A STUDY ON THE FLICKER OF COMMERCIAL LAMPS

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Abstract

Flicker has always been an issue for incandescent and fluorescent lamps with possible important health impacts. The AC operation of these lamps at mains frequency (50 Hz) means that a 100 Hz light output oscillation is exhibited and even with higher frequency (kHz) operating circuits the flicker at that 100 Hz frequency can be decreased but not eliminated. With the ever increasing penetration of DC operated LED lamps in the market we decided to test this technology and compare it to the other two by measuring and recording the light output and flicker behavior of a number of commercial lamps. In each case we calculated the flicker percentages as all available data show a linear relation to the flicker indexes. The measurements and tests show that LED lamps exhibit a range of behaviors, depending on the driving circuit, ranging from no flicker to the largest flicker percentages of all three technologies. The tests also show that for all three technologies exhibiting flicker, the voltage decreases (dimming) make the flicker percentages larger. Finally we propose an easy flicker detection method based on widely available digital camera displays.

AC= Alternating current
DC= Direct current
LED= Light Emitting Diode
CFL= Compact Fluorescent lamp

Introduction

Flicker is the modulation of a lamp's light output caused usually by fluctuations of the mains voltage supply. The mains frequency is 50 Hz (in Europe) causing a flicker at 100 Hz in the lamp's output. Flicker is not perceptible at this frequency but it can still affect people. It would not be uncommon to hear people in offices complain of headaches and dizziness due to the performance of fluorescent lamps with magnetic ballasts [1,2]. In fact research has showed that fluctuations of short wavelength emissions are perceived to a higher extent [3, 4]

People suffering from migraines are also more likely to be sensitive to lighting instabilities [5, 6]. There are more conditions that are supposed to be sensitive to flicker but regardless of how much they correlate to this, everyone would want to see it minimized.

With the ever increasing penetration of Light Emitting Diode lamps in more applications and considering that their mode of operation differs from the other two technologies (DC current for diodes while incandescent halogen and fluorescent lamps operate under AC), we are interested in recording how they perform in terms of flicker and light output fluctuations. We have therefore tested a range of compact commercial lamps (spot and omnidirectional) of all three technologies – halogen, CFL and LED - in order to see the levels of flickering and under which conditions it can be minimized or even eliminated.

Since the research publications suggest that the health impact of flicker can be significant, this testing review is important for the consumers and the lighting designers that care for the well being of the general population in living and working environments employing artificial sources but even more so for the special groups of citizens suffering from the aforementioned conditions.

Flicker measurement set – up

All lamps were operated at 230 Volts (mains) and the set up for the flicker measurements included

- An **integrating sphere** equipped with a **selenium cell**

- A Tektronix 2002B **oscilloscope** for detecting and recording the light waveforms fed from the selenium cell to the oscilloscopes channel via a BNS cable

- A **multimeter** for measuring independently the average light output in millivolts as well as the voltage applied to the lamps

- A **varying voltage power supply** connected to a multimeter for controlling the voltage value

Figure 1 and 2 show the set up

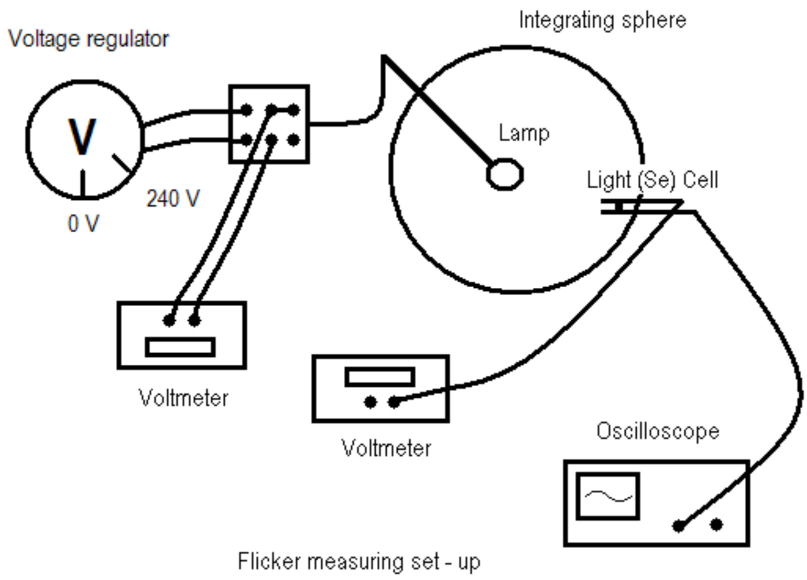

Figure 1. Diagram of the measuring set up

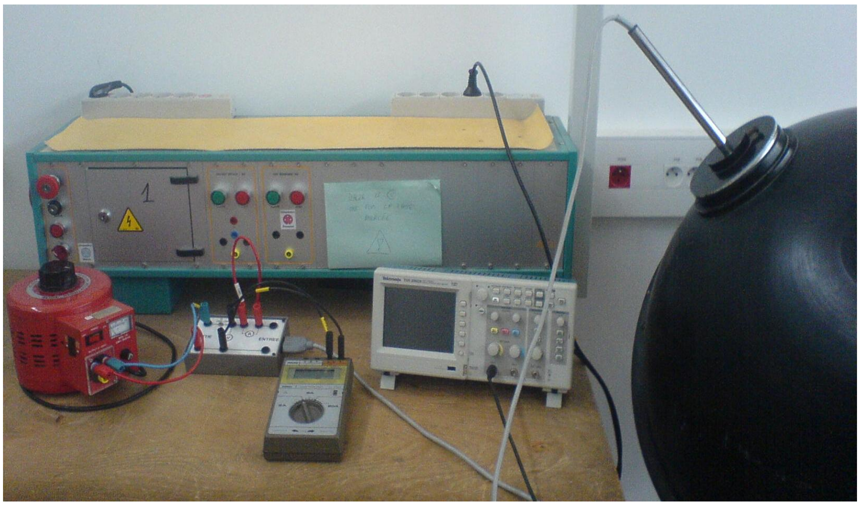

Figure 2. Photograph of the set up that shows the integrating sphere, the oscilloscope, the multimeter and the power supply.

The DC coupled oscilloscope (see the three acquisition options below) could measure the RMS as well as the Peak to Peak values of the fluctuation waves. With the use of the cursors we also recorded the maximum and minimum points of the averaged waveforms in order to use them in the calculation of the percentage flicker of the lamps

Defining the flicker

There are two widely accepted methods for defining lamp flicker

One, called the **percentage flicker**, takes the maximum and minimum points of the fluctuation and performs the calculation

100(Max-Min) / (Max + Min)

The second method measures the **flicker index** and it is less simple as it requires the calculation of the areas above and below the RMS line of the signal (figure 3).

The description can be found in the paper of Lehman et al [7]

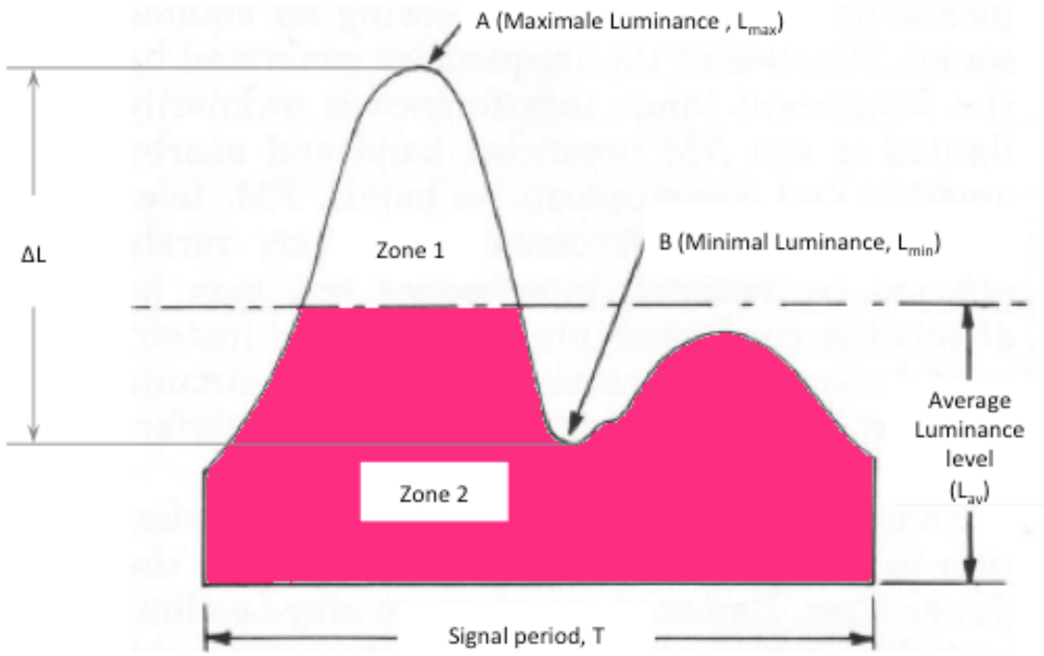

Figure 3. The Flicker Index is measured by calculating the areas above and below the RMS line of the signal

We decided to see the relationship between those two values so we withdrew data from a number of possible sources (figure 4).

We found lamp flicker values using both methods from a number of publications [8-11]

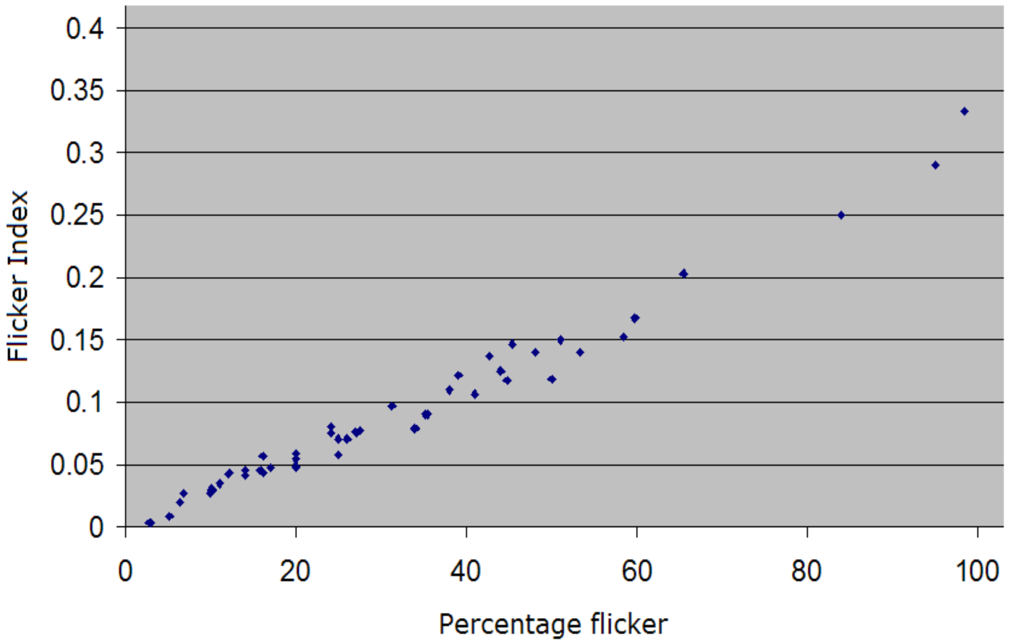

Figure 4. Percentage Flicker (Y axis) versus Flicker Index (X axis)

Our plots showed that there is a linear relationship between percentages and indices and we assume that unless the fluctuation waveform is highly unsymmetrical (such as when one deals with low duty cycle solid state sources but no such waveforms were recorded in this study) then percentages are just as good to give a quick comparison measure between lamps.

Measurements

Figure 5 shows the list of lamps tested and the measured values of percentage flicker in each case (or as stated the lack of flicker) while figure 6 shows the photos of all the lamps (numbered).

Lamp	Type	**percent flicker**	Power / W
1	Halogen	**0.143**	43
2	Halogen	**0.0347**	30
3	Halogen	**0.103**	105
4	CFL	**0.07**	11
5	CFL	**0.11**	15
6	CFL	**0.142**	7
7	CFL	**0.0888**	11
8	CFL	**0.099**	15
9	CFL	**0.096**	15
10	LED	**0.361**	12
11	LED	**0.067**	8.8
12	LED	no flicker	12
13	LED	no flicker	7
14	LED	no flicker	7
15	LED	**1**	1
16	LED	no flicker	4
17	LED	**0.864**	2
18	LED	**0.0837**	7
19	LED	**0.245**	23
20	LED	**0.176**	20
21	LED	no flicker	5.4
22	LED	no flicker	6
23	LED	no flicker	6
24	LED	no flicker	6
25	LED	**0.857**	1.8
26	LED	no flicker	2
27	LED	no flicker	3
28	LED	**0.932**	3
230 V / 50 Hz			

Figure 5. List of all the commercial lamps tested

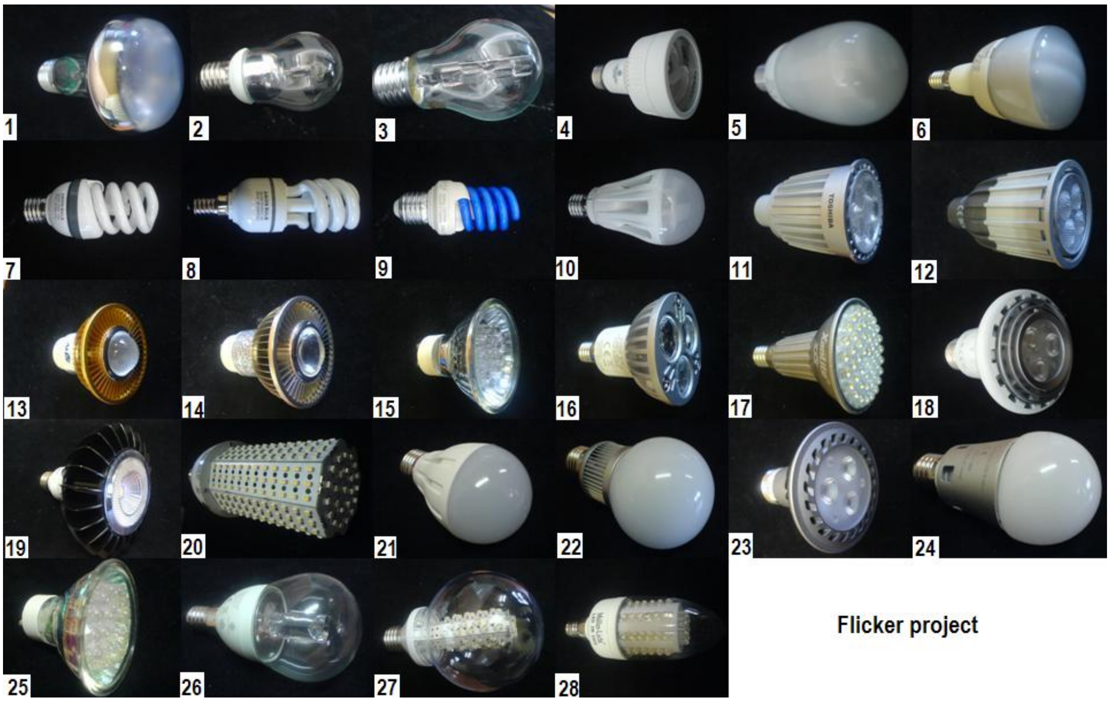

Figure 6. Photos of all lamps tested

While CFL and halogen lamps all exhibit flicker as expected, the tests show that LED lamps show different behaviors ranging from no flicker at all to the largest flicker percentages. Moreover the waveforms of the light output fluctuations are not as smooth and symmetrical as the ones for CFL and halogen lamps. Figures 7 and 8 show some representative waveforms.

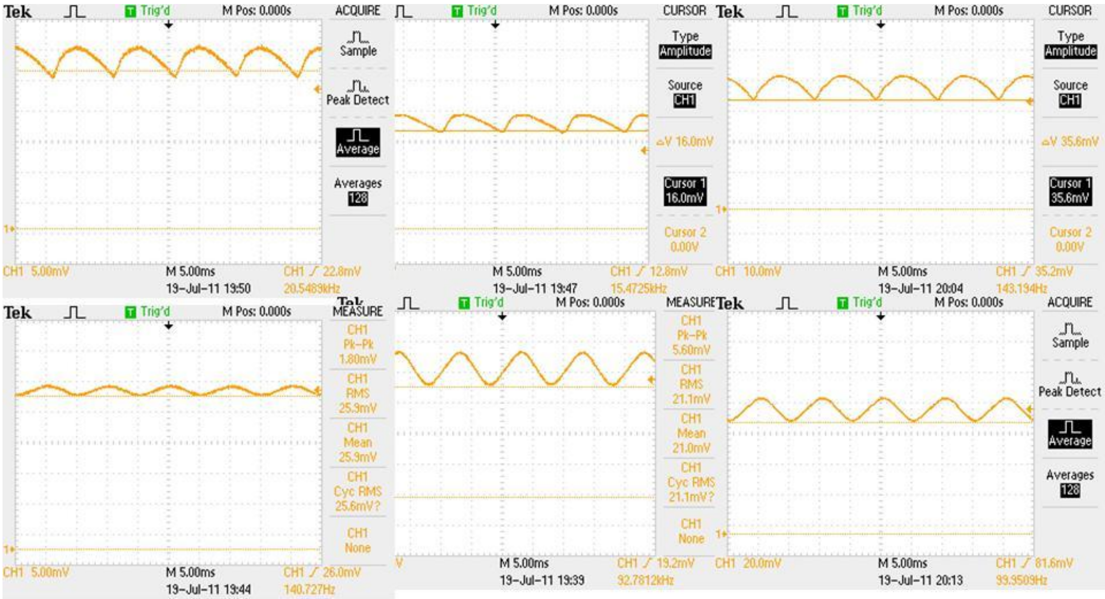

Figure 7. Light output waveforms for CFL (top) and halogen (bottom) lamps

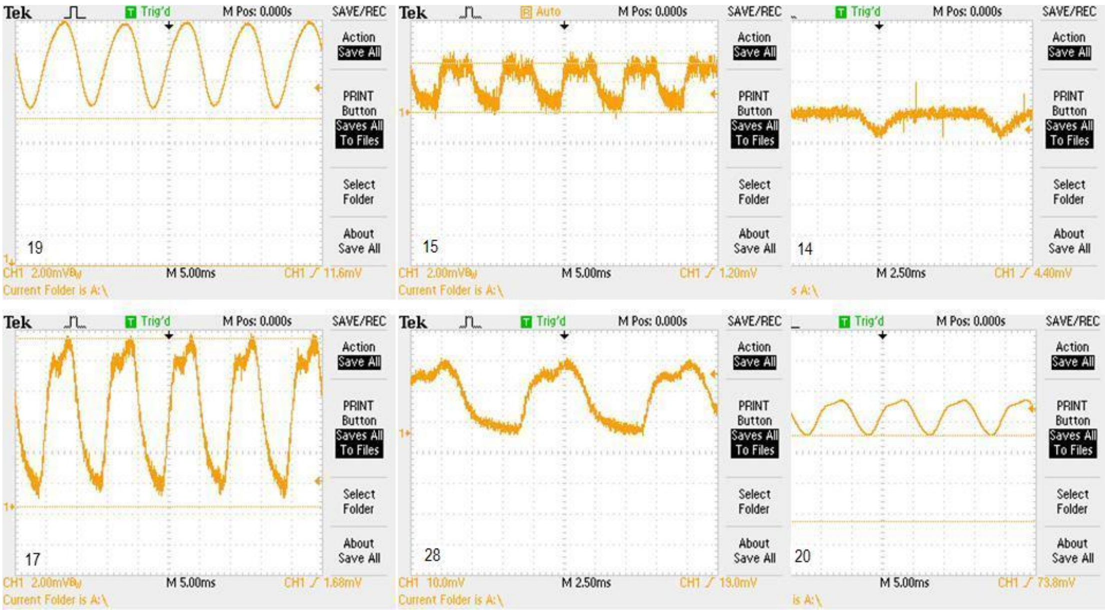

Figure 8. Representative light output waveforms of some LED lamps

For the flickering cases when the voltage was decreased the flicker percentages remained to similar values or increased which shows that for lamps being dimmed the flicker issue becomes larger. In fact even for non-flickering cases one should expect below a certain voltage value the lamp to start flickering or flashing.

The following three diagrams (figures 9-11) show the changes in flicker percentages with voltage decreases for the lamps

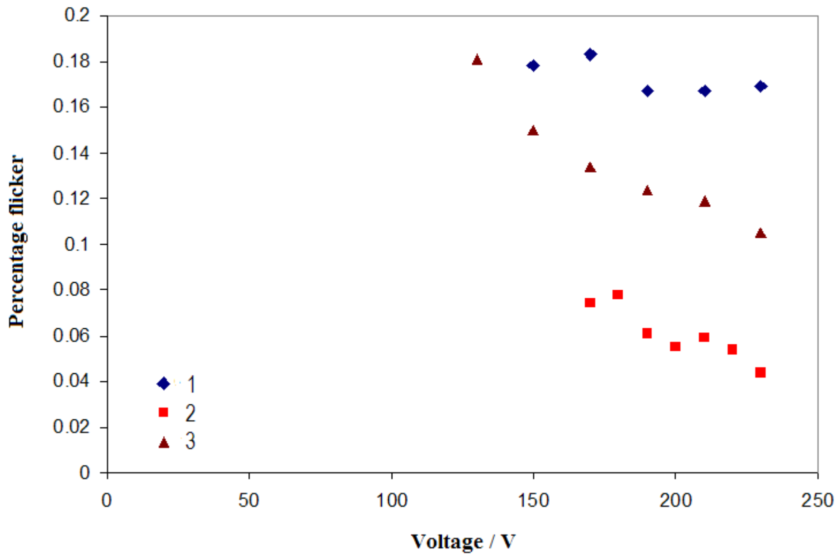

Figure 9. Flicker percentages versus voltage values for halogen lamps

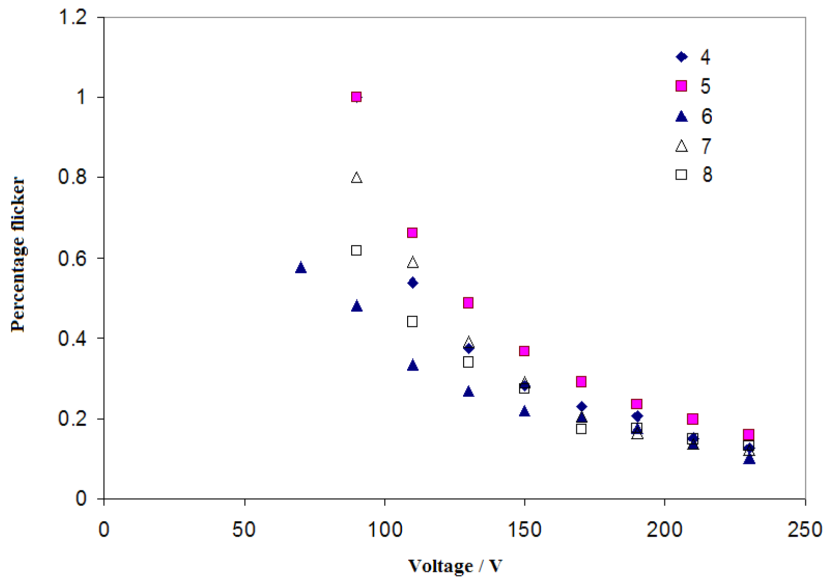

Figure 10. Flicker percentages versus voltage values for CFL lamps

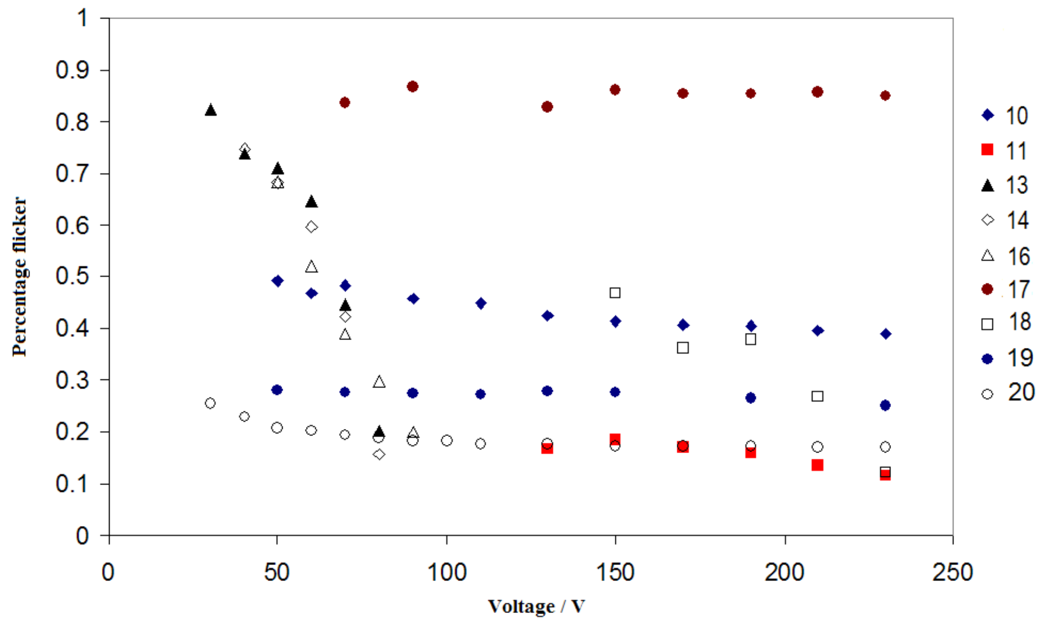

Figure 11. Flicker percentages versus voltage values for LED lamps

It is clear from these tests that the way to suppress flicker is to change the operating mode. For example when electronic gear (30-50 kHz) replaced the magnetic ballasts in fluorescent lamps flicker was suppressed. The fluorescent lighting operating from the magnetic control gear had a modulation of about 45 percent at the frequency of 100 Hz. The same lamps operating from the electronic control gear such as the compact fluorescent lamps we tested have a modulation of less than 15 percent at 100 Hz. Even the halogen lamp with the extra electronic gear (2) had a flicker of around 3% compared to the 10% of the other two. The LED lamps that show no flicker are those that employ self-correcting circuits (current feedback) although such a design adds to the cost and this is why it is not used in all products.

During the tests we discovered that the best way for a consumer to test whether a LED lamp flickers or not (or check the degree of flicker in halogen and fluorescent lamps) is to look at the operating lamp through a digital camera display (such as the mobile phone camera display). The displays usually refresh at 30 frames per second, which is slower than the 100 Hz modulation of mains voltage. So the flicker that is not visible with naked eye becomes visible on the display. Figure 12 shows the comparison between two fluorescent lamp ceiling fixtures. The difference in the flicker degree between the magnetic and electronic ballast lamps is visible through the digital display.

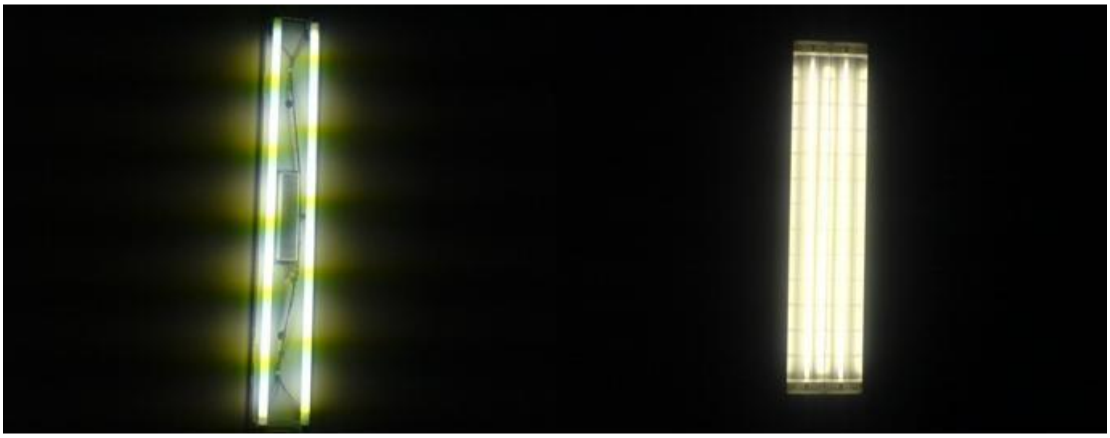

Figure 12. A T8 fluorescent lamp ceiling fixture (left) and a T5 fluorescent lamp fixture (right) as seen during operation on a mobile phone camera display. The larger flicker of the T8 is revealed on the display.

Large fluctuations (i.e. large flicker percentages) are clearly recorded as striped images on the display. The distortions / stripes tend to fade with lower flicker percentages (as in the right part of Figure 12) but they can still be detected by fine tuning the camera settings such as the exposure. Lamps that show no flicker (such as LED lamps with current feedback driving circuits) will be seen with no distortions on the display and the recorded images.

This diagnostic method was put to the test by recording the images or all our lamps during operation. Figure 13 shows all photographs along with markings for those that have no flicker. As it can be seen from the photos the flicker is detected in all cases as a striped and distorted recording. The clear images were indeed those of the LED lamps that had no flicker. Of course the distortion is very visible with the larger flicker percentages but careful examination will reveal flickering of any degree.

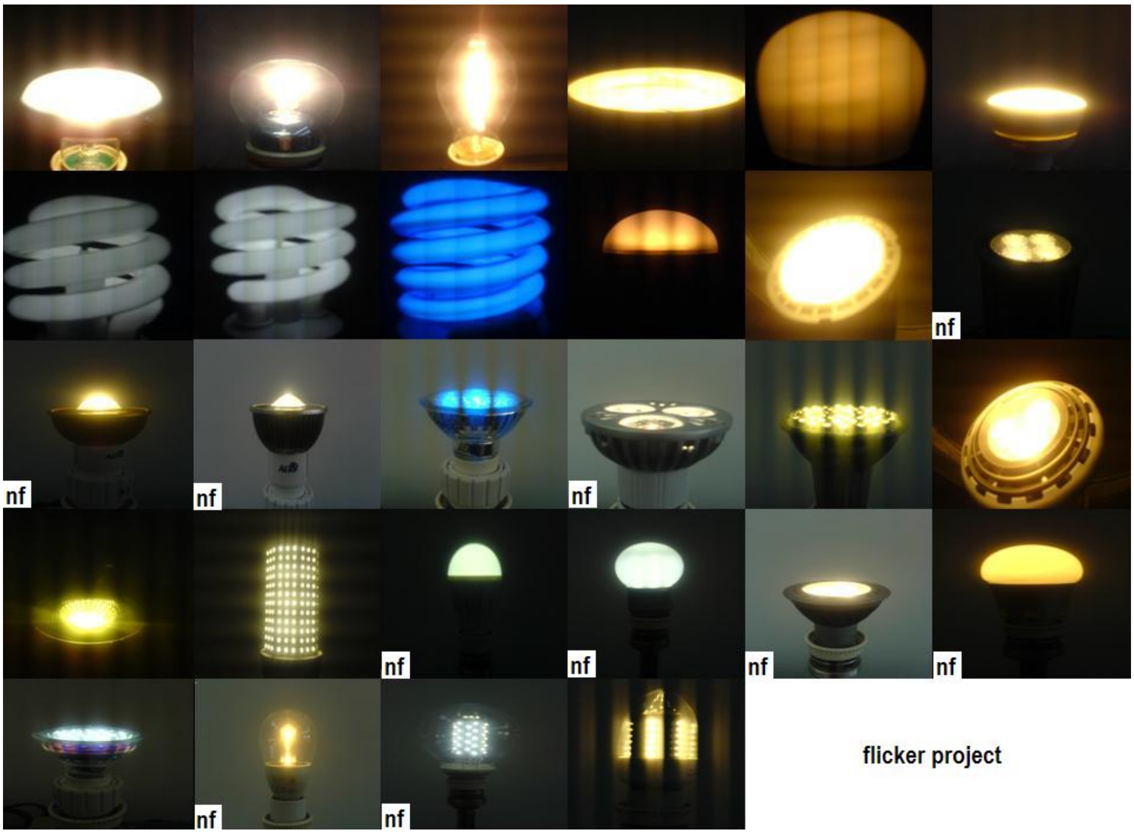

Figure 13. Images of the lamps during operation captured with digital camera (phone camera). Flicker of lamps is recorded as stripes (camera orientation defines the direction of the stripes).

This easy and quick flicker test with such a widely available tool as a mobile phone camera may prove useful to consumers seeking to avoid the undesirable effects of flicker even at such non visible frequencies. It would also be useful as a quick screening method even to the researcher interested in taking further measurements of flickering lamps. Perhaps a method for calculating the color contrasts on the recorded images could give this diagnostic method quantitative besides qualitative powers.

Closing remarks

We measured the flicker percentages for a number of commercial lamps and recorded a range of behaviors. Our tests include non-flickering LEDs, low flickering halogen and CFL lamps (below 15%) and high flickering LED lamps (up to 100%). The mode of operation such as the use of electronic ballasts for CFLs (operation in > 30 kHz regime) or the use of more expensive circuits (with current feedback as opposed to open loop) for LED lamps is the key for decreasing or eliminating flicker respectively. The tests also show that for all three technologies exhibiting flicker, dimming would most likely lead to flicker of greater degrees. Finally we proposed an easy flicker detection method based on widely available digital camera displays. Developing further such a tool is one of our future goals.

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