APPLICATION OF IMAGING ELEMENTS IN VEHICLE LIGHTING DEVICES PHOTOMETRY

Wojciech Moćko

Motor Transport Insitute
Jagiellońska 80 Street, 03-301 Warsaw, Poland
tel.: +48 22 811 32 31 w. 317, fax: +48 22 8110906 e-mail: wojciech.mocko@its.waw.pl

Abstract

Imaging elements has been used in photometry for a few years. They found application in matrix luminance meters and colorimeters. In Motor Transport Institute such device was developed. It uses digital camera as data source. System is called Iluminator. It allows luminance distribution measurement and different kind of analysis. Imaging elements allows to develop a new measurement methods and also to improve already existing measurement methods. This paper describes tests of devices for illumination of rear registration plates and tests of headlamps with use of matrix luminance meter. Devices for illumination of rear registration plate are tested according to Regulation 4 ECE UN. The stand for testing such devices consists of basis on which diffuse colorless material is mounted and luminance meter. Diffuse reflection factor must be known. Dimensions of this material corresponds to dimensions of one from three different types of registration plates. Device under test illuminates diffuse material. Location of illuminating device in relation to diffuse material must correspond to location between device and registration plate shown on approval drawings. After measurement all result are recalculated to diffuse reflection factor equal 1. Measurement results was compared to reference methods. Results of compare shown that measurement methods with use of imaging elements could be applied in practice. Application of matrix luminance meter can significantly speed up and simplify photometric measurements. In this paper compare between values obtained with use of matrix luminance meter and standard method was shown. This compare was done with use of devices for illumination of rear registration plate and headlamp. In both cases obtained results proved that method which use imaging elements can be applied in practice.

Keywords: *matrix luminance meter, photometry, headlamps, illumination of rear registration plate*

1. Introduction

Imaging elements has been used in photometry for a few years [1, 2]. They found application in matrix luminance meters and colorimeters. In Motor Transport Institute such device was developed. It uses digital camera as data source [3]. System is called Iluminator. It allows luminance distribution measurement and different kind of analysis. Imaging elements allows to develop a new measurement methods and also to improve already existing measurement methods.

2. Test of devices for illumination of rear registration plates

Devices for illumination of rear registration plate are tested according to Regulation 4 ECE UN. Diagram of stand for testing such devices was presented on Fig. 1. It consists of basis on which diffuse colorless material is mounted and luminance meter. Diffuse reflection factor must be known. Dimensions of this material corresponds to dimensions of one from three different types of registration plates. Device under test illuminates diffuse material. Location of illuminating device in relation to diffuse material must correspond to location between device and registration plate shown on approval drawings. There are measurement points located on the diffuse material surface. Measurement points has shape of circle of 25 mm diameter. Luminance meter has possibility to move across axis x and axis y of plane parallel to diffuse material surface. It allows to measure luminance in next measurement points. Optical axis of luminance meter must be perpendicular to diffuse material surface. Tolerance of angle between perpendicular to material surface and optical axis of luminance mater equals 5o. After measurement all result are recalculated to diffuse reflection factor equal 1.

Tests of devices for illumination of rear registration plates needs measurement in a few strictly given measurement points. Before every single measurement precise positioning of luminance meter across x axis and y axis must be done. Measurement field of meter must exactly match measurement point on diffuse surface. Sometimes relation between illumination device and registration plates isn't exactly shown. In this case location device which meets requirements of Regulation 4 must be found base on next trays. This kind of work lengthen tests much more.

The alternative way of luminance measurements is application of matrix luminance meter instead of traditional „point" meter. Thanks to that luminance measurements in all measurement points at the same time are possible. It allows to shorten measurement procedure. To check measurement method which uses matrix luminance meter three different types of devices for illumination of rear registration plates was tested. During the tests matrix luminance meter system "Iluminator" developed in Motor Transport Institute was used. Reference values was obtained with use of luminance meter LMT L1009. Uncertainty of measurement method which uses LMT meter equals 11% at trust level equal 95%. Luminance measurement results was presented in Tab. 1. Maximum value doesn't exceeds 11% and it's in the limits of uncertainty of reference method. According to above measurement method which uses matrix luminance meter to tests devices for illumination of rear registration plates could be used in practice.

Luminance distribution over diffuse surface illuminated by tested device was show on Fig. 2. It shows measurement fields according to Regulation 4. Luminance distribution was measured with use of Illuminator system.

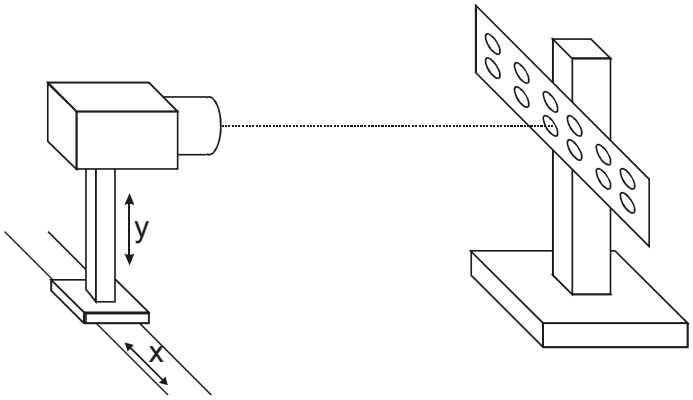

Fig. 1. Diagram of stand for testing devices for illumination of rear registration plates

Tab. 1. Results of tests of devices for illumination of rear registration plate

Measurement field	Device No. 1			Device No. 1			Device No. 1		
	LMT [cd/m^2]	Iluminator [cd/m^2]	Difference [%]	LMT [cd/m^2]	Iluminator [cd/m^2]	Difference [%]	LMT [cd/m^2]	Iluminator [cd/m^2]	Difference [%]
1	0.52	0.48	-8.7%	0.74	0.69	-6.6%	15.93	15.73	-1.3%
2	0.96	0.85	-10.6%	12.70	12.58	-1.0%	57.90	57.73	-0.3%
3	1.62	1.60	-1.3%	15.00	15.31	2.1%	71.10	73.02	2.7%
4	2.87	2.88	0.2%	9.60	9.92	3.3%	76.70	78.61	2.5%
5	6.72	6.70	-0.3%	1.33	1.30	-2.0%	53.70	52.49	-2.3%
6	5.70	6.33	11.0%	0.24	0.22	-9.0%	14.23	13.47	-5.3%
7	6.26	6.52	4.2%	0.50	0.52	3.0%	10.10	9.45	-6.4%
8	7.74	7.86	1.6%	2.27	2.22	-2.1%	27.80	27.10	-2.5%
9	3.24	3.29	1.4%	6.94	7.11	2.5%	28.50	28.74	0.8%
10	1.75	1.77	1.0%	9.80	9.94	1.5%	22.60	23.12	2.3%
11	0.86	0.83	-3.9%	5.65	5.43	-3.9%	18.50	18.41	-0.5%
12	0.61	0.56	-7.7%	3.10	2.94	-5.1%	11.44	10.90	-4.7%

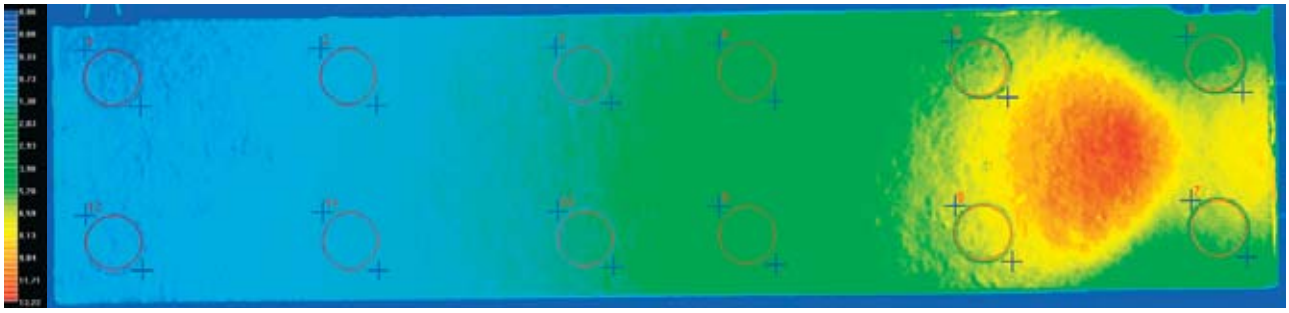

Fig. 2 a) Device No. 1

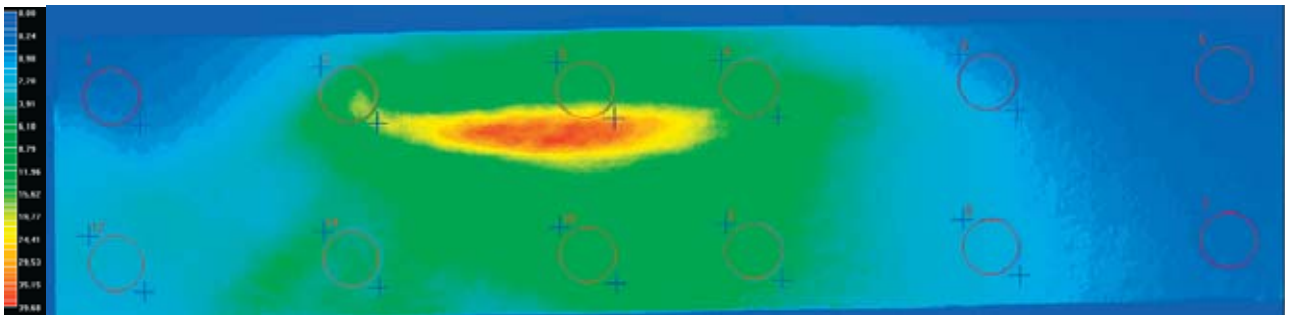

Fig. 2 b) Device No. 2

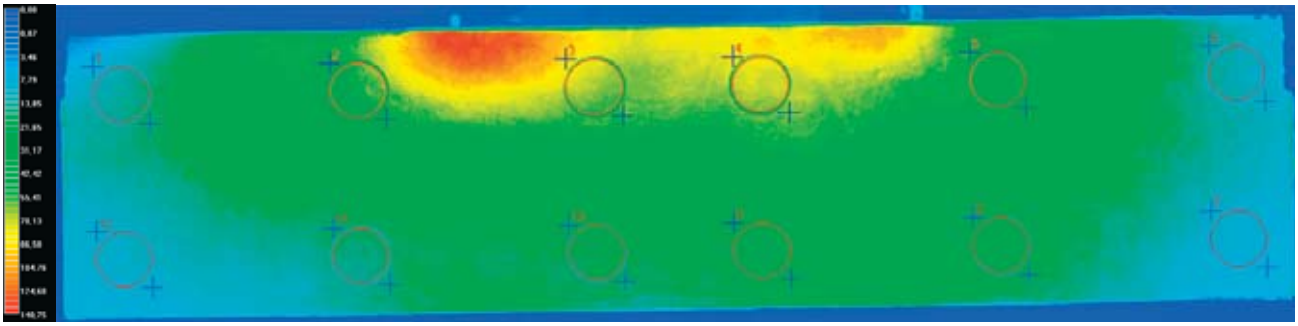

Fig. 2 c) Device No. 3

Fig. 2. Luminance distribution of diffuse material illuminated by tested device

3. Tests of vehicle headlamps

Measurement of photometric parameters of headlamps is usually done in photometric darkroom. Measured value is illuminance value on measurement screen. Measurement screen has exactly defined set of measurement points. They corresponds to particularly pieces of hypothetic road illuminated by tested headlamp. For example point „50R" correspond to area placed 50 m before vehicle. Screen has 8 m wide and 4 m height. Requirements concerning most commonly used headlamps emitting asymmetrical passing beam and driving beam equipped with filament lamps are described in Regulation No. 112 ECE UN. Distance between measurement screen and device under test is 25 meters. The screen illumination values shall be measured by means of a photo receptor, the effective area of which shall be contained within a square of 65 mm side. Measurement can be done manually or automatically. In manual method photo receptor should be placed in turn in all required points. Next minimal and maximal values in areas should be founded. Founding of minimal and maximal values is very difficult in manual method of measurement. This method is time-consuming and may cause problems during seeking of extreme values.

Automatic methods uses moving photo receptor across measurement screen plane or turning headlamp placed on goniometer and recalculation obtained values on coordinates of plane screen. Test stand must be equipped in quick goniometer and quick photometer which allows to take measurement online. Thanks to that whole measurement process could be done in a dozen minutes.

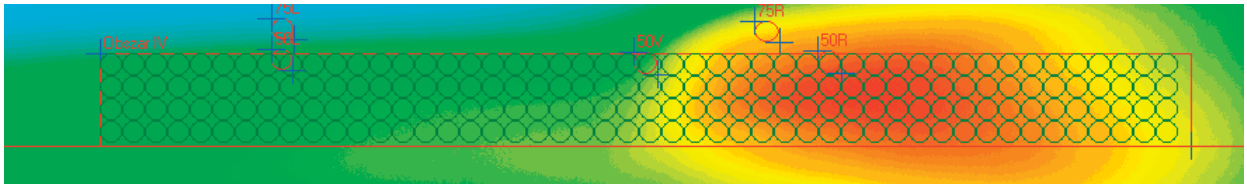

Fig. 3. Measurement of minimal and maximal value

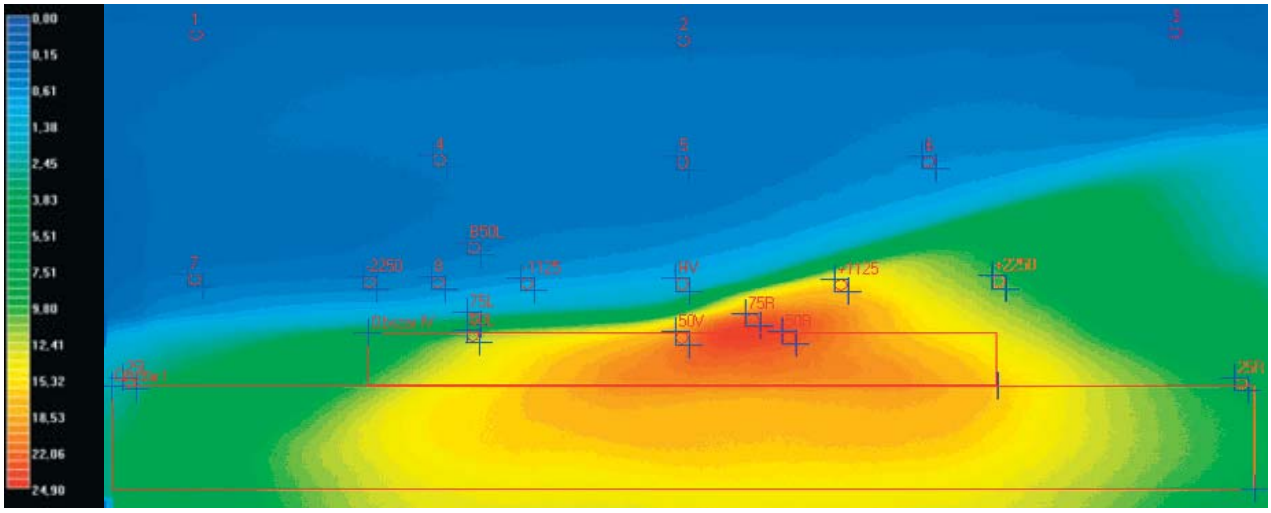

Fig. 4 a) Illuminance distribution on the measurement screen - Headlamp No. 1

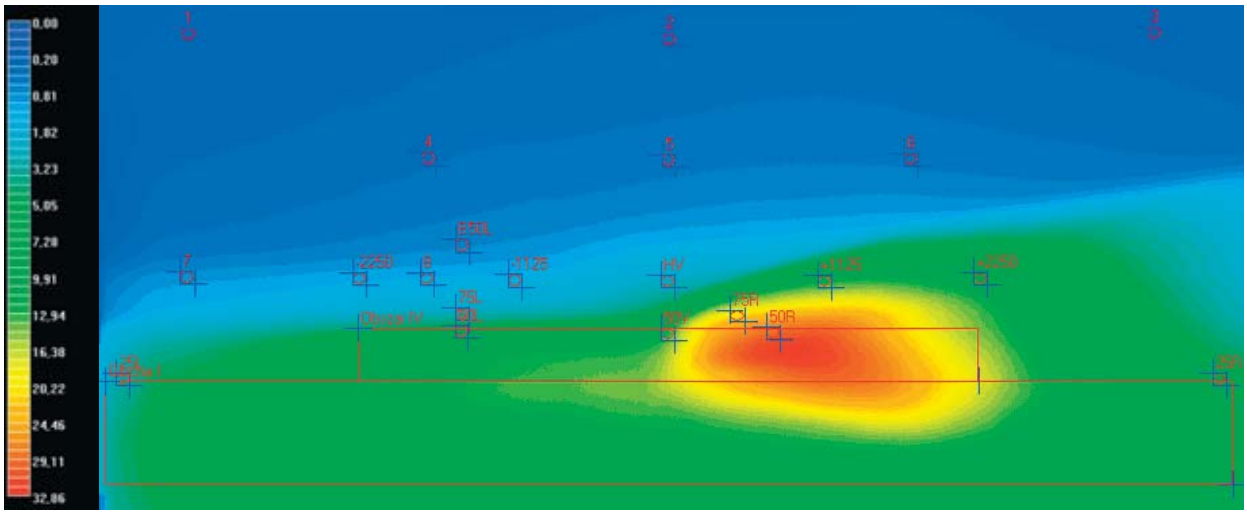

Fig. 4 b) Illuminance distribution on the measurement screen - Headlamp No. 2

With use of described before Iluminator system measurement of illumination on the screen could be done quickly and easy. Distribution of illumination on the measurement screen is derive from distribution of luminance recorded by matrix luminance meter. To be able to measure luminance distribution special uncolored screen coated by diffuse material must be prepared. This screen is illuminated by device under test. Measurement consists of two stages:

- at first picture of measurement screen according to Regulation 112 was done. Base on this picture in Iluminator system measurement points and areas corresponding to points and areas on the screen was defined. After taking a picture position of camera was locked to prevent any movements which may cause displacement between points defined in Iluminator system and on the screen.
- next after remove the measurement screen (which is rolled up) luminance distribution on the diffuse screen is measured. Because luminance is linear function of illuminance on the measurement screen obtained luminance values are scaled to receive illuminance values.

$$E[lx] = k[lx\ m^2/cd]\ L[cd/m^2]. \quad (1)$$

Angle sensitivity of used photo receptor should be cosine. In the case of measurement of luminance on the diffuse screen digital correction of angle sensitivity must be done. This correction will be simulating cosine angle sensitivity of photo receptor. Distance between measurement screen and device under test is 25 m, distance between center of screen and edge of screen is 4 m, distance between center of screen and bottom of screen is 2 m. Maximum correction for corner of screen:

$$k = \cos(arctg(\frac{25}{\sqrt{4^2 + 2^2}})) = 0{,}984. \quad (2)$$

Measurement error caused by lack of cosine correction is rising with distance from center of screen. Maximum value of this error is 1.6%. Owing to small value of this error cosine correction was omitted in this paper.

Tab. 2. Result of tests of headlamps

Punkt/ obszar	Headlamp No 1			Headlamp No 1		
	Photo receptor [lx]	Iluminator [lx]	Photo receptor [lx]	Iluminator [lx]	Photo receptor [lx]	Iluminator [lx]
-2250	0.51	0.50	-1.4%	1.22	1.19	-2.5%
-1125	0.81	0.79	-3.1%	1.46	1.44	-1.4%
1	0.24	0.22	-7.9%	0.20	0.22	8.0%
2	0.34	0.32	-5.2%	0.32	0.35	8.2%
3	0.24	0.23	-5.5%	0.27	0.28	2.9%
4	0.36	0.37	1.4%	0.41	0.44	6.4%
5	0.40	0.42	7.2%	0.54	0.55	2.5%
6	0.63	0.61	-2.5%	0.56	0.58	3.7%
7	0.42	0.39	-5.8%	0.92	0.90	-2.6%
8	0.61	0.60	-2.0%	1.31	1.28	-2.4%
1125	15.72	15.80	0.5%	12.59	12.01	-4.6%
2250	10.52	10.25	-2.5%	10.30	9.81	-4.8%
25L	2.68	2.58	-3.7%	3.24	3.24	0.2%
25R	9.00	8.62	-4.1%	5.66	5.84	3.1%
50L	11.28	10.63	-5.8%	6.77	6.14	-9.4%
50R	24.17	23.87	-1.3%	28.60	29.01	1.4%
50V	20.15	20.46	1.5%	12.45	12.33	-1.0%
75L	2.88	3.07	6.3%	3.17	2.90	-8.6%
75R	22.92	23.06	0.6%	20.42	20.39	-0.2%
B50L	0.44	0.45	2.3%	0.77	0.78	0.8%
HV	1.25	1.26	0.3%	2.51	2.54	1.2%
Area I max	26.81	24.50	-8.6%	27.35	27.90	2.0%
Area IV min	6.85	6.60	-3.7%	6.35	5.97	-5.9%
Area IV max	25.00	25.29	1.1%	32.76	33.29	1.6%

During searching minimal and maximal values in the area measurement field equal to photo receptor size was used. Measurement field was moved across whole area (Fig. 3). Thank to that computer analysis are made similarly to real manual analysis with use of photo receptor.

In Tab. 2 measured photometric parameters of two headlamps was shown. Measurement illuminance distribution was shown on Fig. 4. Measurement was done in characteristic points and areas defined in Regulation No. 112. Values obtained with use of Iluminator system was compared to values obtained with use of manual method.

Manual method of illuminance measurements on the screen is standard method according to Regulation No. 112. In this paper manual method was used as reference method. In Tab. 2 differences between this two methods was shown. Particular values obtained with use of matrix luminance meter are different from reference method less then 10%. It allows to use matrix luminance meters in practice to measure photometric parameters of headlamps.

4. Conclusions

Application of matrix luminance meter can significantly speed up and simplify photometric measurements. In this paper compare between values obtained with use of matrix luminance meter and standard method was shown. This compare was done with use of devices for illumination of rear registration plate and headlamp. In both cases obtained results proved that method which use imaging elements can be applied in practice.

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[6] *Uniform provisions concerning the approval of motor vehicle headlamps emitting an asymmetrical passing beam or a driving beam or both and equipped with filament lamps*, ECE Regulation No. 112.

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