J. Light & Vis. Env. Vol.25, o1, 2001

Research Note

A New Digital Illuminance-meter with a Special Luminance-tubeadapter for Applications in Lighting Engineering

Peter MARX

University of Applied Sciences Berlin, Germany

Received June 30, 2000

ABSTRACT

A new digital illuminance-meter "MINILUX" with a special luminance-tubeadapter is developed by the University of Applied Sciences Berlin in cooperation with the Technical University of Zhejiang China for universal applications in lighting engineering.

1. Introduction

Compared with the total turnover of electrical engineering, the extent of lighting technics is constantly rising. Therefore, the exact measurement of light technical quantities such as illuminance, luminance, luminous intensity and luminous flux gains more and more importance. The following article presents a new, reasonable, universally usable and portable digital illuminance-meter for accurate illuminance and luminance measurements.

The measuring of luminous flux, luminous intensity and luminance is based on the measuring of illuminance by means of the photometric fundamental law. That is, why this quantity has got a special significance. A state-of-the-art illuminance-meter should have the following conditions.

2. Technical Requirements on a State-of-the-art Illuminance-meter

- Fine approximation to the spectral luminous efficiency curve $V(\lambda)$ of the human eye
- Photometer-head with cosine-correction
- Linear relation between illuminance and photocurrent
- Low temperature influence, ageing and fatigue of the lightsensor
- Correct light- measurement of AC-powered discharged lamps (linear mean of wavy light in accordance with the Talbot-Plateau law)
- Wide measure range, so that the following measurements are possible with just one instrument:
  - measuring of daylight up to 200000 lx
  - measuring of indoor lighting up to 2000 lx
  - measuring of low illuminances, e.g. street lighting up to 20 lx
  - Emergency-lighting up to 2 lx
- Simple operation, that means no application of weakening filters and correction-factors
- Correct reading of the measuring results by a digital display

3. Functions of the Digital Luxmeter

Based on the mentioned conditions, the digital illuminance-meter „Minilux" was developed at the University of Applied Sciences, Berlin in cooperation with the Technical University of Zhejiang, China. Concrete, it is a newly developed, portable illuminance-meter for universal applications concerning the whole lighting technic (Fig. 1).

Fig.1. The MINILUX- device with photosensor (silicon-cell with $V(\lambda)$- and cosine-correction in accordance to DIN 5032, class B)

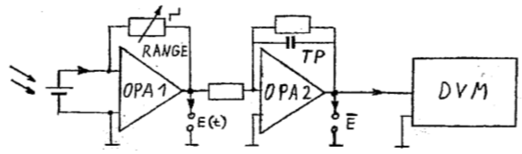

Fig.2 Block circuit of the Minilux illuminance-photometer. Measurement capacity: 0.001 lx…199.9 klx (6 ranges), luminance capacity: 0.1 cd/m2…19.99 Mcd/m² (6 ranges)

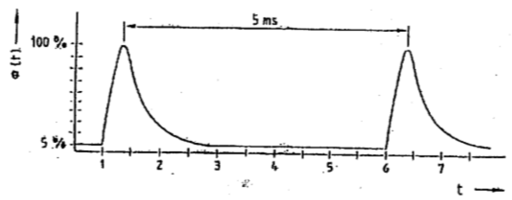

Fig. 3. Time dependence of the luminous flux of a sodium-xenon HID-lamp supplied by pulsed high-frequency current

Fig. 2 shows the block diagram of „Minilux". Two amplifiers with an extremely low bias-current are used for protection against overload, when for example high pressure sodium-xenon lamps with pulsed current supply and a high luminous flux crest-factor are measured (Fig. 3). The first amplifier OPA 1 serves the range, the second OPA 2 works as a mean-forming active low-pass-filter.

Accurate photometry of high-pressure discharge lamps with pulsed current supply calls for a special photocurrent amplifier, which, in accordance with the Talbot-Plateau-law, reliably estimate the linear mean value of luminous flux.

Ordinary luxmeters are generally not designed to measure high pulsating light sources . Therefore, to avoid errors, the staff of photometric laboratories should heed this recommendation before measuring such light sources. Critical evaluation and investigation of the suitability of the photometer for measurements of pulsating light is required.

The new measuring instrument avoids these disadvantages and thereby closes a gap in the market.

4. Important Technical Data

- Silicon photosensor with $V(\lambda)$- and cos-correction (Fig. 4, Fig.5)
- Diameter of the sensitive light area $D = 11$mm
- 6 lux-ranges
- Total measure range: 1 mlx to 199900 lx
- Resolution: 1 mlx
- Class B in accordance with DIN 5032, section 6
- Crestfactor: about 15
- dual-slope-digitalvoltmeter with auto-zero
- 7-segment LC-display
- Automatic low-battery-indicator, if U bat < 7V
- Supply-current : only about 2 mA
- 9-V-lithium-blockbattery with 1,2 Ah (working time of the Minilux with this high-performance battery approximately 600 hours !)
- Analog output 1: to measure the waveform of illuminance E(t) with an oscilloscope
- Analog output 2: 0 ... 199.9 mV DC for recorder, plotter, PC etc
- 4-seconds-delay timer with indication-hold-function inclusive of
- display- light and display-functioning test (e.g. suitable for shadingfree measurings)
- Dimensions: 157 mm x 84 mm x 30 mm
- Weight: 300g
- Price: 400 USD

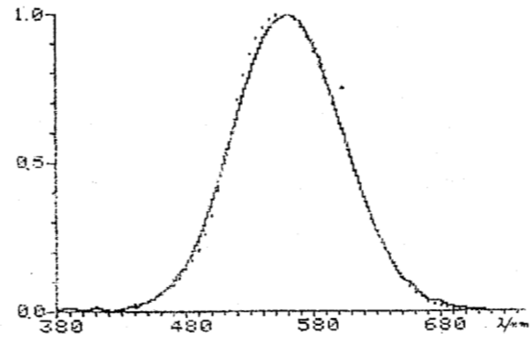

Fig. 4. $V(\lambda)$- approximation of the silicon-photosensor in accordance to DIN 5032, class B

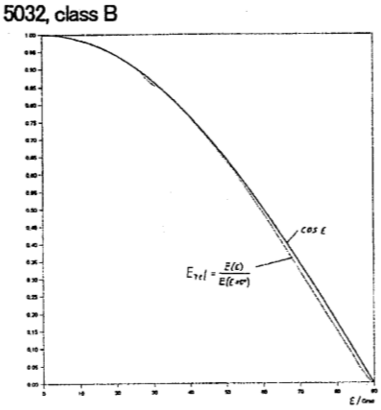

Fig. 5. Cosine-correction of the silicon-photosensor

The instrument measures lux-values from: 1 mlx (resolution) to 199900 lx.

(Note: 1 fc = 10.764 lx // 1 lx = 0.0929 fc)

Range	Typical application
0.000 ....1.999 lx	Emergency measurements
00.00 ....19.99 lx	lighting measurements Street
000.0..... ... .199.9 lx	Interior lighting measurements
0.000..............1.999 klx	Interior lighting measurements
00.00..... ......19.99 klx	Daylight measurements
000.0... ......199.9 klx	Daylight measurements

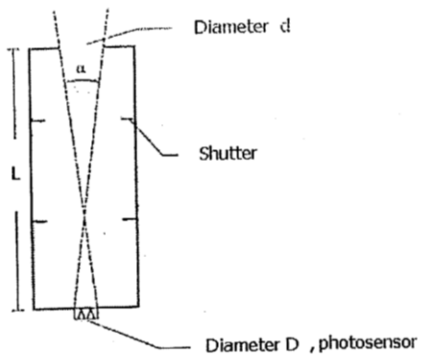

Fig. 6. Luminance-tubeadapter for the Minilux-photometer

The special luminance-tubeadapter (Fig. 6) has a measuring angle of $\alpha = 13°$. The tube-geometry is so calculated, that the relation between luminance and illuminance is very simple:

$$L = 100 \cdot E \qquad E \text{ in lx}, L \text{ in cd/m}^2$$

The procedure of luminance-measurement is as follows:

Put the luminance-tubeadapter on the photocell and hold the tube in the direction, in which you want to measure the luminance of a surface. Read the lux-value from the minilux-display and multiply this lux-value with the constant factor 100. The result is the actual average luminance.

Luminance-capability: 0.1 cd/m²....19.99 cd/m² (6 ranges)

Procedure for reflection-measurements of a diffuse surface: First measure the illuminance on the surface. Then measure the luminance of the surface at the same area. Calculate the reflection-value with the following formula:

$$\rho = (\pi \cdot L) / E \qquad E \text{ in lx}, \quad L \text{ in cd/m}^2$$

5. Fields of Applications

The instrument is suitable for

- the measuring of illuminance, luminance and reflection
- the measuring of luminous intensity by means of the photometrical law: $I\,[\text{cd}] = E\,[\text{lx}] \cdot (R\,[\text{m}])^2$
- luminous flux measurements in accordance with $\phi\ [\text{lm}] = E\,[\text{lx}] \cdot A\,[\text{m}^2]$

Further applications are possible, e.g. for:

- luminous flux measurements in conjunction with the Ulbricht sphere
- control of the turning on and off of street luminaires
- brightness control for roadway tunnels
- Measurements of building materials used in lighting technology (e.g. for measurement of reflection, transmission, absorption, extinction etc.)
- Measurements for solar facilities
- Light measurements for applications in physics, optoelectronics, meteorology, botany, biology and medicine

6. Result

The new lux-meter provides a metrological basis for innovative, energy-efficient and consequently environmentally benign lighting systems. It supports systems based on the use of natural daylight in conjunction with supplementary artificial illuminance which is controlled in accordance with user demand, and which is equipped with dimmable high-frequency electronic ballast devices, which enables power savings of up to 70 %. The presented digital luxmeter contributes to the achievement of this aim.

References

(1) DIN 5032 : Lichtmessung, sections 1...7

(2) P. Marx : New Goniophotometers for lighting-engineering Laboratories. CIE 24TH Session, Warsaw 1995, Proceedings Vol. 1, Part 1, page 189 – 192

(3) Ye Guanrong : Light-sensor for photometry. Zhejiang University, Hangzhou, China

Light & Engineering
Vol. 6, No. 3, pp. 13-16, 1998

Svetotekhnika
No. 4, pp. 35-37, 1998

NEW MINILUX UNIVERSAL DIGITAL LUXMETER

P. Marx

Technische Fachhochschule Berlin, Luxemberger Str. 10, D13353, Berlin

The role of illuminating engineering as an independent field in a broad range of electrical engineering problems is constantly increasing. It is natural that the requirements imposed on the accuracy of measuring the main luminous quantities - luminous flux, luminous intensity, brightness, and illuminance - increase along with this. Since measurements of the first three quantities ultimately can be reduced (according to the main photometric regularities) to measurement of illuminance, this photometric characteristic occupies a central place in applied illuminating engineering.

Requirements imposed on luxmeters

1. Illuminance should be measured with consideration of the spectral sensitivity of the human eye, i.e., the spectral sensitivity curve of the photocell of the luxmeter should be maximally close to the CIE standardized spectral luminous efficiency curve $V(\lambda)$ (Fig. 1).

2. Correction of the angular sensitivity (for a luminous flux incident on the photocell at an angle to the normal) should be provided for achieving a minimum cosine error.

3. It is necessary to provide a linear relation between the illuminance being measured and the photocurrent in the photocell circuit.

4. The photocell should have minimum dependence on the ambient air temperature, aging reduced to the possible limit, and acceptable "fatigue" characteristics.

5. It should be possible to estimate (in accordance with Talbot's law) the average values of illumination during a periodically varying luminous flux (e.g., radiation of high-pressure discharge lamps supplied with an alternating current).

6. A wide range of measured values of illuminance should be provided, making it possible to measure by one instrument:

– daylight illumination up to 200 klx;

– illumination in artificial lighting installations of rooms - up to 2000 klx;

– low illumination, for example, in exterior lighting installations of cities (illumination of road pavements up to 20 lx) or under conditions of emergency lighting conditions (on emergency escape routes from rooms - up to 2 lx).

7. The luxmeter should be easy to service, its operation should be realized without any attachments, without luminous-flux absorbing filter-wedges, and without additional recalculation of the data obtained by means of correcting factors.

8. The measurement results should be put out on a digital display.

Minilux small hand-held digital luxmeter. A new portable luxmeter for universal use in various areas of illuminating engineering created in accordance with the author's idea and meeting all enumerated requirements is described below (Figs. 3 and 4).

Figure 5 shows a block diagram of this instrument, in which are used two precision operational amplifiers with very small leakage currents. This provides both a high sensitivity of the luxmeter (resolving power to 1 mlx) and the possibility of measuring the average values of illuminance created by the periodically varying luminous flux of high-pressure sodium-xenon lamps* supplied by a radio-frequency pulsating current and characterized by deep

*Mercury-free 50- and 80-W high-pressure sodium lamps (type Colorstar DSX of the Osram firm) with a step-varied T_c (2600-2900 K). The arc tube is supplied with a high-frequency pulsed current with a period of 5 msec between pulse packets by means of an electronic ballast and microprocessor built into it. (Translator's note).

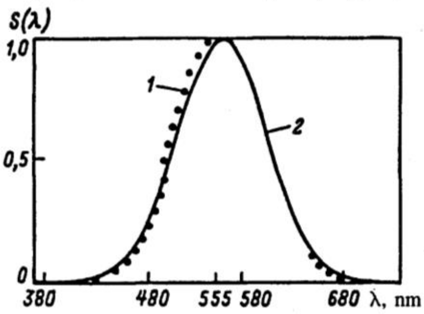

Fig. 1. Spectral luminous efficiency curve: 1) photocell of Minilux luxmeter; 2) $V(\lambda)$.

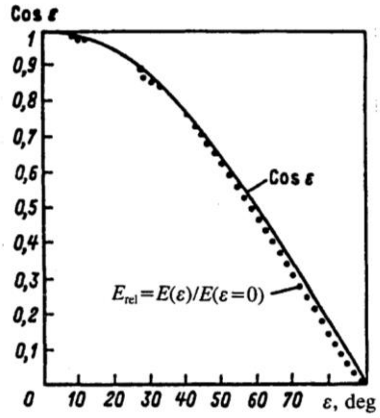

Fig. 2. Cosine error correction curve.

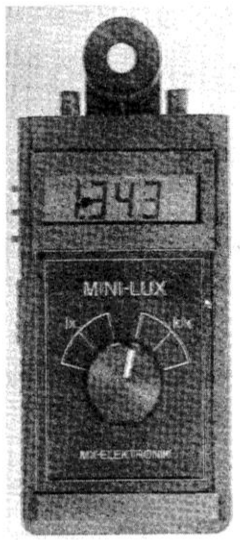

Fig. 3. Minilux luxmeter with permanently added photocell.

Fig. 4. Minilux luxmeter with photocell connected by means of an extension wire.

drops of the radiant flux during the period: $\Phi_{max}/\Phi_{min} = 20{:}1$ (Fig. 6).

The first amplifier provides switching the measurement ranges and the second operates as an active low-frequency amplifier of the signal singling out the average values from the time-variable values being measured.

Standard types of luxmeters are intended primarily for measuring illuminance with a ratio of the extreme values of the luminous flux $\Phi_{max}/\Phi_{max} = 2{:}1$ (high-pressure discharge lamps without a phosphor). Therefore quite perceptible errors can arise during photometering of a light source with a pulsating luminous flux. This undesirable effect is characteristic for almost all photometric systems used in present-day lighting practice.

Consequently, laboratory researchers when measuring the parameters of light sources with a periodically or regularly varying luminous flux, such as the aforementioned sodium-xenon lamp, should critically evaluate the suitability of their own photometric instruments and devices for such measurements. This saves them from serious errors in evaluating the parameters of the light source or luminaires, especially when the characteristics being measured are then entered in technical documents and catalogs of the articles.

The new luxmeter creates also a reliable metrological base for lighting installations with the latest light-controlling systems based on photosensors and infrared detectors. These systems controlling luminaires with fluorescent lamps and adjustable electronic ballasts - changing the levels of illumination depending on the intensity of natural light or presence of personnel in the room - increase the energy efficiency of lighting installations of

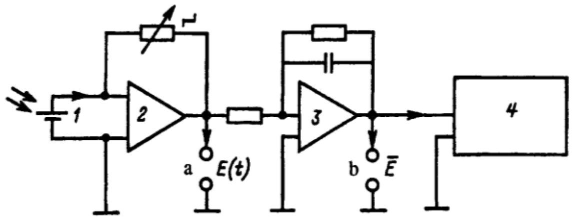

Fig. 5. Block diagram of Minilux luxmeter: 1 - photocell, 2 - operational amplifier with switch of measurement ranges, 3 - low-frequency operational amplifier, 4 - data processing unit with digital display, a - first analog output, b - second analog output.

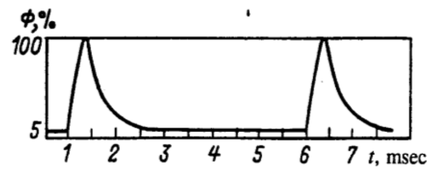

Fig. 6. Temporal variation of luminous flux of mercury-free high-pressure Na-Xe lamp supplied with a radio-frequency pulsating current.

buildings. As practice shows, the savings of electricity in such lighting installations being controlled in such a manner can reach 70%.

About 11% of all electricity being produced in Germany is presently being consumed for the needs of artificial lighting in the country. Light-controlling systems in administrative and other buildings can noticeably affect a decrease of lighting costs and simultaneously make a perceptible contribution to improving the health of the environment (reduction of the emission of toxins, mainly sulfur dioxide, by electric power plants).

Main features and characteristics of the new luxmeter. The photocell being used has a diameter of 10 mm, its sensitivity is corrected for $V(\lambda)$, and cosine correction is provided when measuring illuminance created by an luminous flux striking at considerable angles to the normal of the plane of the photocell.

Illuminance can be measured in limits from $1 \cdot 10^{-3}$ lx (minimum resolving power) to 199,900 lx in the following six ranges:

1) 0-1.999 lx 2) 0-19.99 lx	(emergency lighting, urban exterior lighting installations)
3) 0.199.9 lx 4) 0-1.999 klx	(interior artificial lighting installations)
5) 0-19.99 klx 6) 0-199.9 klx	(natural lighting)

As is seen, the luxmeter meets the needs of various areas of interior and exterior, artificial and natural lighting technology.

With respect to the resultant error (10%), the luxmeter belongs to instruments of accuracy class "B" (German standard DIN 5032 pt. 7).

The luxmeter makes it possible to measure, with the indicated error, the average illuminance during lighting by a light source with a pulsating luminous flux with an amplitude factor (cresfactor) up to 15.

The digital voltmeter has two switchable measurement limits ("luxes" and "kiloluxes") and automatic zero setting.

The luxmeter has a display with a seven-segment liquid-crystal digital indicator and a power supply - a lithium battery (9 V, 1.2 A-hr). The total operating time of the luxmeter with this battery is 500 hr (!). The input current is equal to about 2 mA.

The luxmeter is equipped with automatic signaling about discharging of the battery if its terminal voltage becomes less than 7 V.

The first analog output of the luxmeter is for measuring the temporal variation of illuminance $E(t)$ with an oscillograph and the second analog output [0-199.9 mV (direct current)] is for connecting to recorders, printers, personal computers, etc.

The luxmeter is provided with automatic self-testing (for 4 sec) with lighting and check of the display functions and with preservation of the reading of the measured illuminance.

The overall dimensions of the luxmeter are 157 × 84 × 30 mm; weight 300 g. Price - 790 German marks.

Areas of use. Along with the aforementioned areas of use the luxmeter is suitable also for recording luminous intensity distribution curves with consideration of the classical photometry law - the law of squares of distances: $I(\text{cd}) = E(\text{lx})l^2(\text{m}^2)$; for measuring luminous flux: $\Phi(\text{lm}) = E(\text{lx})S(\text{m}^2)$; as well as for estimating the average brightness of surfaces (with a special tube attachment).

Other possibilities of using the Minilux luxmeter are:

– measurements of the luminous flux together with a photometric sphere (Ulbricht sphere);

– in lighting control systems in vehicular tunnels;

– in devices controlling turning street lights on and off;

– in devices measuring lighting characteristics of materials (reflection, transmission, absorption, etc.);

– measurements in solariums;

– measurements of illuminance during studio and on-location video recording, motion-picture and still photography, in special television technology;

– measurements in laboratory and working practice of various fields of science and technology (physics, optoelectronics, meteorology, botany, biology, medicine).