Light is impact

Light modulation: Effects on human beings and technical devices

Perfectly matched, high-quality lighting systems significantly contribute to creating productive working and living environments while ensuring interference-free interaction with optical devices. Learn more about what matters.

Light is OSRAM

OSRAM

Light modulation as quality criterion

The quality of a lighting installation is determined by various factors: illuminance, color rendering, glare, homogeneity and light color are just a few major criteria. State-of-the-art LED technology now offers entirely new possibilities in terms of energy savings and lighting design. However, the light emission of LEDs responds to temporal fluctuations and other influences of your power supply almost immediately. The resulting temporal modulations of light are another key quality criterion for the design and assessment of lighting applications. Human well-being and health aspects play the most important role in this context, but the proper functioning of optical devices, such as bar code scanners or cameras, can also be affected.

Temporal light artefacts (TLA)

TLAs are all visual effects (i.e. effects visible to the human eye) created by light sources with varying intensity or spectral distribution over time. Two well-known examples of such effects are flicker and the stroboscopic effect.

The latter refers to a change in the perception of motion of a static observer in a non-static environment caused by a light stimulus, the brightness or spectral distribution of which fluctuates over time. The average observer only perceives this effect when a moving or rotating object is illuminated. Light modulation frequencies in the range from approx. 50 Hz to approx. 2 kHz are relevant in this context.

In contrast to this, light flicker also becomes visible without any moving objects, provided that the modulation frequencies of the light are below approx. 80 Hz (more precisely, this is the impression of fluctuation in visual sensations caused by light stimuli with varying luminance or spectral distribution over time).

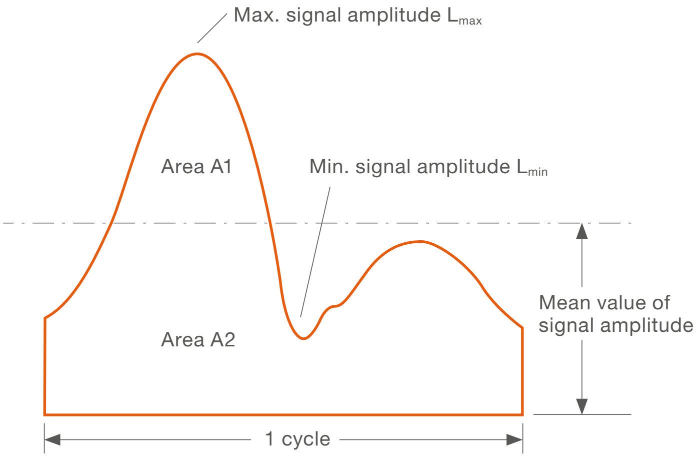
Measurement procedures for the assessment of modulated light

Suitable metrics or physical criteria as well as measurement procedures are required for the proper detection and analysis of modulated light effects.

Modulation depth (MD), flicker index (FI) and ripple current

The modulation depth and flicker index frequently serve as a basis for the assessment of flickering or light modulation. Figure 1 shows an example of the modulated luminous flux from a light source and the relevant parameters for calculating the modulation depth and flicker index.

Figure 1: Example of the modulation depth (MD) and flicker index (FI) metrics



Modulation depth (MD) is defined as follows:

$$MD = \frac{(L_{max} - L_{min})}{(L_{max} + L_{min})} \cdot 100\%$$

This formula corresponds to the classic formula for calculating the modulation depth, which is well known from electrical engineering.

The flicker index (FI) is calculated according to the following formula:

$$FI = \frac{A1}{(A1 + A2)}$$

Here, the areas A1 and A2 enclosed by the curve (modulated light) are considered. The ratio between the area A1 above the mean line and the total enclosed area (A1 + A2) is calculated.

However, the modulation depth (MD) and flicker index (FI) metrics are only of limited use in assessing the effect of modulated light on human beings. This also results from the fact that the shape of the modulation curve and the modulation frequency are not considered.

Instead of the modulation depth for the modulated light, the modulation depth of the electric current flowing through the LEDs can be measured and in most cases serves as a basis. This so-called “ripple current” indicated in % can therefore only be used for the assessment of visual effects when combined with additional information, for example about modulation frequencies. Generally speaking, a low-frequency ripple current at 100 Hz mainly influences the visibility of the stroboscopic effect as well as possible image interference during the use of digital cameras.

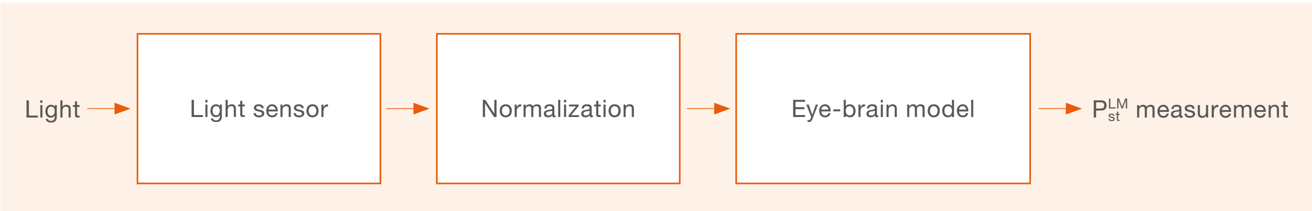
Although high-frequency ripple currents > 20 kHz do not play a role for human visual perception, they can cause functional interference impacting bar code scanners or special cameras.

New, improved metrics for the assessment of TLA

P_{st}^{LM} metric

The purpose of this metric (P_{st}^{LM} for short-term light modulation) is to measure the visible flicker that is caused by light modulation in the frequency range from 0.3 to 80 Hz. Figure 2 shows a simplified block diagram of the P_{st}^{LM} measurement setup.

Figure 2: Block diagram of the P_{st}^{LM} measurement setup



A P_{st}^{LM} measured value of 1 means that the flickering of the measured light source is just at the perception threshold. This means that half of a group of normal observers is still able to perceive the flickering of the light source, whereas the other half can no longer perceive this effect.

A P_{st}^{LM} measured value > 1 indicates that more people can perceive the flicker effect; if the P_{st}^{LM} measured value is < 1, it is perceived by fewer people or no one at all. A P_{st}^{LM} limit value of 1 is therefore recommended for most general lighting applications.

OSRAM LED drivers do not produce visible flicker.[1)]

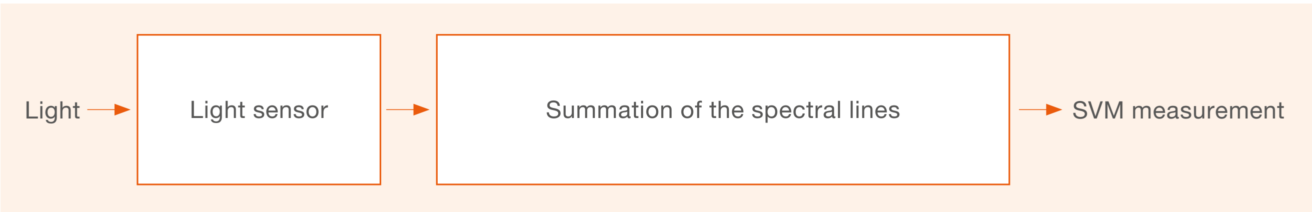
This applies to the following product families: OTi DALI, OTi DALI Industry, OTi DALI TW, OT FIT and OT Outdoor 1DIM and 4DIM. The P_{st}^{LM} value for all mentioned product families is below 1, evaluated according to the test conditions of IEC TR 61547-1 ED2.

1) This statement refers to a majority of average observers.

SVM metric

The stroboscopic visibility measure (SVM) metric assesses the stroboscopic effect, which can occur in relation to moving or rotating objects.

Figure 3: Block diagram of the SVM measurement setup



Similar to the P_{st}^{LM} metric, an SVM measured value of 1 indicates that half of a group of normal observers can still perceive a stroboscopic effect, whereas the other half is no longer able to perceive the interaction between light modulation and moving objects. High SVM values of e.g. > 5 indicate clearly visible stroboscopic effects.

However, it is still too early to provide general recommendations with regard to possible SVM limits, because the requirements for various light application areas can differ significantly and no extensive experience is available up to now.

Even though there are no generally accepted limit values for the SVM metric so far, OSRAM LED drivers with low SVM values from the OTi DALI[2], OTi DALI Industry, OTi DALI TW[2] and OT FIT families should be used for demanding lighting tasks, e.g. for office workstations or work areas with challenging visual tasks – especially in combination with moving objects.

In non-critical areas of application (corridors, stairwells, warehouses, decorative lighting etc.), high SVM values are usually of lesser importance.

In workplaces where there is a danger from rotating machines and possible stroboscopic effects, a risk assessment adapted to this workstation is required. An evaluation of the used lighting systems with the help of the SVM metric can provide useful information but is not sufficient on its own.

2) Exceptions: OTi DALI CV and OTi DALI TW in preselected PWM mode.

Light modulation interactions with technical devices and machinery

Bar code scanner

As a result of interference in environments with modulated light, certain bar code scanners can have problems capturing bar code information in a reliable way.

Widely used laser scanners include types with the laser beam moving quickly along a thin line over the bar code in order to capture the reflected lighting intensity over time. This scanner technology is far more sensitive to temporally modulated ambient light than CCD-based bar code scanners, which scan the entire bar code more or less simultaneously.

In addition to the scanner technology, the modulation frequency of the ambient light, the modulation depth and the illuminance are important factors.

Figure 4 illustrates the areas in which interference may occur due to modulated ambient light. However, this illustration refers to rather critical testing conditions with an illuminance of 1,300 lx as well as 500 lx on the scanned object generated by only a single modulated light source.

This graphical representation shows that the interaction of LED lighting systems with bar code scanners depends primarily on the high-frequency ripple of the LED drivers, whereas the low-frequency 100 Hz ripple plays practically no role in this context.

As a rule, CCD bar code scanners do not cause any malfunctions due to the interaction with modulated light. The selection of OSRAM LED drivers is therefore not restricted.

When using laser scanners, malfunctions can theoretically occur under unfavorable operating conditions, which depend on many parameters[1] (type of LED driver, operating parameters, illuminance at the bar code etc.). In practice, however, no problems are known.

Digital cameras

In order to better assess the effect of modulated light on camera images, it is necessary to make a distinction between standard cameras for conventional photos or videos and high-performance cameras for professional studio and sports images. The following considerations refer mainly to the first category of standard cameras including, for example, compact cameras, reflex cameras, smart device cameras and web cams as well as monitoring cameras.

Certain image artifacts are due to the image capturing technology used by the cameras. Whereas striped image interference can occur with customary CMOS cameras with rolling shutters, cameras with global or mechanical shutters enable different lighting levels for consecutive single images.

1) In particularly critical individual cases, detailed information can be given according to the specific operating conditions.

Figure 4: Possible interference areas of bar code scanners in environments with modulated light

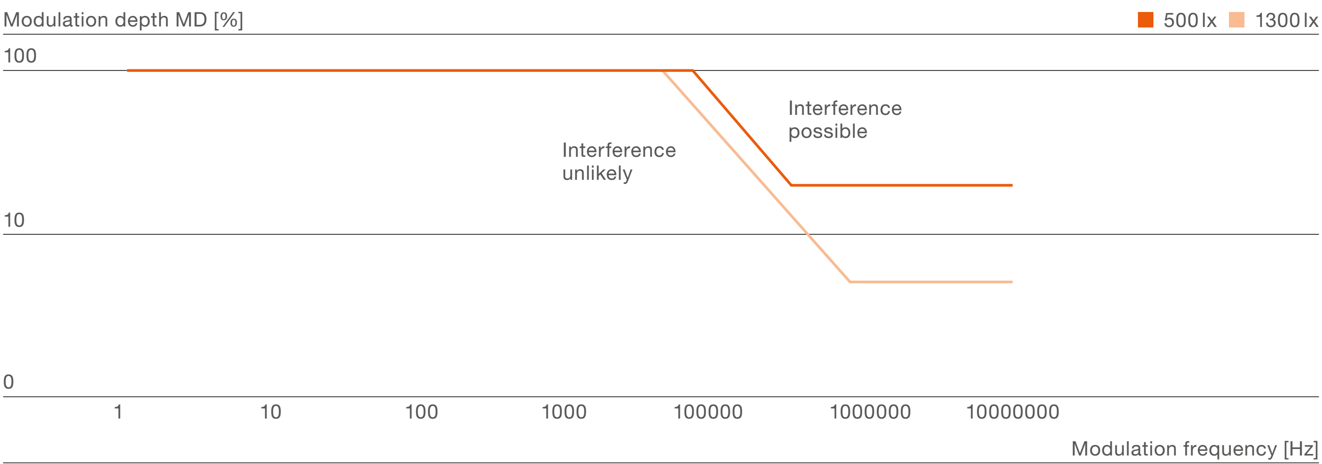


Figure 5: Example of striped image interference with a rolling shutter camera

State-of-the-art smartphone cameras increasingly use software solutions to reduce the image artifacts caused by modulated ambient light.

Lighting systems emitting modulated light in a frequency range below approx. 5 kHz can cause more or less pronounced image artifacts in standard cameras, in which the permissible modulation depth depends strongly on the modulation frequency. The 100 Hz ripple current of the LED driver used plays a key role in this context. The behavior of standard cameras with regard to the influencing frequency spectrum is therefore almost complementary to the behavior of bar code scanners.

Figure 6 illustrates the modulation depth and modulation frequency ranges in which image artifacts can occur in standard cameras in the event of lighting with temporally modulated light or in which no negative impact is to be expected. In the area of the “visibility limit” (in the center of the graph), perceivable image artifacts can theoretically occur with special exposure times. These, however, are hardly perceived in practice. This diagram is based on a minimum camera exposure time of 1/100 s.

PWM dimming

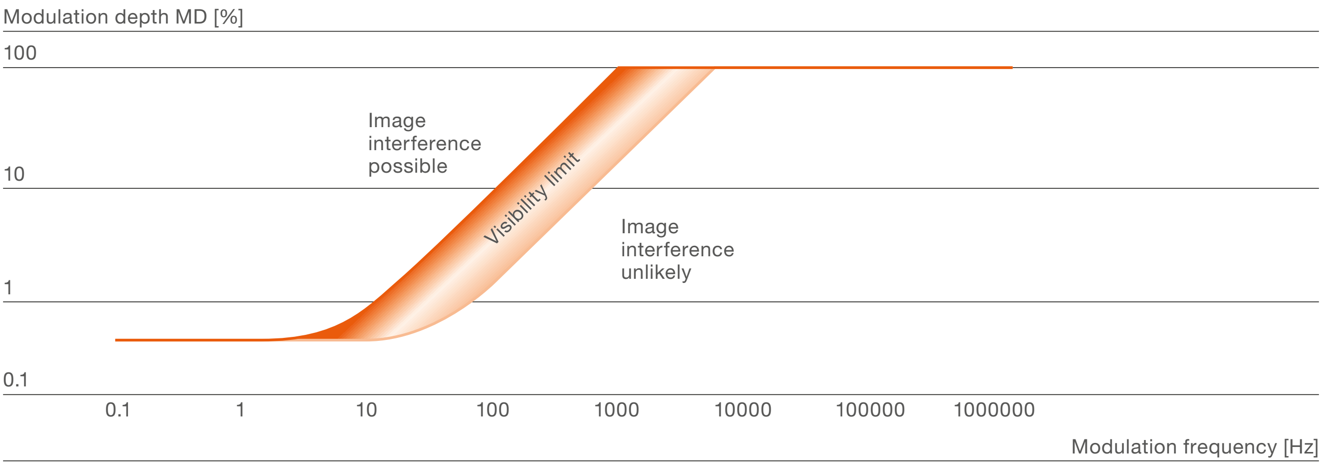
Certain lighting systems dim LED light sources by employing a procedure that interrupts the LED current in time packages. The repetition frequency of these packages is in the range from 100 Hz to approximately 2,000 Hz, which the human eye cannot directly perceive. Since the brightness of the dimmed light sources depends on the switch-on/switch-off time ratio of the LED current, this method is also referred to as PWM dimming.

With PWM dimming, the light modulation depth for camera shots reaches 100 % in the above-mentioned frequency range, i.e. in a corridor that can cause image artifacts. However, perfectly matched lighting and camera systems with high PWM frequencies enable successful use, for example for professional studio applications.

Lighting installations with OSRAM LED drivers from the OTi DALI[2)], OTi DALI Industry, OTi DALI TW[2)] and OT FIT families generally lead to no or only weakly pronounced artifacts with standard cameras.

2) This does not apply to devices with PWM dimming (e.g. first-generation DALI device types and dimmable CV devices).

Figure 6: Modulation depth and modulation frequency areas of lighting systems in which image artifacts in standard camera systems are possible or unlikely



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