Q&A March webinar 'Is it all Flicker?'

- **Q1**: Is there a term or description for the flicker of led light. Like there is CRI for color? Can manufactors give a value on there led lights for this flicker? Are cheaper led`s more sensitive to flicker effects?
  A1: Yes. As explained in this webinar we distinct two important temporal light artefacts (TLAs): flicker and stroboscopic effect. The term 'flicker' refers to unacceptable light variation that is directly perceived by an average (or normal) observer. 'Stroboscopic effect' is an effect which may become visible for an average observer when a moving or rotating object is illuminated. From perception studies it is known that the perception of 'flicker' and 'stroboscopic effect' is frequency dependent. Flicker becomes visible if the frequency of the light modulations ranges from a few tenths of Hertz (Hz) up to approximately 80 Hz, whereas stroboscopic effects may occur for light modulation frequencies up to 2 kHz. For both TLA effects the threshold of perception also depends upon the way the light ripple varies with time. For instance flicker and stroboscopic effects induced by sinusoidal, saw tooth and rectangular light variations are perceived differently. Furthermore if the light ripple contains multiple frequency components the summation effect of these frequency components must be taken into account. For 'flicker' the maximum sensitivity is around 10 Hz. For flicker a widely applied and IEC-standardized metric exists, the 'short-term flicker severity' (PstLM), which takes all of the previously mentioned issues into account (see IEC TR 61547-1 [4]). For the objective assessment of stroboscopic effect the Stroboscopic Visibility Measure (SVM) has been developed. The SVM metric incorporates the frequency dependency, wave shape and summation effect.

- **Q2**: AS a light consultant, while lighting a luminiare specification for LED. How shall we take care of this stroboscopic, flicker, and phantom array effect so that only qualtiy products will be able to meet it
  A2: See A1. No validated metric and limit exists to specify the limitation of phantom array effect.

- **Q3**: Shouldn't we operate with a minimum modulation rate in KHz?
  A3: For stroboscopic effect, indeed the frequency content of the light ripple in the range between 80 Hz and 2 kHz must be limited. See A1.

- **Q4**: what do those different testing methods change for end users?
  A4: The metrics and associated test methods for flicker and stroboscopic effect proposed in this webinar have a better relationship what end users actually perceive in practice. See also A1.

- **Q5**: can you explain how we can see the visible flicker of LED traffic signals when watching then on a video?
  A5: Cameras also suffer interference from residual light ripples, but in a different way than humans. On videos or on your smart phone camera you may also perceive flicker, stroboscopic effect or banding effect. The effect you perceive depend very much on the operation of the camera (type of shutter – global or rolling shutter, shutter speed frame rate and sensor technology). Also the properties (frame rate) of the display play a role. So much more factors are involved on how light ripples appear via a camera on a display. Generally modulation depth as a function of frequency, between 50 Hz and a few 100 kHz is used to specify the maximum ripple of lighting equipment in order to avoid unwanted artefacts through cameras.

- **Q6**: Title 24 requires dimming which increases the chances of flicker in LEDs....is that statement correct? Why do we have to use different dimmers to operate correctly?
  A6: Yes, light regulation or external dimming, but also voltage fluctuations on the mains (that are allowed to a certain level through EMC/power quality regulation) play a role in the final flicker and stroboscopic effect behavior. The way dimming affects flicker or stroboscopic effect depend on the dimmer technology and on the dimming levels. Currently, in IEC and NEMA the effect of dimming is considered in dimmer compatibility standards. This work is underway. Already a standardized phae-cut dimmer can be used for that purpose (the NEMA SSL7 spec).

- **Q7**: I have a project just installed, and there is flickering throughout the facility; are there any measures we can look at, or take action on, in order to get rid of this brain altering issue?
  A7: Typically, three main factors play a role for flicker: the lighting equipment itself, light regulation or dimming and voltage fluctuations. If in your facility heavy electrical machinery is operated where heavy loads are switched, then high level of voltage fluctuations may be the root cause. See also A5.

- **Q8**: In an office under several LED luminaires 120Hz modulated eight hours of work, how do you think it can affect human health?
  A8: During the past years the scientific committees IEEE PAR 1789 and EC SCENIHR have assessed the potential health, performance and safety-related effects resulting from flicker and stroboscopic effects. Possible adverse effects on human health are migraine and aggravation of autistic behavior, and even photosensitive epileptic seizure under extreme conditions (e.g. flash lights). IEEE Std 1789 gives a good overview of the health effects.

- **Q9**: There are some relationship between flicker and the correlate color temperature (CCT)?
  A9: I'm not aware of studies that specifically looked into relation between CCT and TLAs. However, we conducted a small internal study (not published) in which we looked into the relation between the CCT (we tested one warm CCT of around 2700K and one cold CCT of around 6000K) and the visibility of the stroboscopic effect and we found no effect. In other words, based on a small internal experiment we found no relation between CCT and TLAs.

- **Q10**: Does color of the light and color of the background have effect on the perception (strobo, flicker, ghost)?
  A10: Generally, we have higher sensitivity to lightness flicker as compared to Chroma and hue flicker. I attach the paper: Changing color over time, in which you can read how perception of TLAs depends on color.

- **Q11**: Does sensitivity to flicker, stroboscopic effects and ghosting change with different reflectance values in the space?
  A11: For flicker, people are differently sensitive at different visual angles. We are most sensitive to flicker in the central vision for low frequencies, up to ~20-30Hz, and we are most sensitive in the periphery for high frequencies, > 30Hz. This means, that if you have a flickering stimulus at 50Hz, it will be easier for you to detect it in your peripheral vision, i.e. in the corner of your eye. Conversely, if you have a stimulus modulated at 10 Hz, it will be easier for you to detect it in your central vision. That being said, I wouldn't overestimate the impact of reflecting surfaces in space. The sensitivity might increase slightly if you have a lot of highly reflecting surfaces, but for most regular viewing conditions in typical applications (office, home) it shouldn't matter too much.

- **Q12**: How do you feel about US DoE A Much-Needed Recommended Practice for LED Flicker (http://goo.gl/GDe2fc)?
  A12: You refer to a paper on the IEEE Std 1789-2015 entitled "Recommended Practice for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers" which was published last year. The overview of the possible health effects is good. However in its recommendations it applies the metrics Modulation Depth (MD) and Flicker Index (FI) to quantify TLA, which do not account for the effect of possible complex wave shapes of the light output. So it recommends usage of wrong metrics. Some of the recommended limits are overly strict which could add unnecessary costs to LED products. Note that this document is to be used by other organizations to develop lighting-application-specific recommended practices.

- **Q13**: Have any coded light or lifi technologies been evaluated using these metrics?
  A13: Yes. Within Philips coded-light equipment has been evaluated/tested and is found OK.

- **Q14**: isn't there a connection in between the quality of the control gear and the amount of flicker?
  A14: Yes, certainly. Apart from external factors such as dimming or voltage fluctuations, the quality of the control gear (driver) is the major source of unwanted residual light modulations (in case of LED). A current ripple from the driver has almost a one-to-one relationship with the light output. The driver topology (single stage, dual stage), the size of the buffer capacitor, the way light regulation is implemented all play a role in the magnitude of the residual current / light ripple.

- **Q15**: is there flicker on OLEDs ?
  A15: Yes, in the same way as LED. See A14.

- **Q16**: if We use different phases of a three phase power network can avoid flicker?
  A16: Not for flicker, yes for stroboscopic effect. Generally the mains frequency is doubled in the residual current ripple that is fed to the LED. So 50/60 Hz is visible as a 100/120 Hz ripple which may give unwanted stroboscopic effect. If the light sources are fed through three different driver channels that are fed with different phases of the mains network, then the frequency content of the ripple will change, and this will reduce the level of stroboscopic effect. The doubled mains frequencies do not affect flicker.

- **Q17**: First of all thank you for the presentation! How would you describe the visual effect that may occur when two light sources at (let's say 2kHz) high frequencies interfere. Would that be flicker as well?
  A17: First of all if the light sources have, say a 1 kHz residual ripple, it will not give flicker (the frequency is above the visible flicker range), but it may give stroboscopic effect depending on the wave shape. Generally, the 1 kHz frequency of light source ripples will not be synchronized (in phase), so the ripple of the total light level (if the sources are close together) will generally be reduced and the stroboscopic effect will be reduced also. If the 1 kHz ripples are in phase then the stroboscopic effect is not reduced: the magnitude of the ripple and the average level increase in the same way.