Temporal Light Artefacts and LED Lighting

Iva Petrinska, Dilyan Ivanov, Valchan Georgiev – TU Sofia, Bulgaria

Abstract: *Although fast emerging and very perspective, the Light Emitting Diodes (LEDs) still need serious investigation in order to assure quality of lighting. There is a significant range of problems, introduced by the nature of their light generation principle. One of these problems is the introduction of temporal lighting artefacts (TLAs) – stroboscopic effect, flicker and phantom array. These effects are induced by the LED drivers. Human vision is directly affected by light fluctuations at frequencies up to 200 Hz. The TLAs can lead to very interesting effects when applied to architectural lighting, but are unwanted and harmful when it comes to general indoor lighting.*

There is a huge variety of LED retrofit lamps, available on the market today. The current paper presents an investigation and gives an estimation of the TLAs, introduced by some of these LED products, available for mass use.

1. Introduction

The LEDs as a fast emerging and very promising lighting technology develop at a fast rate. As bright light sources with small size they can be applied everywhere. The application of LEDs in retrofit lams, however should be done carefully in order to achieve similar quality of light as that of conventional lamps. This is so, because the use of LED lamps and especially their drivers, leads to the appearance of unwanted and harmful effects called Temporal Light Artefacts (TLAs) [1]. TLAs are flicker – visible, invisible perceptible and detectable, Stroboscopic (luminous flux modulation made perceptible by the motion of objects, when the observer's eye is still) and phantom array (luminous flux modulation made perceptible by the motion of the observer's eye, when the light source is still) effects. The factors that lead the appearance of flicker and thus to both visible and invisible effects on humans are: modulation frequency, modulation amplitude, DC component and Duty Cycle of lighting. The direct visibility of flicker depends on the dominant frequency. The natural light has no flicker, while the thermal light sources – incandescent and halogen lamps have minimum flicker, because of their relatively long persistance. On the contrary gas discharge and solid state lamps have no or very short persistance, which puts the necessity to supply them with ballasts and drivers with stable or high frequency power. However this leads to greater size and cost of the LED lamps, so usually minimum processing of the AC signal is done. The problem with flicker becomes even worse when LED lamps are dimmed [2].

Quality indoor lighting can be achieved if evenly distributed light with steady light output and color temperature is ensured. Also the sensitivity of the human eye to changing or fluctuating light intensity at low frequencies should be considered. If these issues are not considered, negative effects as irritation, eye fatigue, headaches and seizures can be observed. All these effects have negative influence on humans and are due to visible and invisible flicker [3].

2. Approach and considerations

According to the CIE TN 006:2016 [4] temporal light modulation of LED light sources is used for control of their intensity and color. Both intended and unintended sources of light modulation can give rise to changes in the perception of the environment. This effect is desired only in specific entertainment applications, but is absolutely undesirable for everyday lighting. A number of measures for quantification of flicker visibility exist. IESNA has defined two metrics for flicker: percent flicker, which is estimated with 0-100% scale, accounts for average, peak-to-peak amplitude and does not account for shape, duty cycle and frequency; and flicker index which is estimated with 0-1 scale, accounts for average and peak to peak amplitude, shape and duty cycle, but does not account for frequency [5].

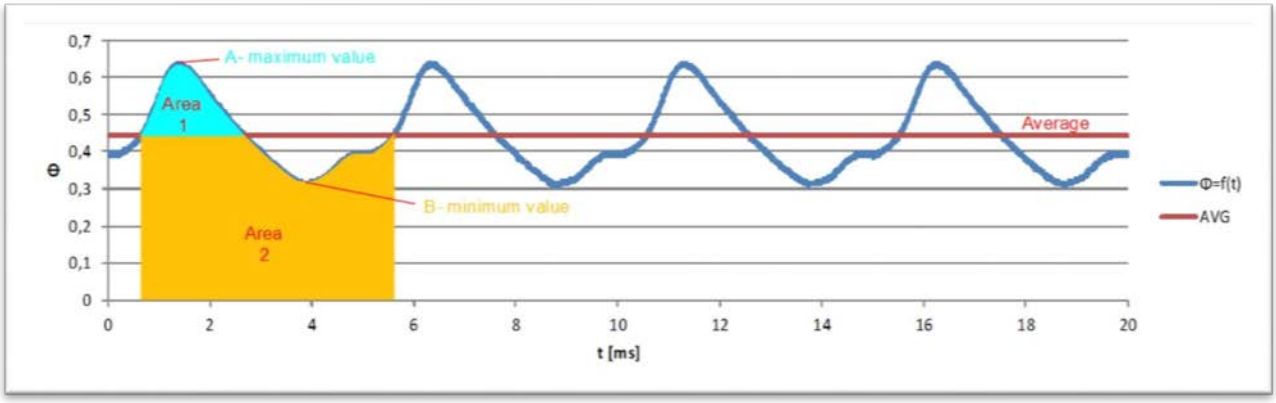

Fig. 1 Flicker estimation diagram

Percent Flicker = (A-B/A+B).100, % (1)

Flicker Index = (Area 1/Area 1+Area 2) (2)

There is also an applied metrics, given by the equation [3]:

Max%Ficker ≤ Flicker frequency x 0.08 (3)
for low-risk level and

Max%Ficker ≤ Flicker frequency x 0.0333 (4)
for no observable effect level

The effects of flicker depend both on frequency and modulation depth. While for visible flicker, the amplitude of the Fourier fundamental predicts flicker fusion, the effects of different waveforms on imperceptible flicker are not studied in detail. In this sense in the IEEE Standard 1789-2015: “Recommended Practice for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers” new measures and definitions of flicker that rely on Fourier series of the flicker have been proposed. This standard also allows lighting designers and specifiers to specify a requirement for low flicker. Products more likely to flicker are AC LEDs, DC LEDs with simple / inexpensive drivers (e.g., inadequate capacitors), integral lamp LEDs on some electronic transformers, LEDs dimmed with phase cut dimmers (triac, e.g.), LEDs with Pulse Width Modulation (PWM) drivers.

3. Flicker measurement and results

Although a lot of research has been carried out on the subject [6], the paper aims to show most recent investigation of flicker of LED retrofit lamps. For the investigation made in the current paper the methodology, described in CIE TN 006:2016 has been followed [4]. The measurement of flicker for seven randomly selected LED lamps has been performed. A combination of photo detector, with spectral sensitivity, corresponding to human eye spectral sensitivity, connected to amplifier and oscilloscope has been used.
The results obtained are shown as following:

1. Incandescent lamp 60W

Fig. 2. Flicker of Incandescent lamp 60W

2. LED Lamp – sample 1 – CELED, 7W, 230V, Ra=80, 500lm, 25000h, cool light 5500-6000K

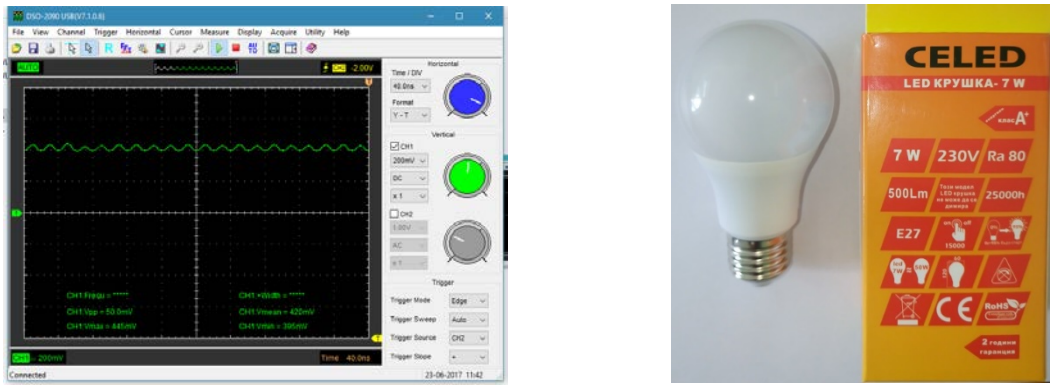

Fig. 3. Flicker of Sample 1

3. LED Lamp – sample 2 - CELED, 7W, 230V, Ra=80, 500lm, 25000h, warm light 2700-3000K

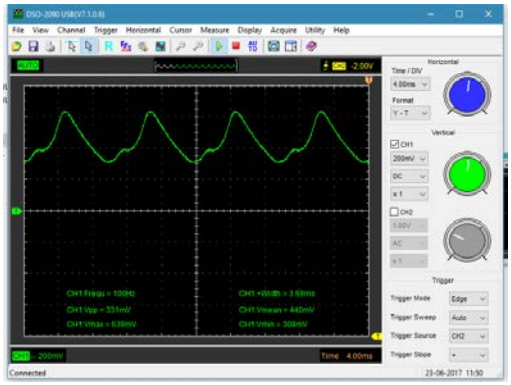

Fig. 4. Flicker of Sample 2

4. LED Lamp – Sample 3 – OSRAM PARATHOM RETROFIT CLASSIC A60, 7.2W, 230V, Ra=80, 806lm, 15000h, warm light 2700K

Fig. 5. Flicker of Sample 3

5. LED Lamp – Sample 4 OSRAM PARATHOM ADVANCED CLASSIC A60, dimmable, 10W, 230V, Ra=80, 806lm, 25000h, warm light 2700K

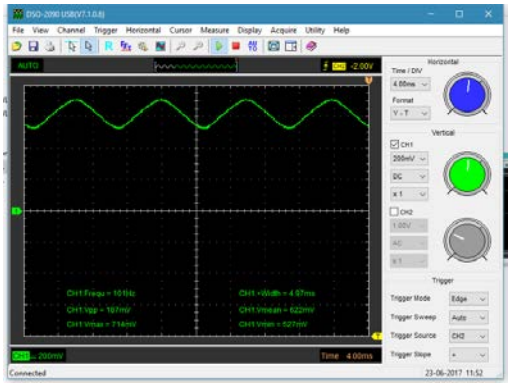

Fig. 6. Flicker of Sample 4

6. LED Lamp – Sample 5 – Vivalux, 10W, 230V, Ra=80, 806lm, 25000h, day light 6400K

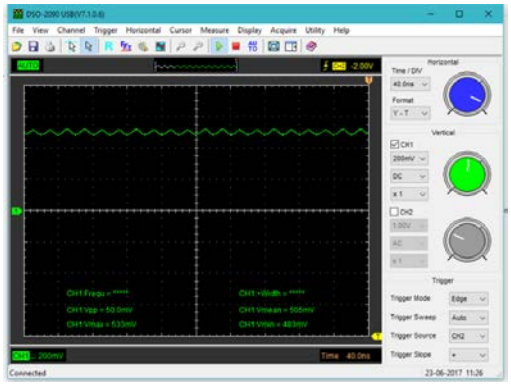

Fig. 7. Flicker of Sample 5

7. LED Lamp – Sample 6 – OSRAM PARATHOM RETROFIT CLASSIC A60, 6W, 230V, Ra=80, 806lm, 15000h, warm light 2700K

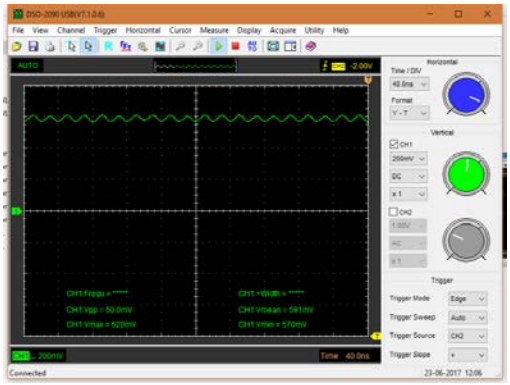

Fig. 8. Flicker of Sample 6

8. LED Lamp – Sample 7 - Neolux, 9.5W, 230V, Ra=80, 806lm, 15000h, warm light 2700K

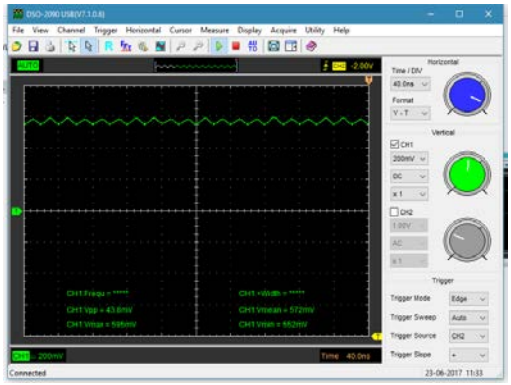

Fig. 9. Flicker of Sample 7

The summarized results for the flicker by the investigated samples of LED retrofit lamps are given in table 1.

Table 1 Flicker of the investigated samples of LED Lamps

Sample №	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Incandescent Lamp
max=	0.446	0.640	0.565	0.715	0.533	0.640	0.602	0.211
min=	0.396	0.308	0.521	0.527	0.490	0.590	0.552	0.120
avg=	0.419	0.443	0.542	0.624	0.509	0.611	0.576	0.163
Percent Flicker	5.942	34.950	4.031	15.102	4.278	4.068	4.333	27.377
Area 1	26.567	213.270	26.188	132.849	24.235	29.230	25.891	66.019
Area 2	2069.277	2002.187	2681.962	2986.289	2521.383	3024.483	2854.372	750.852
Flicker Index	0.013	0.096	0.010	0.043	0.010	0.010	0.009	0.081

4. Conclusions:

A lot of research has been don on the topic of TLAs. Also some recommendations about how LEDs should be drived in order to mitigate flicker have been done by researchers and scientists. The results from the current paper, however show that the problem with flicker by LED light sources still exists and the research in the area should be continued.

Flicker Frequency alone is an inadequate measure of flicker. More detailed studies are necessary in order to develop appropriate thresholds for flicker metrics. Flicker from LED luminaires can be much more significant than flicker from conventional sources. The Flicker Index metric is a useful tool for evaluating both the percent modulation and duty cycle of flicker in all types of light sources.

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