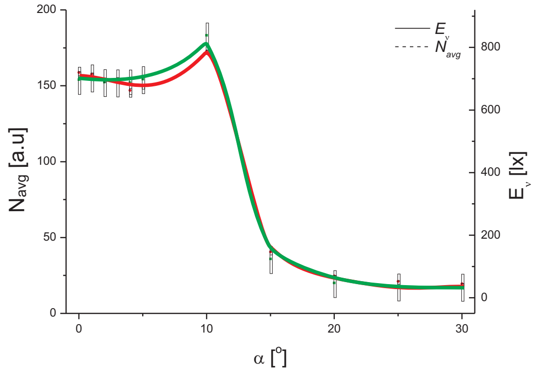

Fig. 10. Illuminance E_υ and the average brightness N_{avg} in the function of the angle α at $r = 100\,\mathrm{m}$ and I_F = 20 mA for the white diode LED5R.

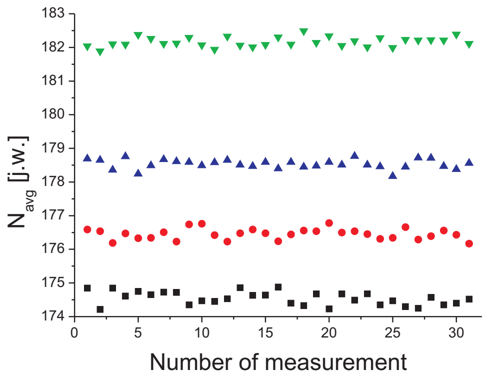

Fig. 13. Average brightness N_{avg} for selected settings of the sharpness for $I_F = 20\,\mathrm{mA}$ at $r = 100\,\mathrm{mm}$ for white diode LED5WW.

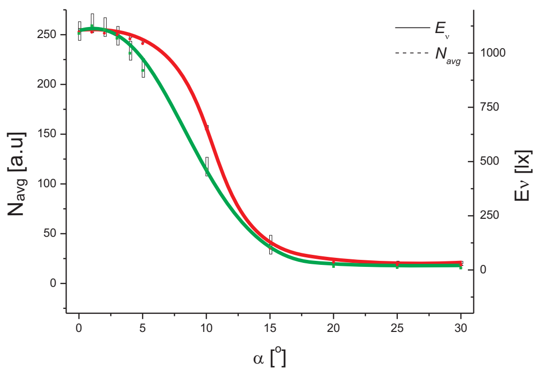

Fig. 11. Illuminance E_υ and the average brightness N_{avg} in the function of the angle α at $r = 100\,\mathrm{m}$ and I_F = 20 mA for the white diode LED5B.

D. *Influence of Setting of the Focus*

Measurements were carried out for three successive sharpnesses settings (I, II, III) and the decisively different from the remaining fourth setting (IV) in order to check to what degree the inaccuracy of the sharpness setting affects the result of registration with the CCD camera (Figs. 13– 16). A substantial change of the value N_{avg} was observed only with a significant change of the sharpness setting (setting IV). Only in the case of the blue LED (Fig. 16b)) important differences in the value N_{avg} with sharpness change were observed. Perhaps it is caused by the measuring distance or related with the colour of radiation emitted by the diode. However the change step of the setting, which was selected here, was much greater than the real inaccuracy of the sharpness setting during registration with the CCD camera, therefore making it all the more possible to state, that differences in the sharpness setting don't have a significant effect on the final result. On the figures the following sharpness settings were indicated: I – with the black colour, II – with the red colour, III – with the blue colour and IV – with green colour.

E. *Comparison of Influence of Selected Factors*

Shown on Figs. 17 and 18 is the value of the standard uncertainty $u_{\mathrm{A}\%}$ of results achieved from registration with the CCD camera and from the light meter measurements in order to compare their values and to imagery differences in scattering of results caused by individual factors with reference to values of total scattering. For registration with the CCD camera, the scattering of results related with distance,

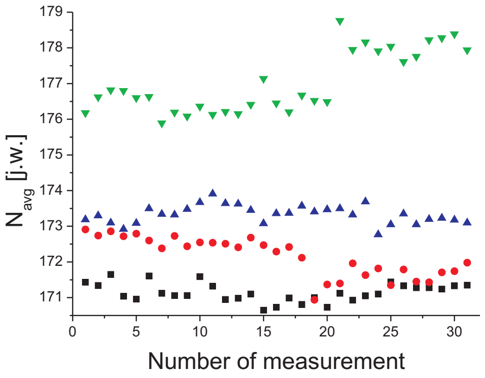

Fig. 14. Average brightness N_{avg} for selected settings of the sharpness for $I_F = 20\,\text{mA}$ at $r = 100\,\text{mm}$ for white diode LED5W.

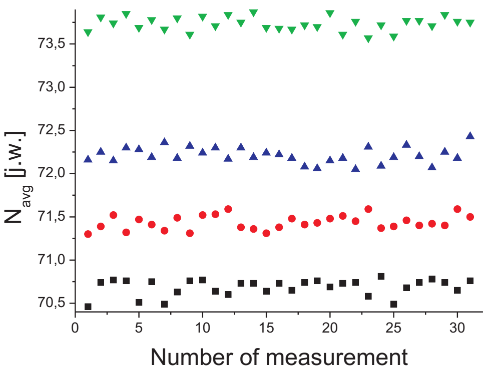

Fig. 15. Average brightness N_{avg} for selected settings of the sharpness for $I_F = 20\,\text{mA}$ at $r = 316\,\text{mm}$ for white diode LED5G.

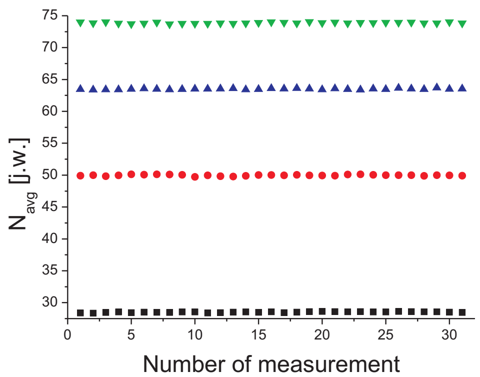

Fig. 16. Average brightness N_{avg} for selected settings of the sharpness for $I_F = 20\,\text{mA}$ at $r = 316\,\text{mm}$ for white diode LED5B.

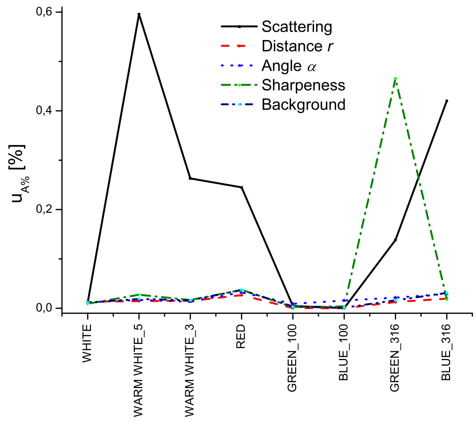

Fig. 17. Comparison of the values of the relative standard uncertainty $u_{A\%}$ of results obtained from the registration with CCD camera for selected factors

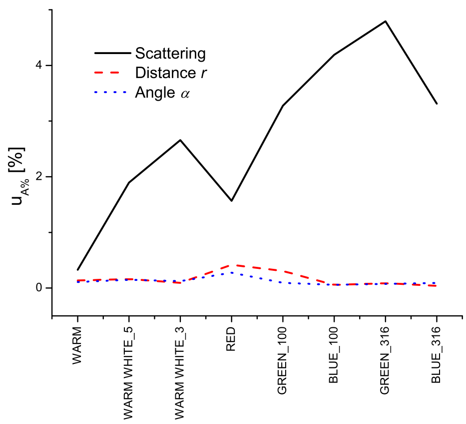

Fig. 18. Comparison of the values of the relative standard uncertainty $u_{A\%}$ of results obtained from measurements light meter for selected factors

background and sharpness is not significant in comparison to the total scattering for all examined LEDs, except for the green, blue and warm white diode LED5W (Fig. 17). In the case of the green and blue diodes, the differences are caused by an image saturation effect, which appeared during registration at the distance $r = 100\,\text{mm}$. After the change of distance on $r = 316\,\text{mm}$ the effect of saturation doesn't have influence on results. For the light meter measurements, the total scattering of results is definitely greater than the scattering caused by inaccuracy of the distance itself for all studied LEDs (Fig. 18). It results from the light meter being more susceptible to changes of the angle α than the image obtained from the CCD camera and even the low inaccuracy in placing the examined diode and the detector towards itself causes differences in the result of the measurement.

III. Summary

The parameters of elements of the measurement system, such as: distance between the CCD camera and the LED, location of the diode with regard to the detector (angle between geometrical and optical axes of the LED and the photosensitive surface of the camera), placing of the camera screen and the time of exposition have a significant influence on the result obtained in every measuring condition, because the amount of radiation emitted by the LED diode that is reaching the photosensitive surface of the detector depends on them. The influence of the other parameters and factors, such as e.g.: the sharpness setting of the CCD camera and the external illuminance (background) on it, what part of the emitted radiation the CCD camera will record is not very significant in the determined laboratory measuring conditions. Determining the significance of the other disrupting factors requires further research.

REFERENCES

[1] *Handbook of LED Metrology*, 2010.

[2] R. Young, "Measuring light emission from LEDs," 2006, reprint (R35).

[3] P. Fiorentin, P. Iacomussi, and G. Rossi, "Characterization and calibration of a CCD detector for light engineering," *IEEE Trans. Instrum. Meas.*, vol. 54, no. 1, pp. 171 – 177, 2005.

[4] J. Parzych, "Model of radiation detection in a system: LED – CCD matrix," *Przeglad Elektrotechniczny*, vol. 92, no. 6, pp. 176–179, 2016.

[5] E. Schubert, *Light Emitting Diodes*. Cambridge University Press, 2003.