Flicker and stroboscopic effects
–
measurements made easy

New legislation is coming in September 2021.

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Today, we are going to take you through some background on flicker and stroboscopic effects.
The updated EU Ecodesign Directive will force all companies that market lighting equipment in EU to specify flicker in their products. This is new.
Since many products are produced in Asia this is important also for many Asian clients. And very soon legislation in the US will probably follow through.

Agenda

- Why are flicker and stroboscopic effects a problem?
- Types of flicker
- TLA metrics – old and new
- New EU legislation
- TLA and dimming
- Measuring TLA – LIVE DEMO
- Output in reports – SOFTWARE DEMO
- Why LabFlicker from Viso Systems

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We shall go through a little background on why flicker and strobeoscopic effects are a big problem in lighting, and how we can quantify flicker.
Then, we will turn to the new legislation, and we'll make a live demonstration of LabFlicker and the software.

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Why care?

- Photo epilepsy – flashing lights stimulate epileptic seizures
- Stroboscopic effect – dangerous when working with rotating machinery
- Migraine or severe headache
- Increased repetitive behavior among persons with autism
- Asthenopia (eye strain), including fatigue, blurred vision, etc.
- Other: panic attacks, anxiety, increased heart rate, dizziness
- Also: interference with imaging devices (video & security cameras, etc.)

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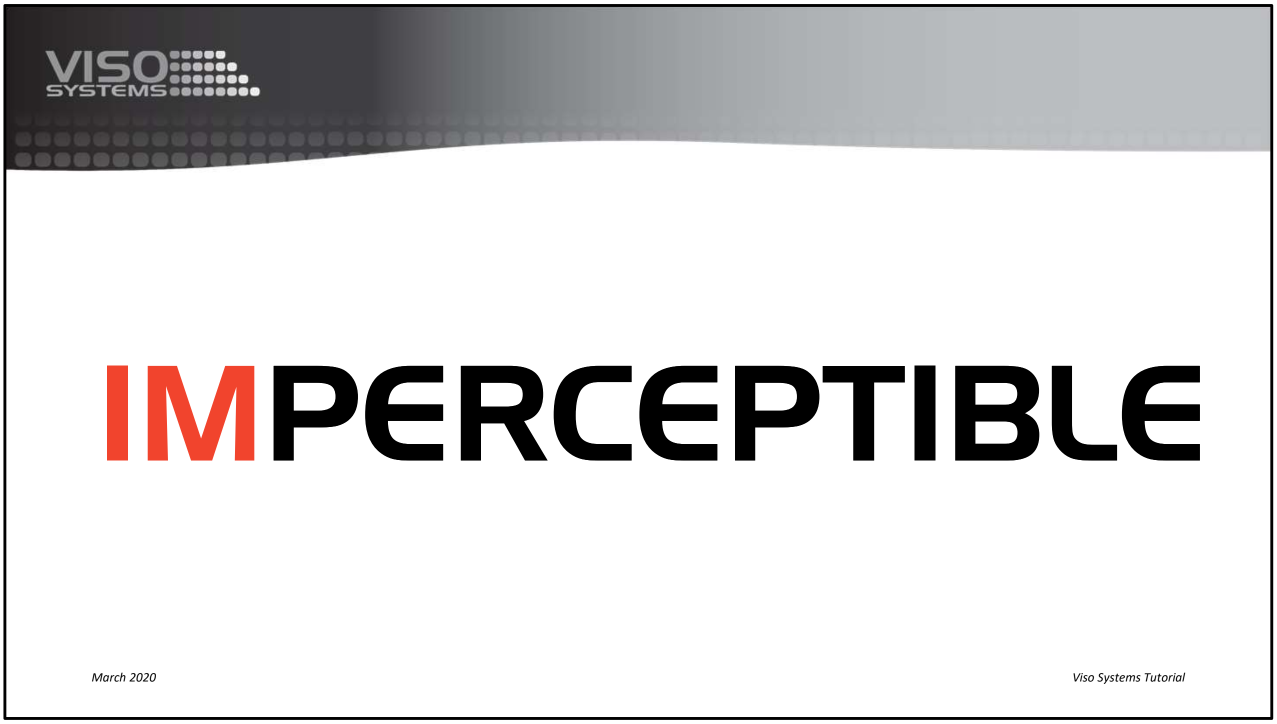
So, why do we care?
Actually, flicker and stroboscopic effects can cause a lot of disturbance. But what research also shows is that there are great differences in how people experience these effects and whether they sense it at all.
So, some people get migraine attacks or flicker stimulated epileptic seizures. And some people are just mildly annoyed.
But there might be a lot of us that suffer from fatigue or eye strain – and never get around to blaming the lighting. You might as well think that the air is too dry, or your eyeglasses need an upgrade, or you're just tired.



So, there is certainly perceptible flicker and then there might be an even bigger problem related to imperceptible flicker.

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Types of Effects

CIE 17.443 e-ILV (International Lighting Vocabulary):

Temporal light artifact (TLA): **an undesired change in visual perception induced by a light stimulus (Temporal Light Modulation, TLM) whose luminance or spectral distribution fluctuates with time**	**Object**	**Observer**
Flicker: Perception of visual unsteadiness for a static observer in a static environment. 3 - 80 Hz	Static	Static
Stroboscopic effect: Change of motion perception… for a static observer in a non-static environment. 80 Hz - 2000 Hz	Moves	Static
Phantom array effect (ghost effect): change in perceived shape or spatial layout of objects… for a non-static observer in an otherwise static environment (e.g. saccade, normal head movement, or while driving). 80 Hz – 2500 Hz	Static	Moves

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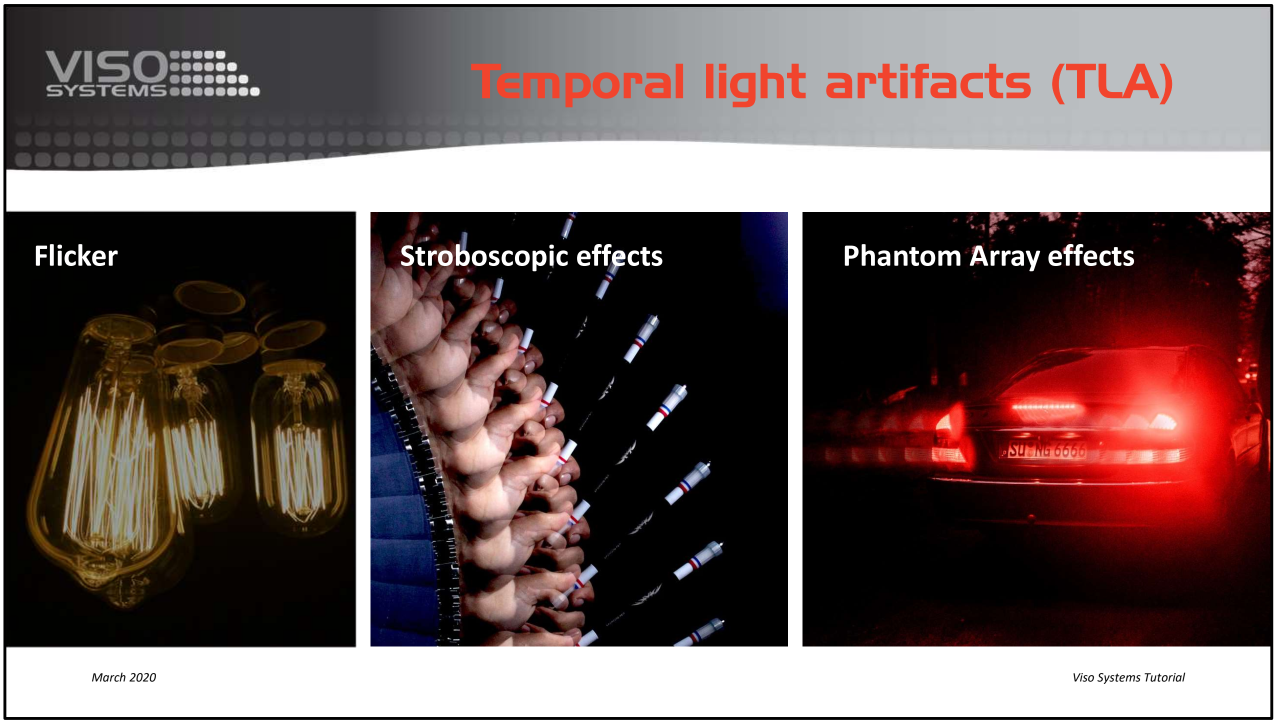
In general, the International Lighting Vocabulary advises us to call fluctuating light "Temporal Light Artifacts", or TLA's

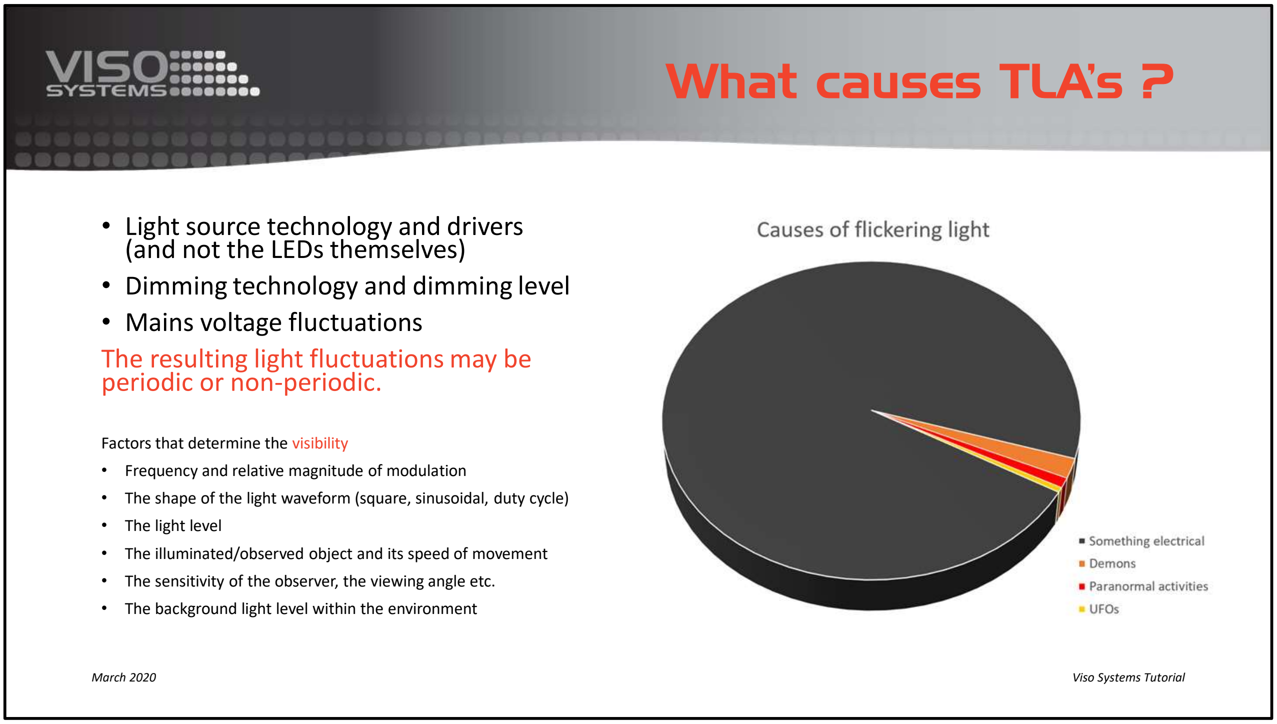
There are three types of TLA's: Flicker, Stroboscopic effects, and Phantom array effects.

- Flicker is the most obvious type since it is visible even if both the light source and the eye is static. It is visible because the frequency is low, only 3-80 hertz.
- Stroboscopic effects are when we see things moving in a fast fluctuating light and the movement seems split up in separate images. The frequency is higher – about 80 to 2000 Hz. Most strobe light for dance floors are actually not stroboscopic according to this definition, because the frequency is only 10-12 Hz. But the effect is similar. We call it stroboscopic when the object moves and the eyes are static.
- The last type is the so-called "Phantom Array Effects". This is somewhat exotic but occurs when the object (the light source) is static but the eyes move. Fast eye saccades could trigger a series of separate images to be built on the retina. The effect occurs in about the same frequency range as the stroboscopic effects.



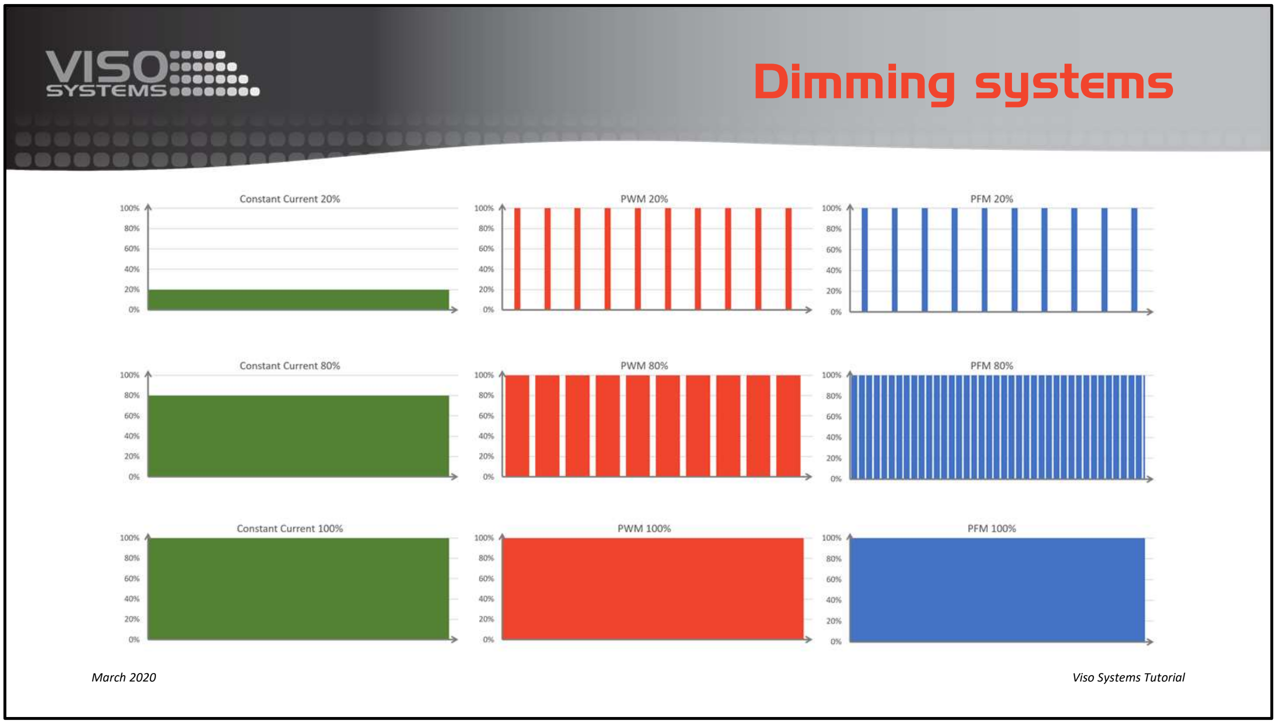
So, here is another illustration:

- Flicker is what we encounter for instance in cheap LED bulbs – some can see it looking directly at the light source, others see it better in their peripheral vision, in the corner of their eye.
- Stroboscopic effects are experience as movement chopped up in pieces. This sort of lighting can be really dangerous for instance when working with rotating machinery. Rotation can be disguised as stand-still.
- The last image is supposed to illustrate phanthom array effects from the rear lights of a car which is standing still. Fest eye movement from side to side could cause the powerful red light to build a series of separate images on your retina.



It is certainly not true that LEDs cause flicker since LEDs are run on DC. So, the problem is usually AC/DC converters and dimming systems.
LED drivers typically lets some of the 50 or 60 hertz fluctuation from the mains supply pass through.
Dimmers are a problem too: Ideally, LEDs should be dimmed simply by reducing the DC current. But in real life, some dimmers just chop up the current in short on/off pulses that can add significantly to flicker and stroboscopic effects.

So, what makes TLA’s visible?
First of all, the frequency is important and so is the type and magnitude of intensity modulations. Incandescent bulbs actually also flicker somewhat. But because the glowing tungsten wire doesn't cool off between current pulses the modulation is small – maybe +/- 6%.
LEDs turn on and off instantaneously.
It also matters if the light level is high, or the contrast is high. And it is important exactly how sensitive the observer is



So, here's some dimming systems:
The upper 3 are all dimmed to 20%, the middle row to 80% and the bottom row is not dimmed at all.

The green graphs on the left are examples of the ideal constant current dimming where the signal is steady.

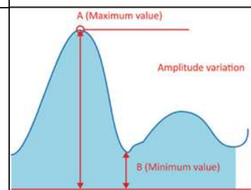
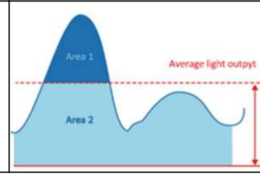
The other two are examples of crude, square signal, on/off dimming.

The orange graphs in the middle are Pulse-Width-Modulation dimming that run with the same frequency in all dimming levels but where the width of the signal is broadened to let the average light level go up.

On the right-hand side you will find Pulse-Frequency-Modulation dimming. The width of the signal is unchanged, but the frequency goes up to let the average light level go up.
In all other dimming situations than the lowest, PFM is better than PWM because the eyes and the brain find high frequencies easier to interpret.

But, how do we measure flicker?

Old TLA Metrics

Index	Defined By	Definition Point	Formula	Index Range
Frequency	Universal	Time component of flicker	Main pulse per second	1 to ∞ Hz (in practice 50-2000 Hz)
Percent Flicker	Illuminating Engineering Society (IES)	A relative measure of the cyclic variation in the amplitude of a light.	 $\text{Percent Flicker} = \frac{A - B}{A + B} * 100\%$	0% to 100% The lower the percent flicker, the less substantial the flicker.
Flicker Index	Illuminating Engineering Society (IES)	A measure of the cyclic variation taking into account the shape of the waveform.	 $\text{Flicker Index} = \frac{\text{Area 1}}{\text{Area 1} + \text{Area 2}}$	0 to 1 The lower the flicker index, the less substantial the flicker.

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Most suppliers of lighting equipment will be able to specify these old flicker metrics: *Flicker frequency*, *Percent Flicker* and *Flicker Index*.

Now, both the frequency and the modulation shape is important.

In practice, frequencies higher than 2000 Hz seldom cause problems no matter how high the modulation is. Even PWM dimming (a square waveform) is ok above 2000 Hz.
The metric *Percent Flicker* will tell you a story about the modulation amplitude, and the metric *Flicker Index* will tell you more about the actual waveform. Both metrics assume a cyclic waveform.

But why would we need new metrics?

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Why do we need new metrics?

- Tendency to forget the very important frequency component – and just talk about Percent Flicker/Flicker Index
- Measure procedure for old metrics were limited to short review periods.
- Data that was captured at different frequencies could not be directly compared
- Need for metrics to handle new lighting systems with LED **(new types of intensity fluctuations)**
- **Need for taking into account new knowledge about different eye and brain sensitivity**

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There are several reasons:
First of all, some people actually forget to talk about frequency and think that TLAs can be described with Percent Flicker or Flicker Index.

Next, LED light sources have new fluctuation patterns. So, in order to compare different systems with different frequencies and modulation patterns it would obviously be better with one index and not three metrics.

But most importantly, new metrics should be better adapted to human perception of flicker and stroboscopic effects.

New TLA Metrics

Index	Defined By	Definition Point	Formula	Index Range
PstLM	IEC/TR 61547-1 IEC 61000-4-15	PstLM ="short-term light modulation" measures visible flicker	$P_{st} = \sqrt{0{,}0314\ P_{0,1} + 0{,}0525\ P_{1s} + 0{,}0657\ P_{3s} + 0{,}28\ P_{10s} + 0{,}08\ P_{50s}}$ • Spectral analysis in time domain • Filter: Demodulation and eye-brain filters • Weighted summation of percentiles	TLA in the frequency range between 0.3 Hz and 80 Hz. Index range is 0 to ∞ PstLM =1 is modulation that 50% of people can perceive New European limiting value = 1.0
SVM	IEC TR 61547-1 IEC 61000-3-3 IEC 61000-4-15	SVM = "Stroboscopic visibility measure“ assesses the strobe effect which can occur in conjunction with moving objects	$SVM = \sqrt[3,7]{\sum_{i=1}^{N(\leq 2kHz)} \left(\frac{Ci}{Ti}\right)^{3,7}}$ The normalized frequency components of the signal (Ci) are weighted and summed up via Ti according to the human perception	TLA in the frequency range from 80 Hz to 2,000 Hz. Index range is 0 to about 8 SVM =1 is modulation that 50% of people can perceive New European limiting value = 0.4

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So, here are the new metrics – one describes flicker, the other describes stroboscopic effects. These belong to two different frequency ranges:

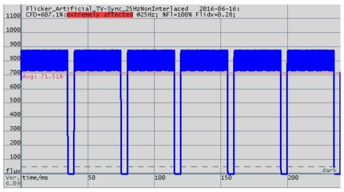
- Visible flicker is from 0 to about 80 Hz
- Stroboscopic effects are from 80 Hz and to about 2000 Hz.

The PstLM index measures visible flicker while taking human brain demodulation and eye-brain filtering sensitivity curves into account.
The SVM index measures stroboscopic effect while taking human perception curves into account

A value of PstLM = 1 means that the average observer has a 50% probability of detecting flicker.
The value SVM = 1 represents the visibility threshold for an average observer.

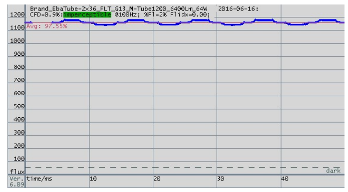
Going as low as possible on both indexes is obviously good.

Examples



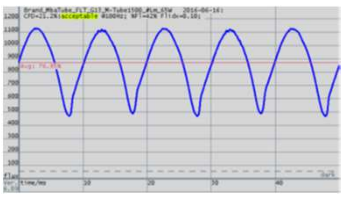
TV screen, non-interlaced:

- Percent flicker = 100.0%
- Flicker index = 0.285
- Frequency = 25 Hz
- PstLM = 34.956
- SVM = 1.078



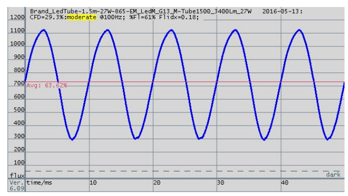
Fluorescent tube with electronic ballast:

- Percent flicker = 2.4%
- Flicker index = 0.005
- Frequency = 100 Hz
- PstLM = 0.020
- SVM = 0.049



Fluorescent tube with magnetic ballast:

- Percent flicker = 41.9%
- Flicker index = 0.101
- Frequency = 100 Hz
- PstLM = 0.177
- SVM = 1.252



LED illuminant with moderate ballast:

- Percent flicker = 61.0%
- Flicker index = 0.176
- Frequency = 100 Hz
- PstLM = 0.044
- SVM = 2.158

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Source of Examples
Background information: Light flicker – Determination and Assessment– Discussion Paper by Peter Erwin, October 2017

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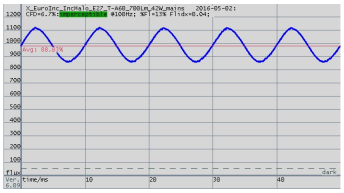
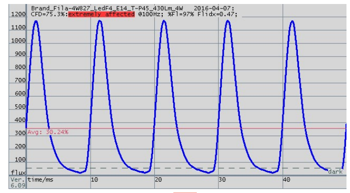
Examples



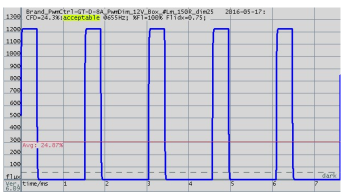
Incandescent lamp
at mains power:

- Percent flicker = 13.2%
- Flicker index = 0.040
- Frequency = 100Hz
- PstLM = 0.017
- SVM = 0.494



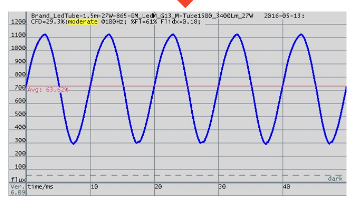
LED illuminant
with insufficient ballast:

- Percent flicker = 96.9%
- Flicker index = 0.466
- Frequency = 100Hz
- PstLM = 0.107
- SVM = 5.301



LED without ballast on a
PWM dimmer

- Percent flicker = 100.0%
- Flicker index = 0.746
- Frequency = 655Hz
- PstLM = 0.133
- SVM = 2.060



LED illuminant with
insufficient ballast
dimmed to 25%:

- Percent flicker = 100.0%
- Flicker index = 0.860
- Frequency = 100Hz
- PstLM = 0.154
- SVM = 8.111

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Source of Examples:
Background information: Light flicker – Determination and Assessment– Discussion Paper by Peter Erwin, October 2017

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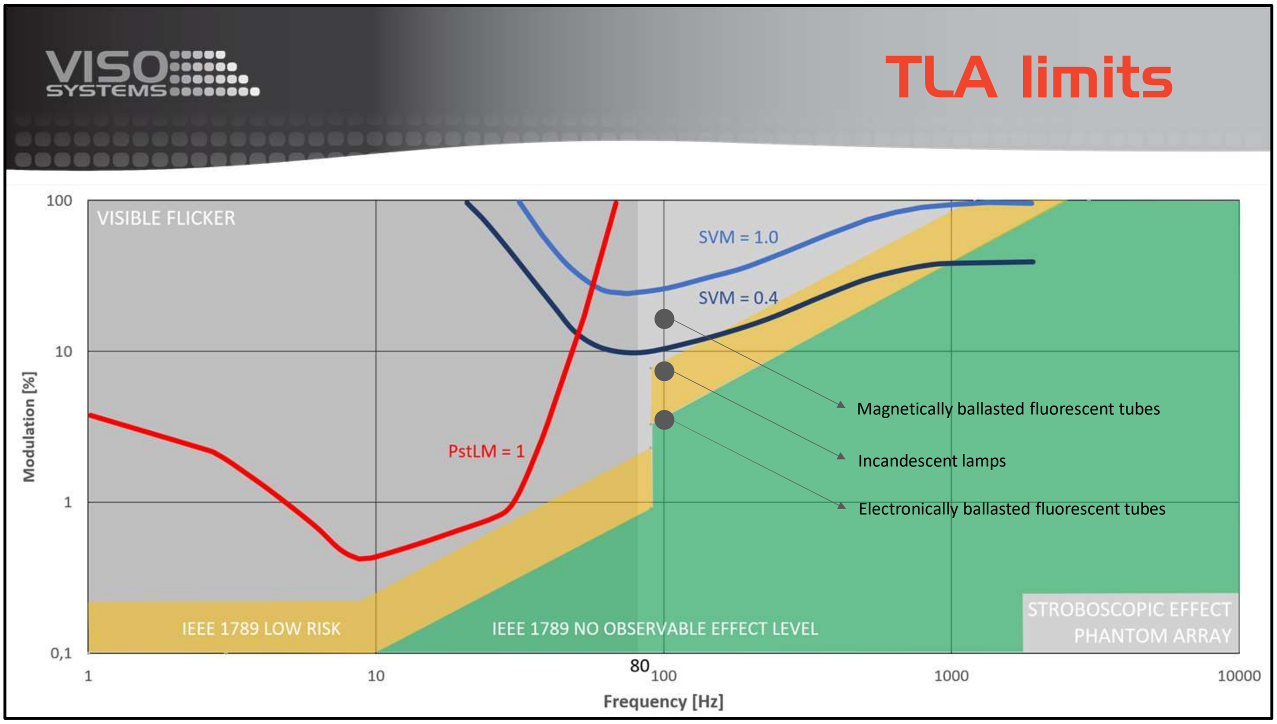

In this page, you'll get an overview of the limiting value and sensitivity curves.
First of all, the graph is divided into two grey spaces: Below 80 Hz and above. Note that both scales are logarithmic. Also the modulation on the y-axis.

The next layer shows the limits as they were expressed in relation to the old metrics. According to American standard IEEE 1789, the green area with either high frequency or low modulation or a combination was “safe”. The yellow area indicates low risk.

The third layer indicates the new limiting values in terms of the new metrics, PstLM and SVM. It can be said, that PstLM = 1 and SVM 0.4 will actually allow more light sources to be accepted than IEEE 1789 especially around 50-100 Hz. But ´then again IEEE 1789 was never law in Europe or anywhere else.

The last bit here indicates where a few common light sources would be plotted. As you can see, magnetically ballasted fluoprescent tubes as they were 25 years ago would not be allowed, whereas high frequency electronically ballasted tubes would still be ok. Incandescent light would be ok, which also seems intuitively right.

New EU Legislation

5.12.2019 EN Official Journal of the European Union L 315/209

COMMISSION REGULATION (EU) 2019/2020

of 1 October 2019

laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012

(Text with EEA relevance)

Ecodesign requirements are not new to the lighting industry – but **flicker limits** are!

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So, this is the header on the of the revised Ecodesign directive that was decided on 1st October 2019, and will come into force on 1st September 2021.

Ecodesign has been around since 2009, so this version of the directive basically gathers four documents into one. But it also adds new requirements – thus also on flicker and stroboscopic effects.

This legislation will cover almost all lighting products that are put on the market in the EU. Household light sources, professional light sources and luminaires of all kinds for both indoor and outdoor use. Specialty light sources as signaling lamps, ultraviolet lamps, and lamps for ovens etc. are exempt.

So this is actually really huge. Almost no manufacturers can measure PstLM and SVM today. So in a short while, everybody will be looking for equipment to do so.

Objectives and New Limits

(c) setting more stringent requirements on flicker and stroboscopic effects, while extending them to separate control gears;

(d) setting requirements on dimming, including the interaction with flicker;

Flicker for LED and OLED MLS	P_{st} LM ≤ 1,0 at full-load
Stroboscopic effect for LED and OLED MLS	SVM ≤ 0,4 at full-load (except for HID with Φ_{use} > 4 klm and for light sources intended for use in outdoor applications, industrial applications or other applications where lighting standards allow a CRI< 80)

So, here are the limits.
Please note that both limits are at “full load”.
Naturally, it is recommended to test both at full load and at all relevant dimming stages.
Dimming down to 10 or 20% could render a totally different result.

Further, a lot of luminaires actually run all the time in a dimmed stage. Many end customers prefer to have the same luminaire all over the building and then they will just dim them to the required illuminance level to save energy.

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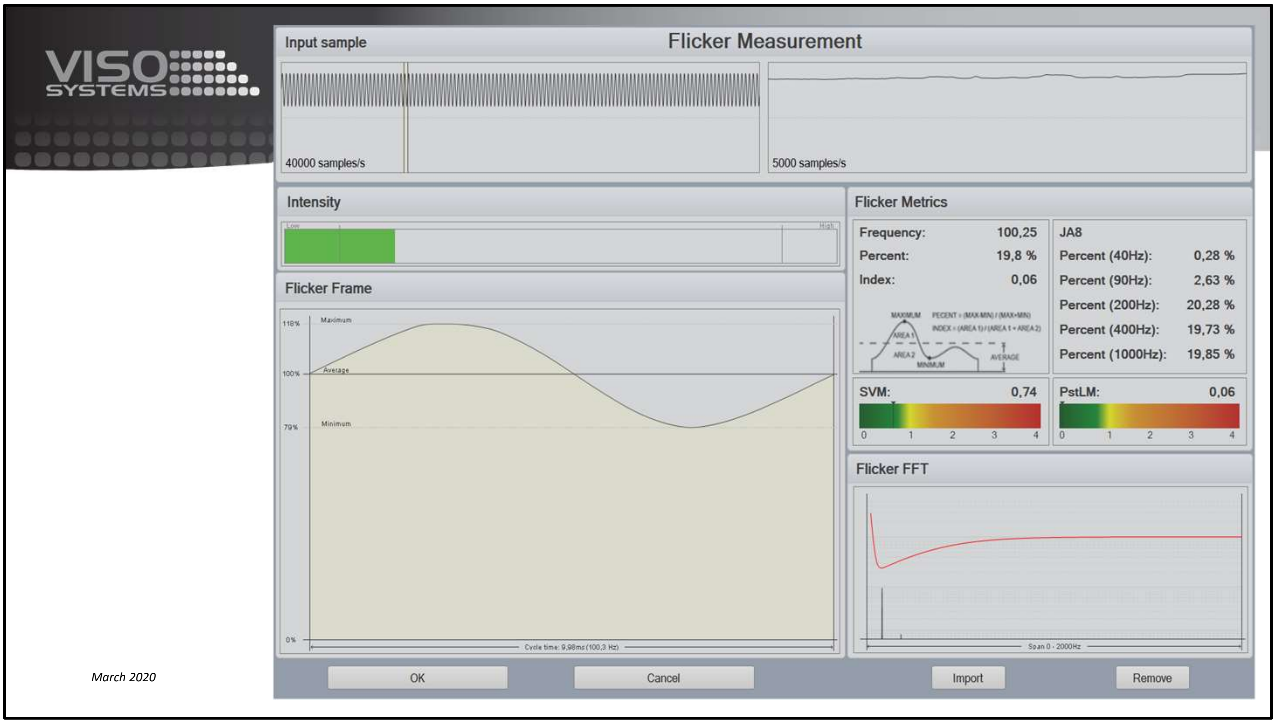

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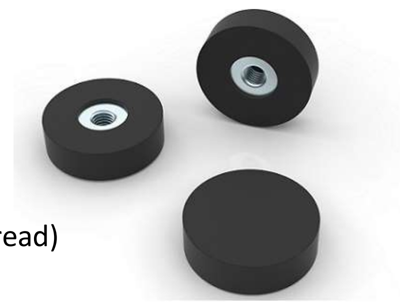
Other advantages

- Not many others can measure PstLM
- LabFlicker integrates directly with advanced and free Viso software
- Live readout and nice download and reporting options
- Sampling rate is 40 kHz (minimum requirement for TLA is 4 kHz, 10 kHz recommended)
- LabFlicker is not limited by internal processing or storage capacity
- LabFlicker can be mounted on any camera stand via included rubber magnet (1/4 internal thread)
- Self-explanatory use (just one start/stop button)



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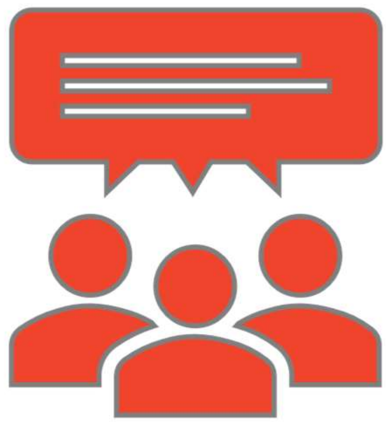
Questions ?



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