Flicker experimental set up and visual perception of flicker

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***Abstract*— This paper talks about the measurements of luminous flux of different light sources and the production of an experimental set up for the purpose of observing light phenomena in LEDs. With the help of measurements, an insight on how luminous flux usually fluctuates in the various types of lamps was obtained. For easy observation and study of temporal light artefacts in LEDs, such as flicker and stroboscopic effect, an experimental set up with an option to adjust the supply voltage signal was constructed. At the end, we also show some of the results of the visual perception of flicker.**

***Index Terms*—flicker, LED, luminous flux, Stroboscopic effect, temporal artefact**

I. Introduction

Nowadays, the number of LED lights on the market is increasing, as they are becoming more and more popular due to their high efficiency and extended lifetime expectancy compared to other lights [1]. Additionally, LEDs are distinguished by their properties, such as easy control, the size of the light source according to the produced light, and the fast response of the emitted light to the current flowing through the diode [2].

When talking about response to the current, unlike LEDs, conventional lamps are relatively slow. Non-LED light sources such as gas-discharge or incandescent lamps typically do not exhibit a zero-light output, even during the off-cycle. Phosphor in the gas-discharge or the filament in incandescent lamps continues to glow even when the AC supply voltage passes a zero point [1]. Because of this, it is expected that light from LEDs will be perceived differently than light from conventional lamps that operate at the same low frequency voltage (50 Hz or 60 Hz depending on country). This difference can cause visible temporal artefacts, such as flicker or stroboscopic effect [2].

Flicker is the most well-known temporal artefact and it is described as visible fluctuation of luminous flux. At a certain frequency, called critical flicker frequency (CFF), there is no more visible fluctuation of luminous flux – no visible flicker. The CFF is different for different observers but usually lower than 100 Hz [2].

Another temporal light artefact is stroboscopic effect, which is at first invisible to a static observer in static environment. But as soon as there is a moving object, it will appear to move discretely rather than continuously. Because visibility of this effect depends on the speed of the observed object, it can be seen at any modulation frequency [2].

II. Measuring luminous flux changes

In the first experiment, different types of light sources that are currently available on the market have been measured. With this, it was desired to secure an approximate display of the luminous flux fluctuations in different types of light technologies on the market.

A. Setup

To measure changes in the luminous flux of light sources, it is necessary to have a measuring procedure. Given that there is no standard test procedure for measuring light fluctuations [3] except IEC Technical report 61547-1[4], measuring setup was designed by Laboratory for lighting and photometry at the Faculty of Electrical Engineering in Ljubljana. The setup is primarily composed of light-impermeable box (106 x 46,5 x 48,5 cm), an analogue photosensor (chip TSL252) and digital oscilloscope (Agilent, DSO-X 2024A, 200 MHz, 2 GSa/s). The composite system is shown in Fig.Figure 1.

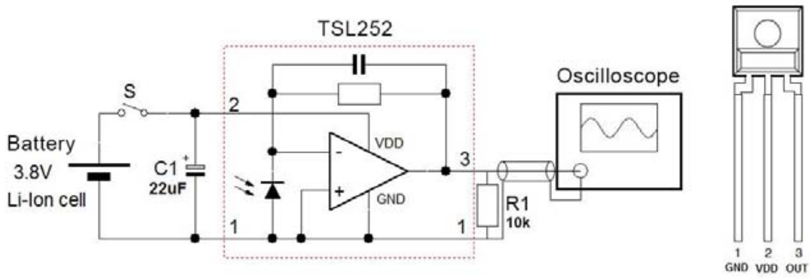

Figure 1. Composite measuring system.

All measured lamps were connected to the regulated power source with voltage of 230 V and frequency of 50 Hz (THD_U<2%). Measurements were carried out in our dark room in a light-impermeable box to prevent disturbances that would otherwise take effect due to the light from the surroundings. Additionally, the lamps were measured 5 minutes after switching them on to get stabile light output. Opened measuring box is shown in Fig.Figure **2**.

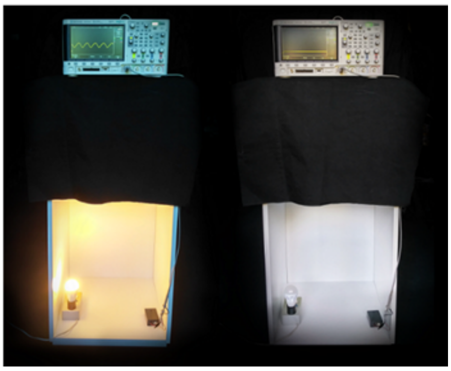

Figure 2. Measuring box.

B. *Results of measurements of light sources*

Data was captured using an oscilloscope with a resolution of 20k value / 100 ms, saved in a csv file and then processed with Matlab. Measured data is presented in TableTABLE **I**.

Flicker index and Percent flicker were calculated for each measured light source. Percent Flicker is calculated with equation (1), where A is maximum and B is the minimum light output during a single cycle.

$$PF = \text{Percent Flicker} = (A - B) / (A + B) * 100 \quad (1)$$

Flicker Index is calculated by equation (2), where A1 is area above the line of average light output and the A2 is area under the average light output curve for a single cycle.

$$FI = \text{Flicker Index} = A1 / (A1 + A2) \quad (2)$$

TABLE I. MEASURED LAMPS AND THEIR PROPERTIES

Measurement #	Technology	Power [W]	Base	PF [%]	FI [-]	Figure
1	Incandescent	60	E27	11,15	0,03	Figure 3 – L
2	Halogen	70	E27	9,96	0,03	Figure 3 – D
3	Fluorescent	20	E27	8,65	0,02	Figure 4 – L
4	Fluorescent	9	E27	18,7	0,04	Figure 4 – D
5	Fluorescent	20	E27	8,11	0,01	-
6	Fluorescent	20	E27	9,79	0,02	-
7	Fluorescent	23	E27	6,89	0,01	-
8	Fluorescent	20	E27	12,37	0,02	-
9	Fluorescent	20	E27	16,87	0,03	-
10	Fluorescent (UV)	25	E27	35,97	0,07	-
11	LED	9	E27	18,34	0,05	Figure 5 – L

12	LED	9	E27	21,29	0,03	Figure 5 – D
13	LED	2	E27	100	0,29	Figure 6 – L
14	LED	4	E27	1,95	0	Figure 6 – D
15	LED	5	E27	7,39	0,02	Figure 7 – L
16	LED	2,5	E27	14,19	0,04	Figure 7 – D
17	LED	1	E14	64	0,17	Figure 8 – L
18	LED	5,5	GU10	6,49	0,01	Figure 8 - D
19	LED	12	E27	43,58	0,13	Figure 9 – L
20	LED	12	E27	3,12	0	Figure 9 – D

In most of the measurements of the luminous flux, a strong 100 Hz component can be noticed. With fluorescent lamps, as shown in Fig.Figure 4, high-frequency components also can be further observed. These high-frequency components are most likely the result of an electronic ballast operating at high frequencies.

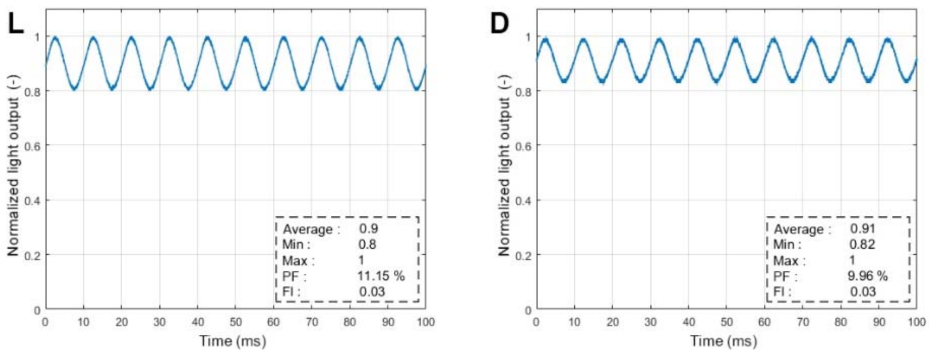

Figure 3. Examples of Incandescent lamp #1 – L, Halogen lamp #2 – R.

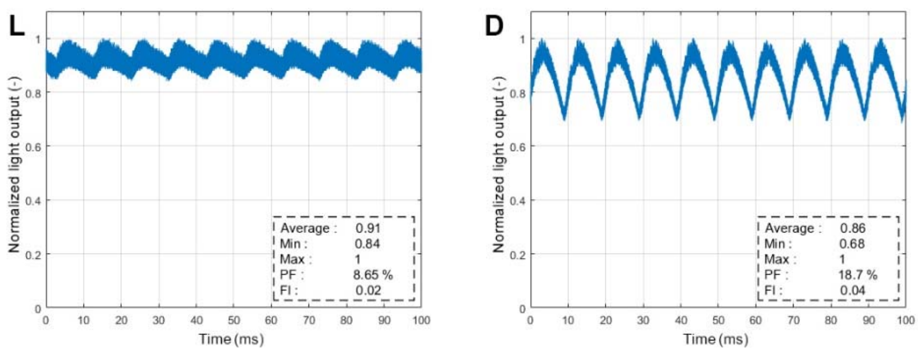

Figure 4. Examples of Fluorescent lamps #3 – L, #4 – R.

Measurements of LED light sources are shown in Fig. Figure 5 to Fig. Figure 9, where many different signal patterns can be noticed. The appearance of the stroboscopic effect is highly probable for the lamps in Fig. 5 - L, Fig. 8 - L and Fig. 9 – L. The visibility of this phenomenon is less likely for other LEDs because the oscillations of luminous flux is very low or invisible to the human eye due to the high oscillation frequency.

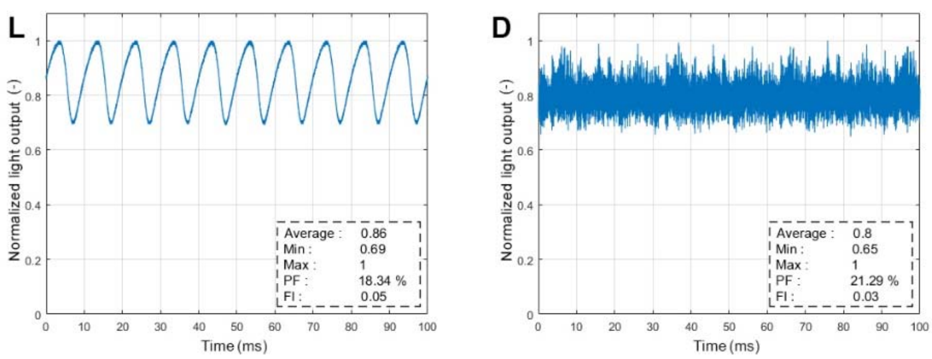

Figure 5. Examples of LED lamps #11 – L, #12 – R.

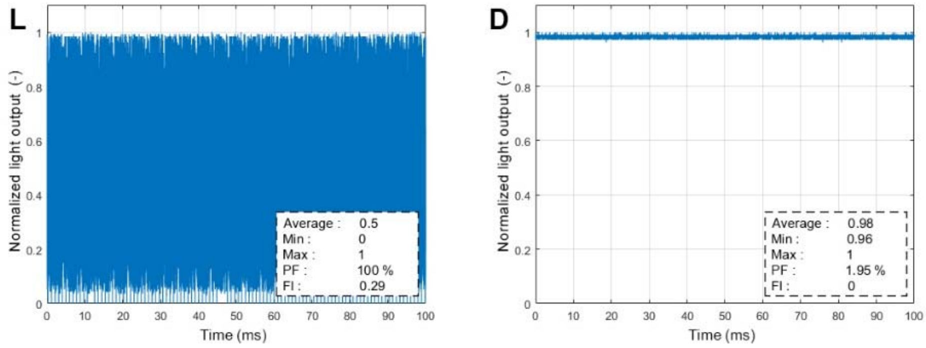

Figure 6. Examples of LED lamps #13 – L, #14 – R.

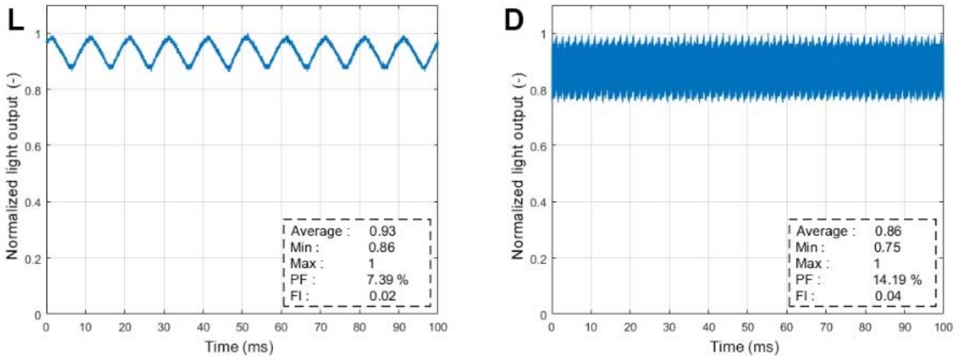

Figure 7. Examples of LED lamps #15 – L, #16 – R.

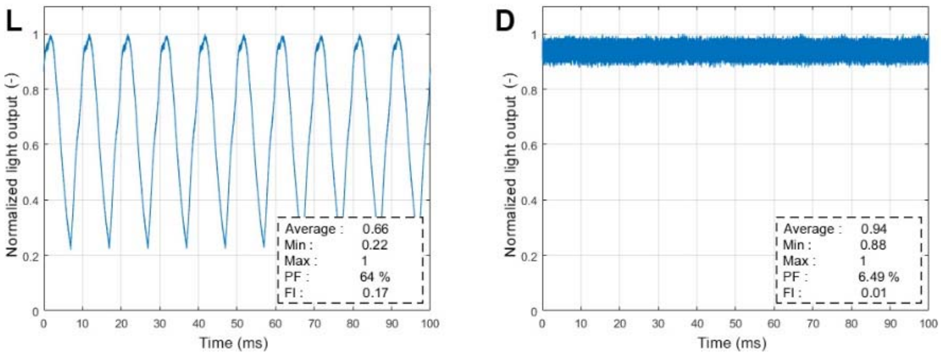

Figure 8. Examples of LED lamps #17 – L, #18 – R.

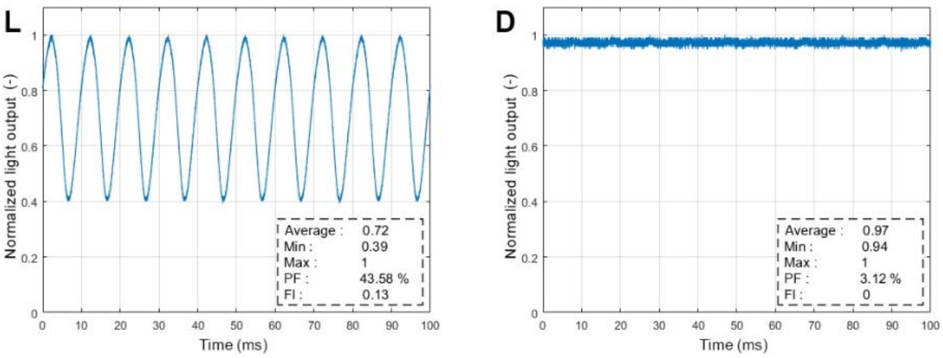

Figure 9. Examples of LED lamps #19 – L, #20 – R.

III. EXPERIMETAL SET UP BOX

To observe the problems caused by temporal light artefacts in LEDs, two experimental set up boxes were made. For each box, an identical electrical circuit (Fig. Figure **10**) and front panel (Fig. Figure **12**) were designed and manufactured. One of the completed boxes is shown in Fig. Figure **11**.

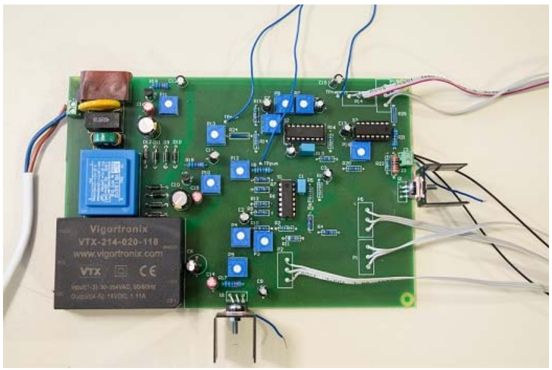

Figure 10. Electrical circuit.

Figure 11. Complete expo box with front panel at the top.

Observation of temporal light artefacts is done with two identical boxes that are side by side. Each box has a front panel (Fig. Figure 12) with potentiometers for adjusting the signal properties, a switch for selecting the desired signal (sine / square) and an oscilloscope showing the shape of the luminous flux captured with a photosensor. The potentiometers can change the different characteristics of the signal by which the light emitting diodes are powered (frequency from 50 Hz – 500 Hz, duty cycle from 0 % – 100 %, amplitude from 0 - 1 and offset from 0 - 1). This way, the observer can set different light settings in each box and compare the light of one and the other.

Figure 12. Front panel of expo box.

Using these experimental set up boxes, it is easy to observe various lighting phenomena in LEDs with different power supply settings. In the future, it will help to observe and study the visibility of the flicker and the stroboscopic effect.

IV. CONCLUSIONS

Temporal light artefacts, such as a flicker and a stroboscopic effect, are common in light-emitting diodes that are improperly designed for alternating voltage. Nowadays, there are many LEDs for alternating voltage on the market, among which there are also those that are unsuitable for use in rooms where people spend most of their time. Such lamps have a bad influence on human well-being and can be extremely dangerous to a certain population. Given that the presence of LEDs on the market is increasing, a standard should be established to determine which lamps are suitable for use and which ones are not.

It was necessary to create some kind of a system for demonstrating and observing temporal light artefacts. Therefore, this exhibition box was designed and manufactured. There were quite a few problems with the frequency interference and instability of the signal during the production of the power supply for the expo box. All problems were successfully solved. The final product has the option of selecting a sinusoidal or square signal with a switch, adjusting the frequency from 50 Hz to 500 Hz, adjusting the duty cycle at a square signal from 0% to 100%, setting the amplitude from 0 V to 11 V and setting the voltage offset from 0 V to 11 V. With the help of an experimental set up box, the observer can successfully observe flicker or stroboscopic effect in LEDs.

V. REFERENCES

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