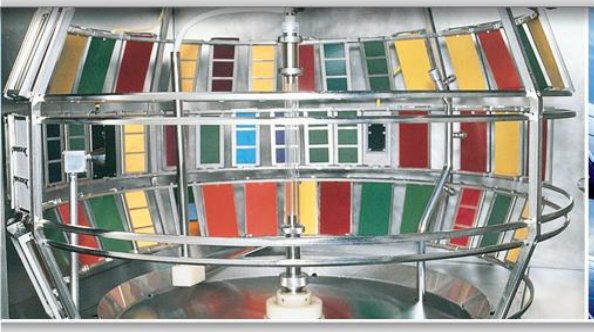
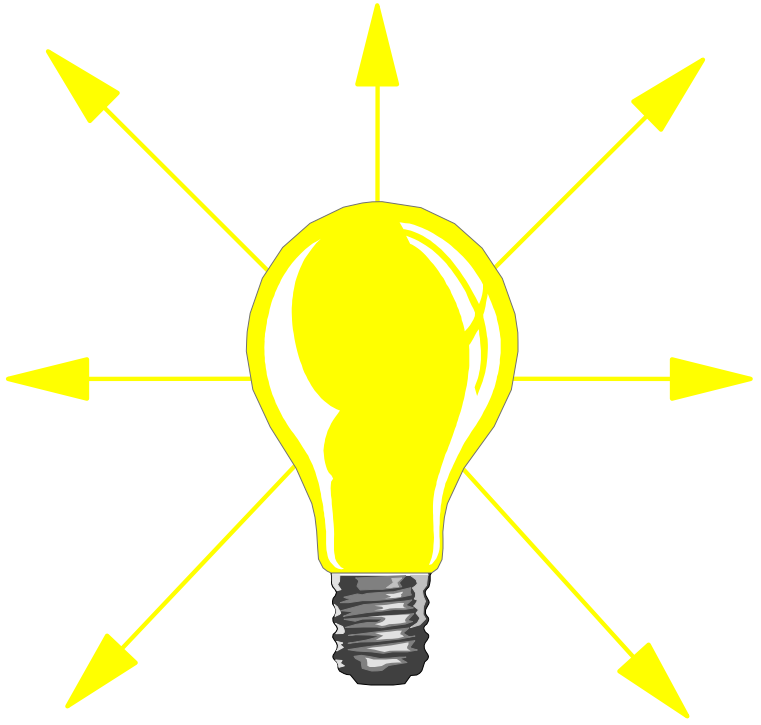


# High speed Lighting

## The Luminous Flux

Unit: Lumen (lm)

The luminous flux indicates how much light the lamp radiates in all directions.

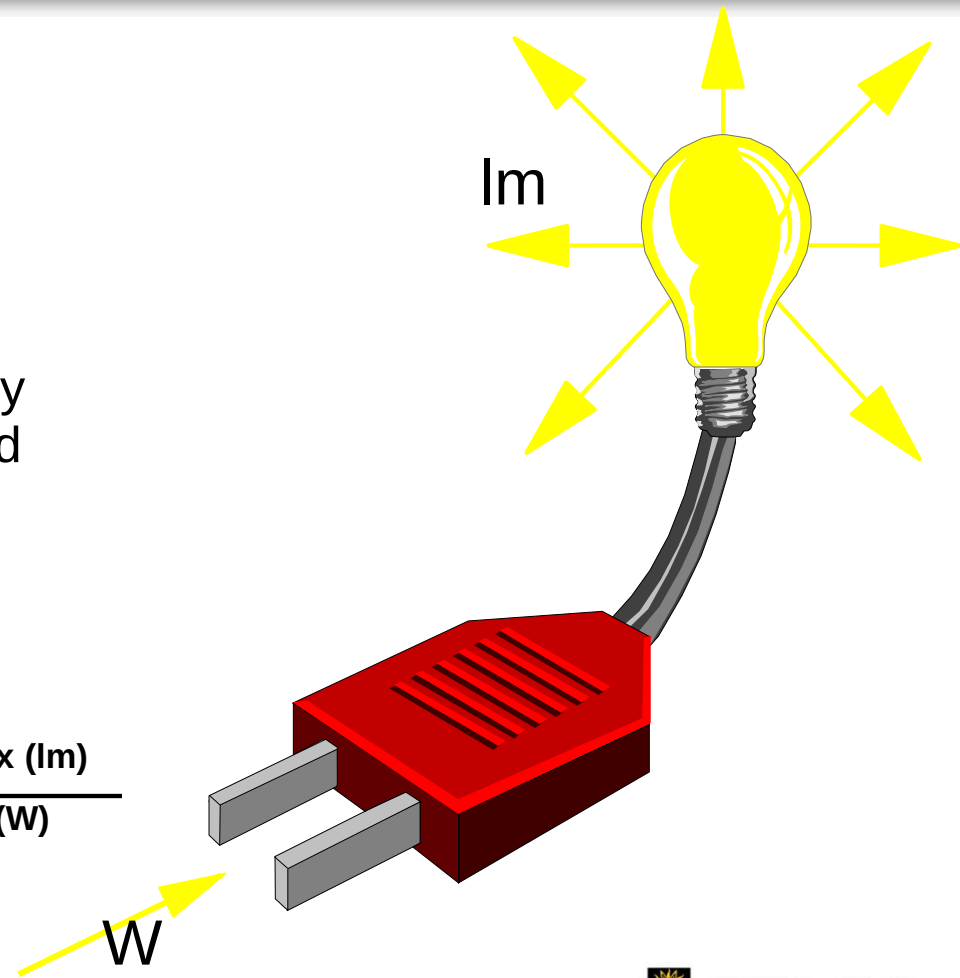


# Light theory

## The Luminous efficiency

Unit: Lumen per Watt (lm/W)

Indicates with which efficiency the input power is transformed into visible light output.




$$\text{Luminous efficiency (lm/W)} = \frac{\text{Luminous flux (lm)}}{\text{Input power (W)}}$$

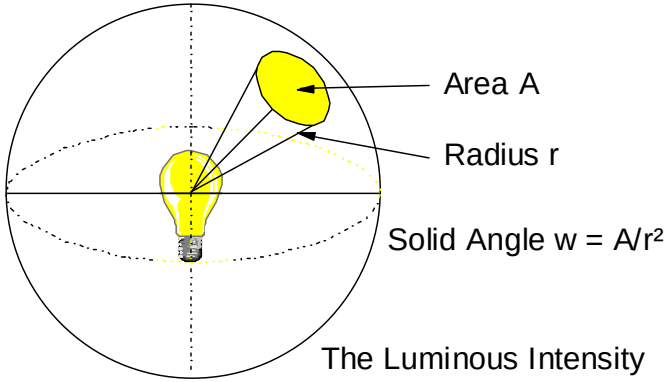
# Light theory

## The Luminous Intensity

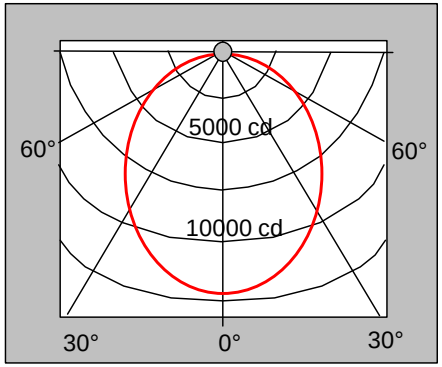
Unit: Candela (cd)

Indicates how much luminous flux is radiated by a lamp or luminary per solid angle w (Greek: omega) in a given direction.

The luminous intensity is different in the various directions of a lamp or luminary. These values are normally indicated in polar diagrams.




The Luminous Intensity



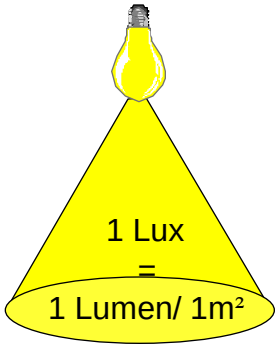

Polar Diagram

$$\text{Luminous intensity (cd)} = \frac{\text{Luminous flux in the solid angle (lm)}}{\text{Solid angle } \Omega \text{ (sr)}}$$

## The Illuminance

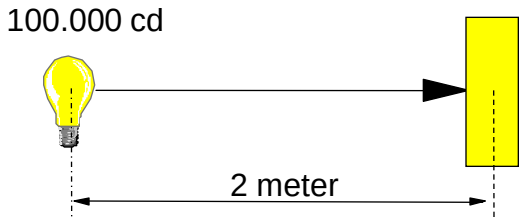
Unit : Lux (lx); Indicates how a surface is illuminated, what luminous flux reaches a unit of surface

$$\text{Illuminance (lx)} = \frac{\text{Incident luminous flux (lm)}}{\text{Illuminated area (m²)}}$$




The illuminance can be calculated if the luminous intensity and the distance of the luminary to the illuminated area is known by using the "Inverse square law"

$$\text{Illuminance (lx)} = \frac{\text{Luminous intensity (cd)}}{\text{(Distance in meters)}^2\ (\text{m}^2)}$$




$$\text{Illuminance (lx)} = \frac{100.000}{4} = 25.000 \text{ Lux}$$

Luxmeter

## The Luminance

Indicates the brightness that the human eye perceives when looking to an area emitting or receiving and reflecting light.

For areas receiving and reflecting light, the unit is:

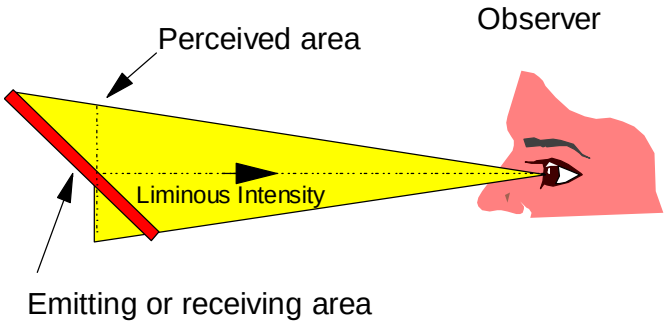
Candela per square meter (cd/m²)

For areas emitting light, the common used unit is:

Candela per square centimeter (cd/cm²)

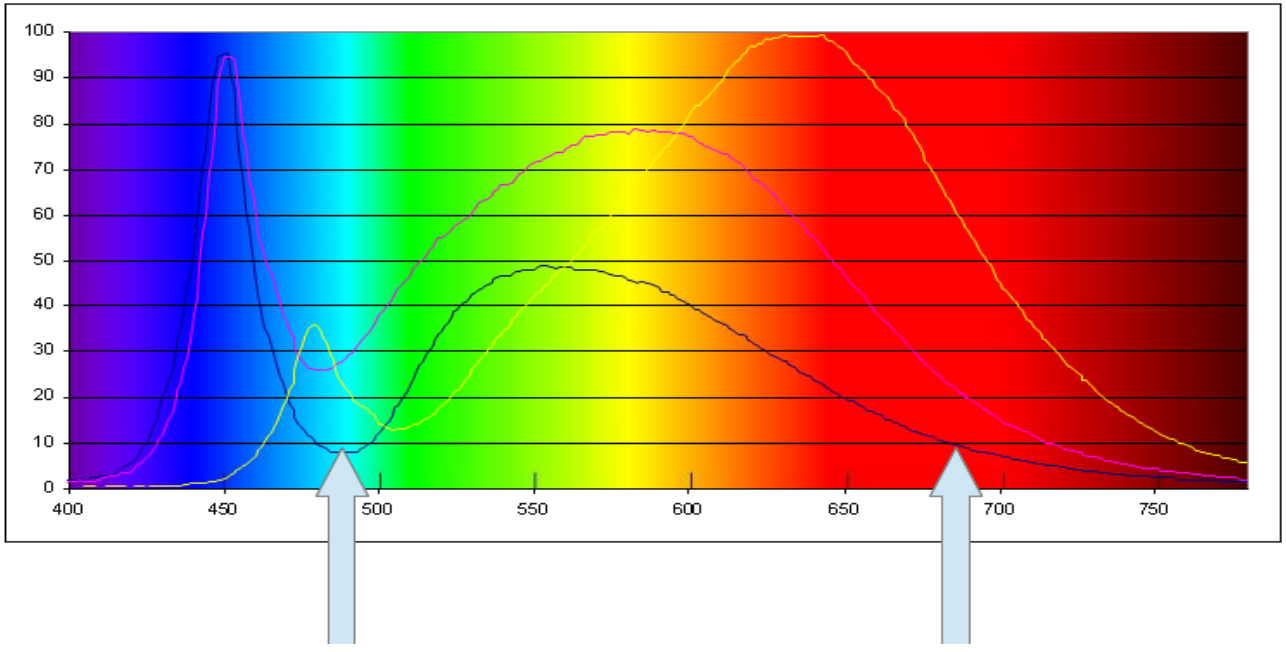
The use of cd/m² would result in very high values.

$$\textbf{Luminance (cd/cm}^2\textbf{)} = \frac{\textbf{Luminous intensity (cd)}}{\textbf{Perceived Area (cm}^2\textbf{)}}$$



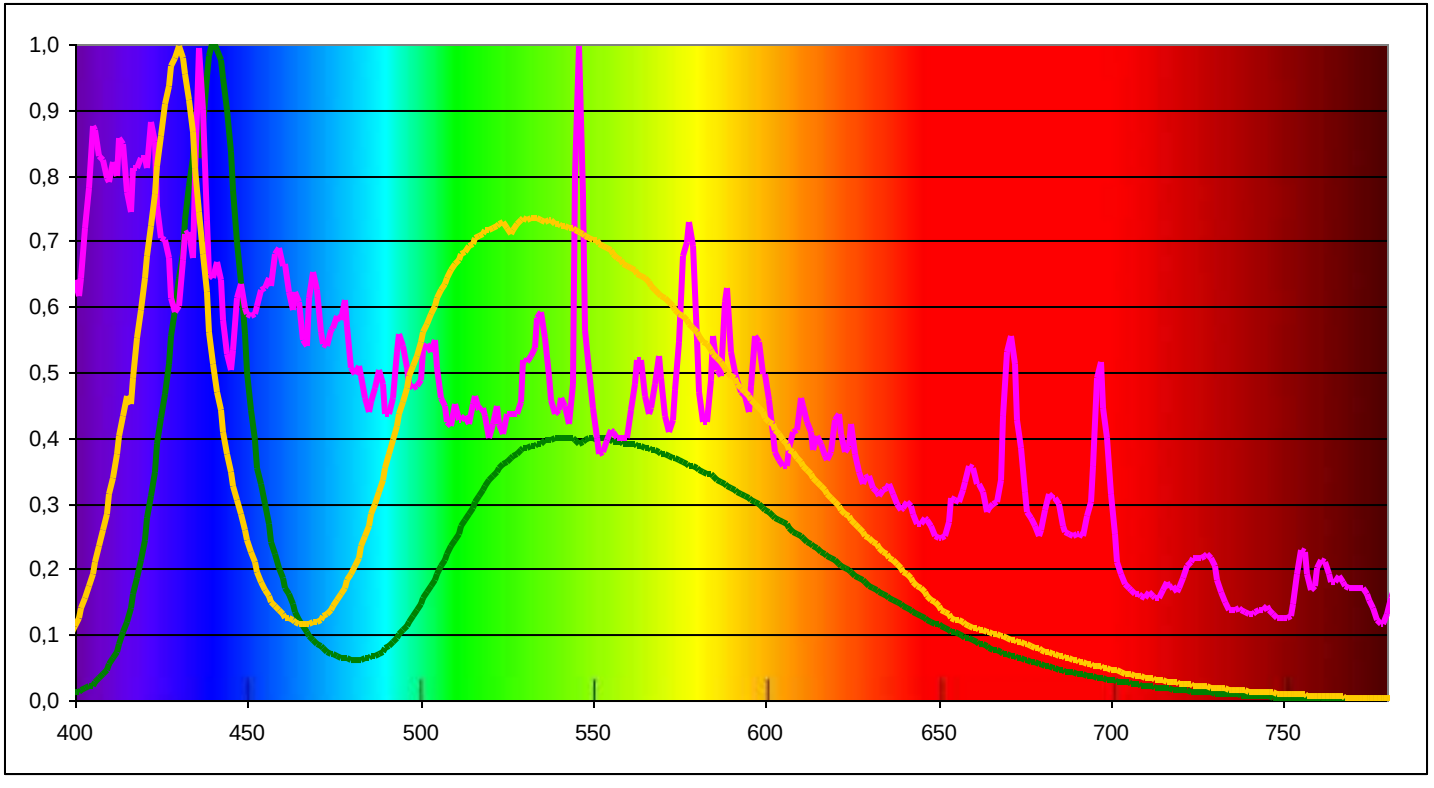

Spotmeter

# High speed Lighting




Various White LEDs / Rel; irradiance

# LED and HMI




Normalized to peak

HMI
M=LED 1000
LED 950W

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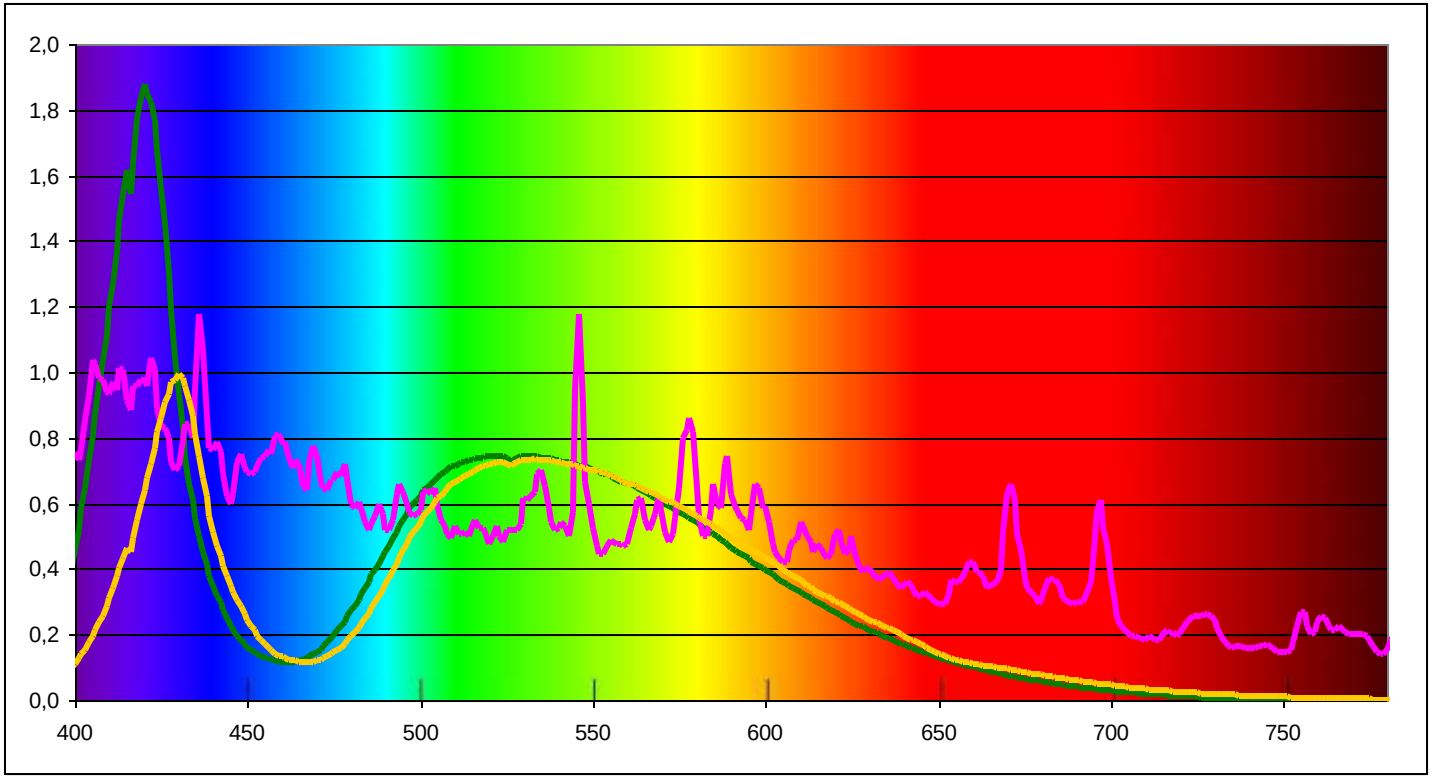
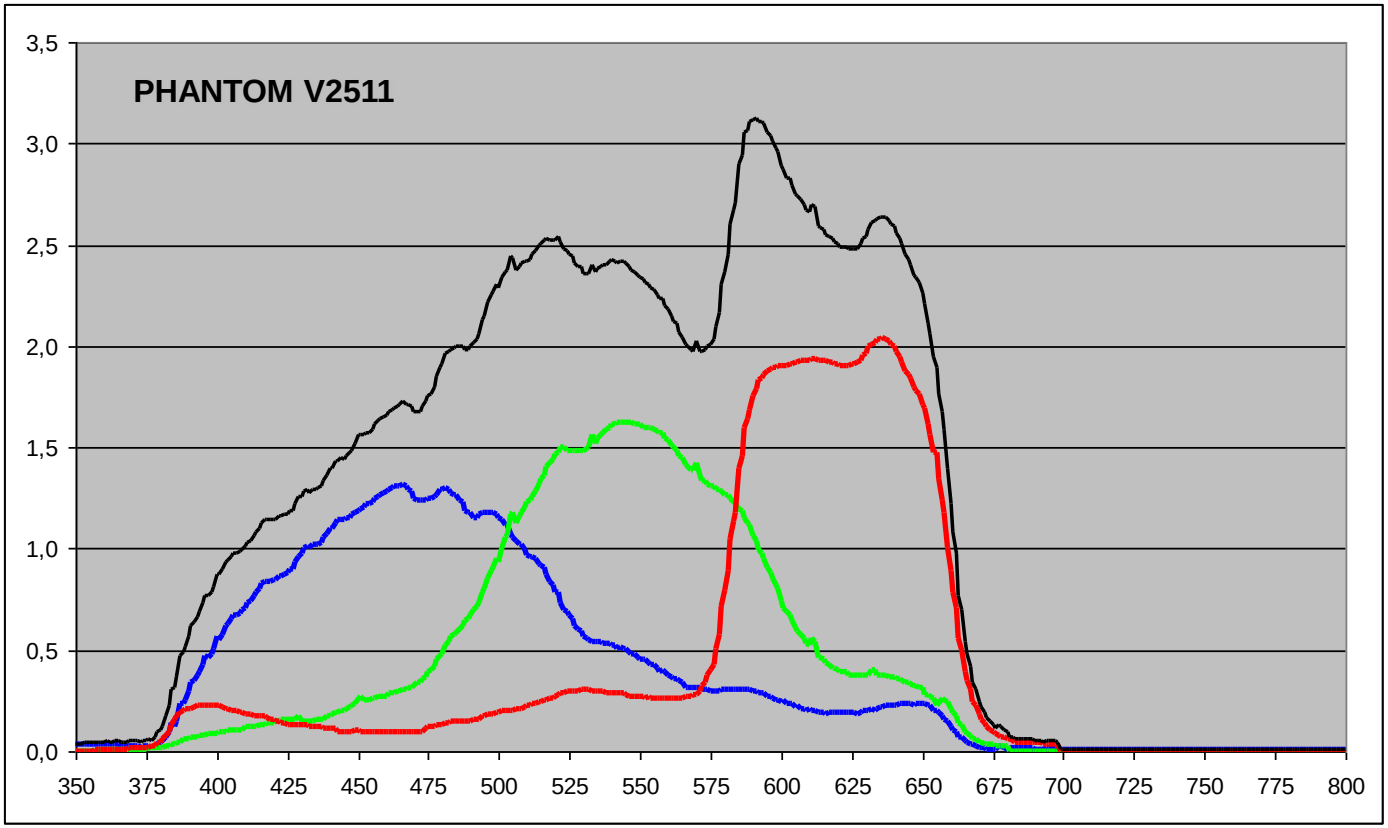
# LED and HMI / E(λ)



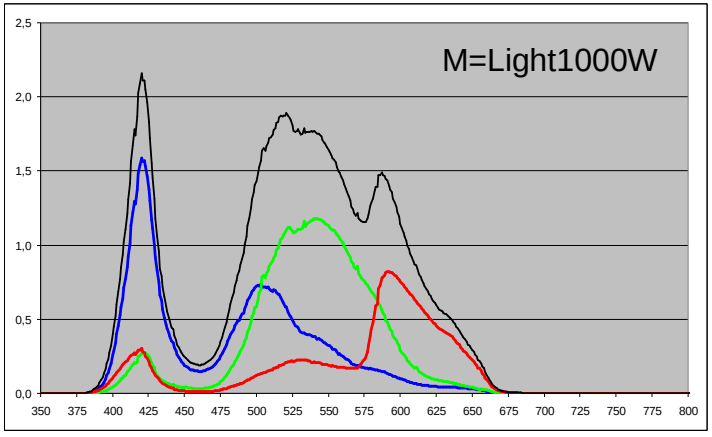

Normalized to same Lux value

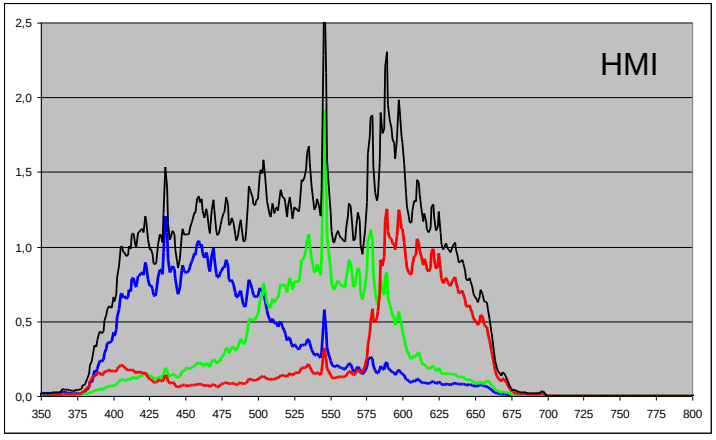
- HMI
- M=LED 1000
- LED 950W

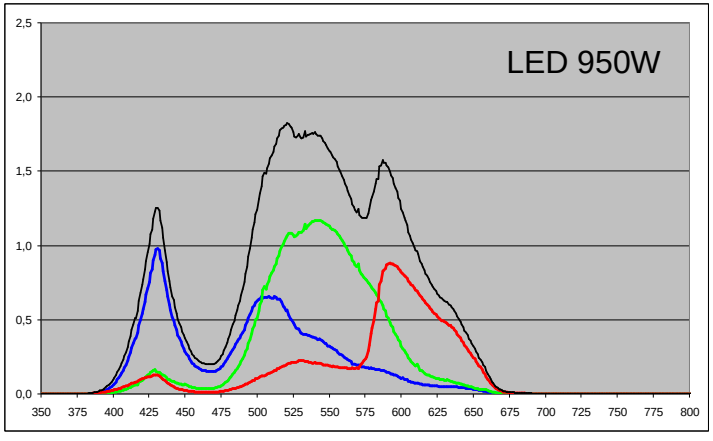
# Camera sensor efficiency / CS(λ)



# Camera sensor efficiency / Light source



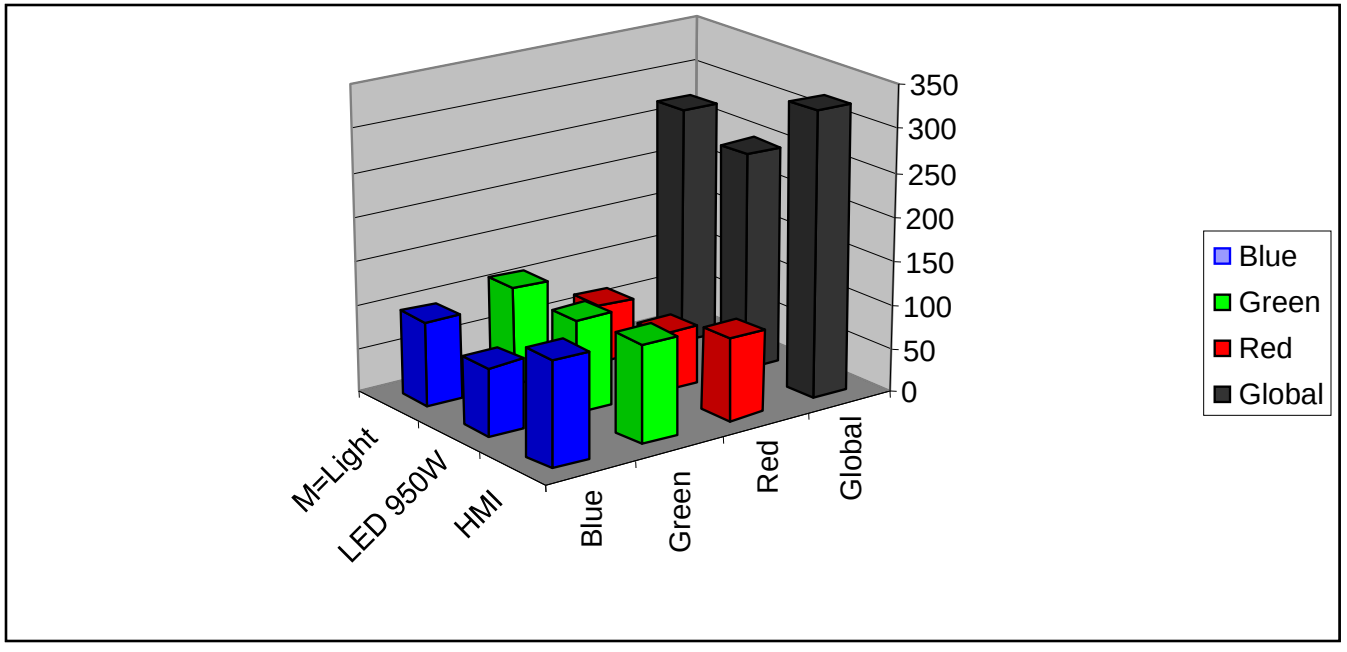

$\Sigma$ CS(λ) x E(λ)

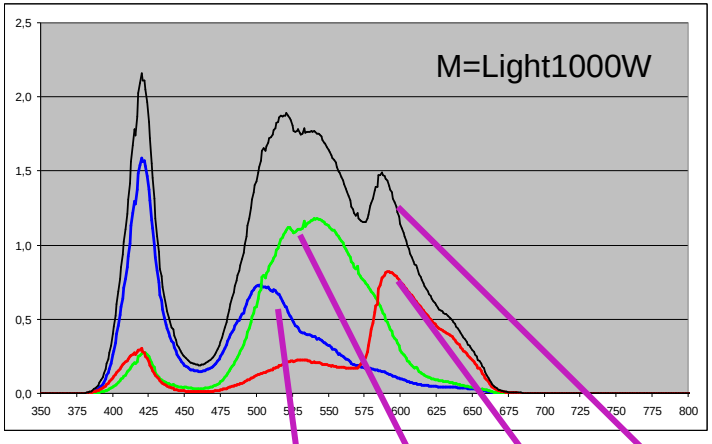
CS(λ)=Camera sensitivity

E(λ)=Irradiance

# Camera sensor efficiency / Light source

| Efficiency | Blue | Green | Red | Global |
|---|---|---|---|---|
| M=Light | 96,2 | 110,2 | 66,3 | 272,7 |
| LED 950W | 77,4 | 106,1 | 65,8 | 249,3 |
| HMI | 119,9 | 111,8 | 94,0 | 325,6 |



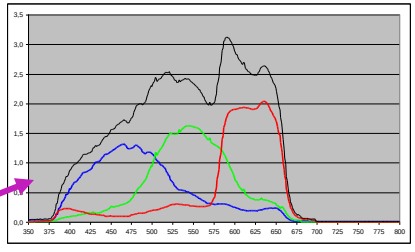


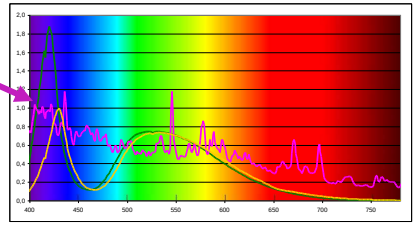

Arbitrary / Relative unit

$\sum$ **CS(λ) x E(λ)**

CS(λ)=Camera sensitivity

E(λ)=Irradiance



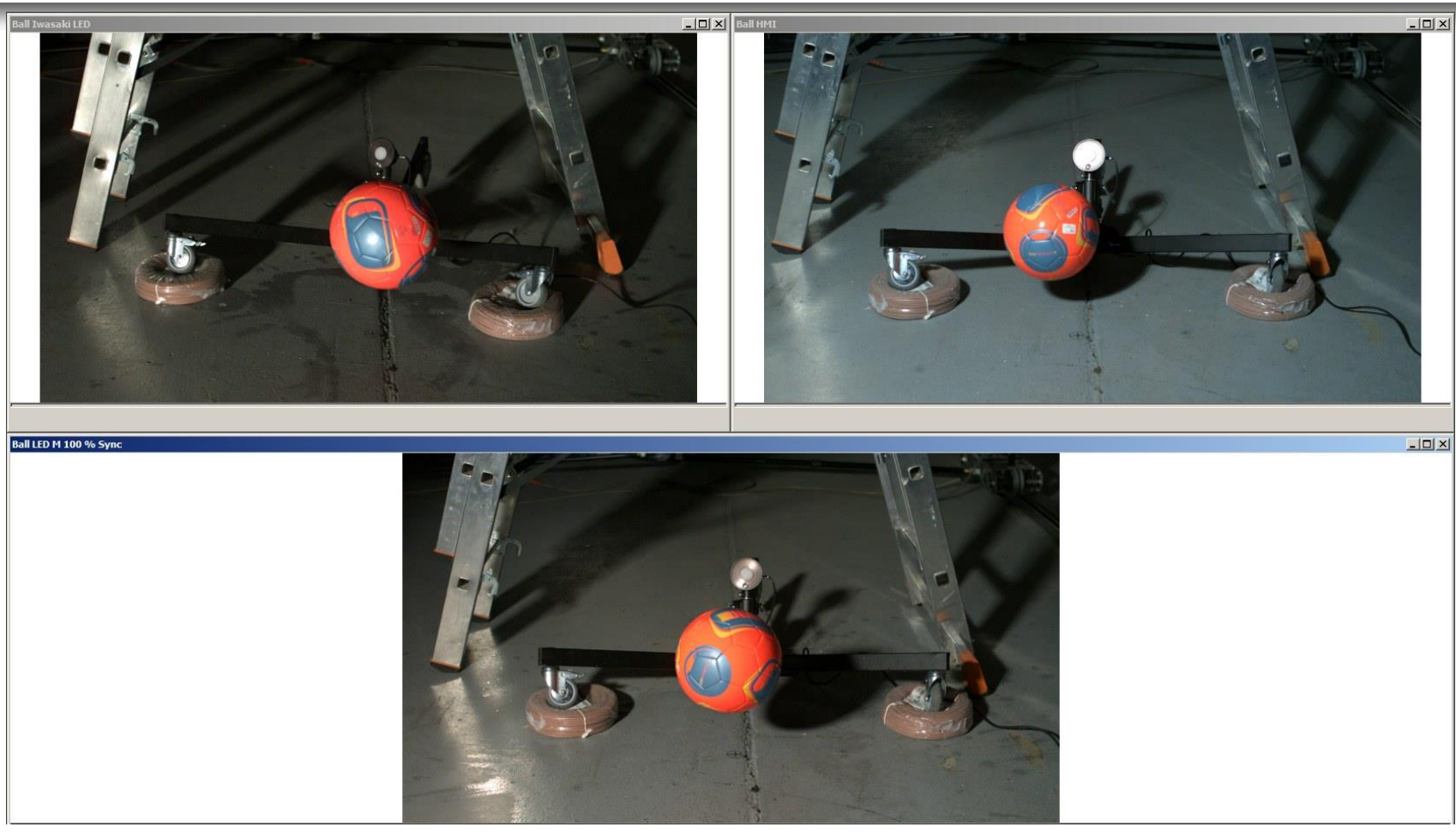


| Efficiency | Blue | Green | Red | Global |
|---|---|---|---|---|
| M=Light | 96,2 | 110,2 | 66,3 | 272,7 |
| LED 950W | 77,4 | 106,1 | 65,8 | 249,3 |
| HMI | 119,9 | 111,8 | 94,0 | 325,6 |

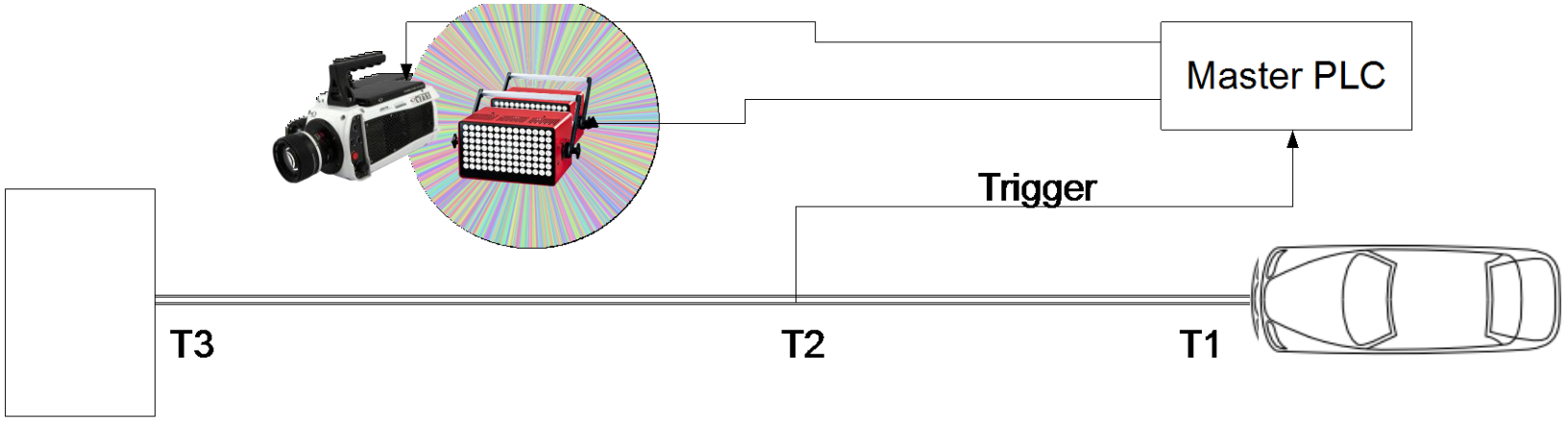
# Camera sensor efficiency / Light source

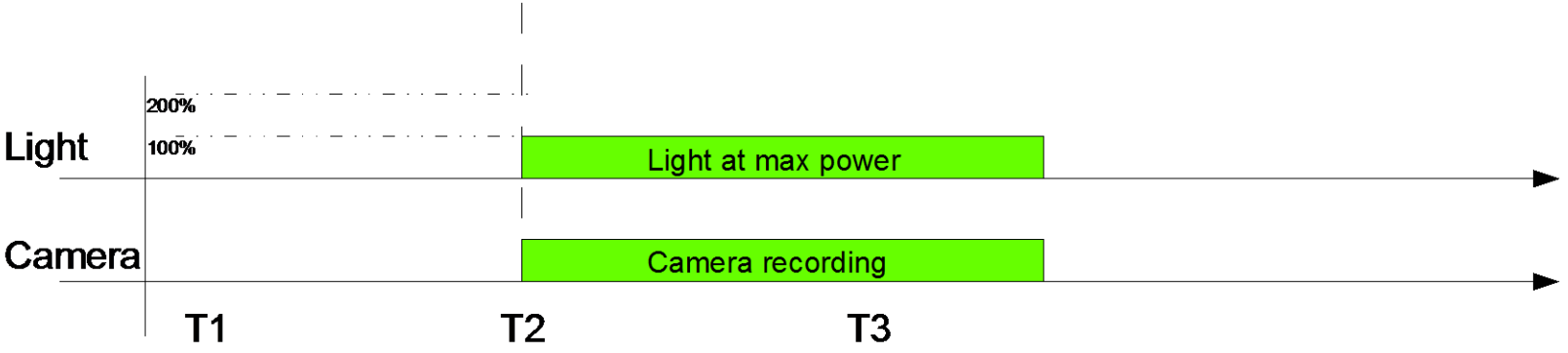


# Camera sensor efficiency / Light source

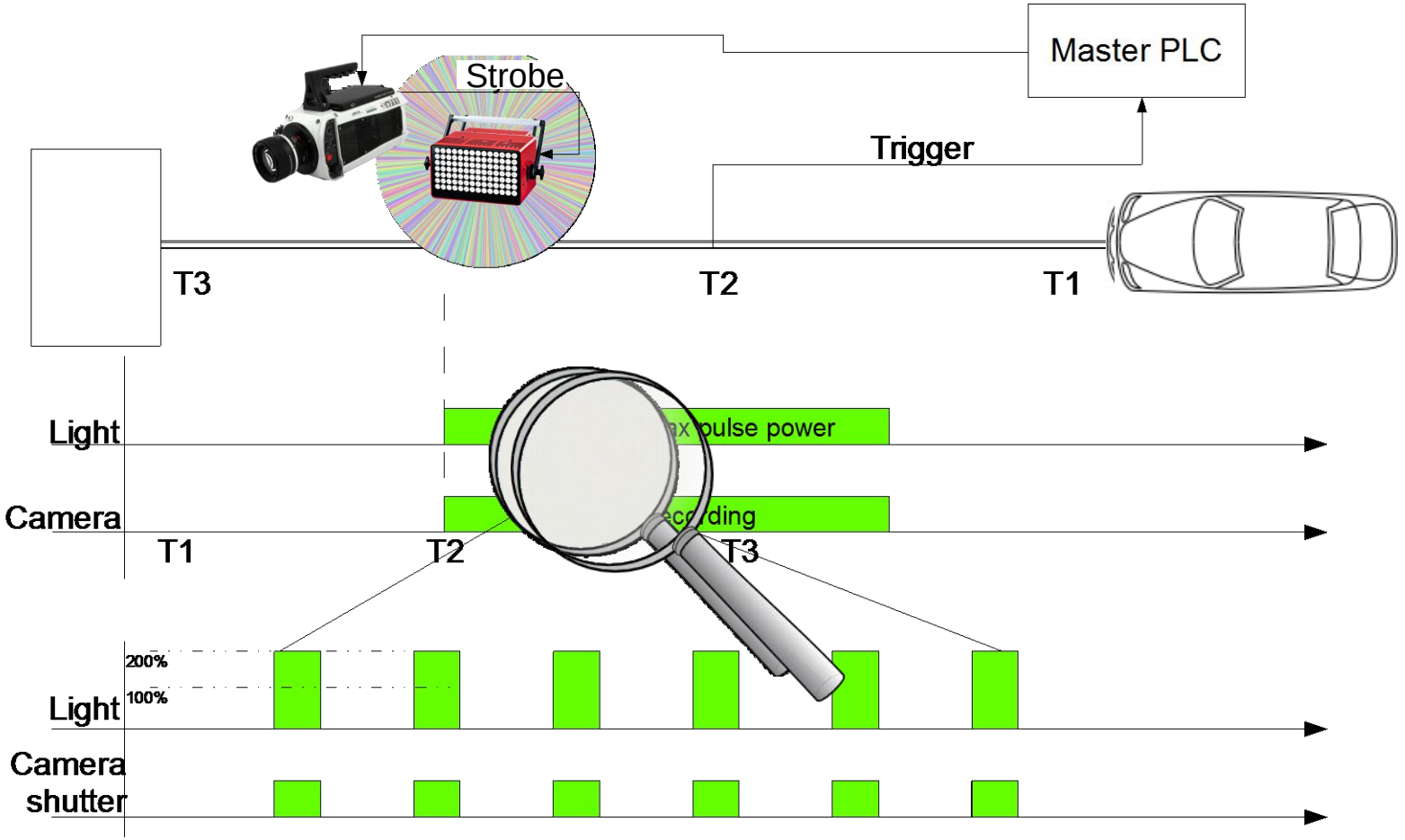


# Event synchronization

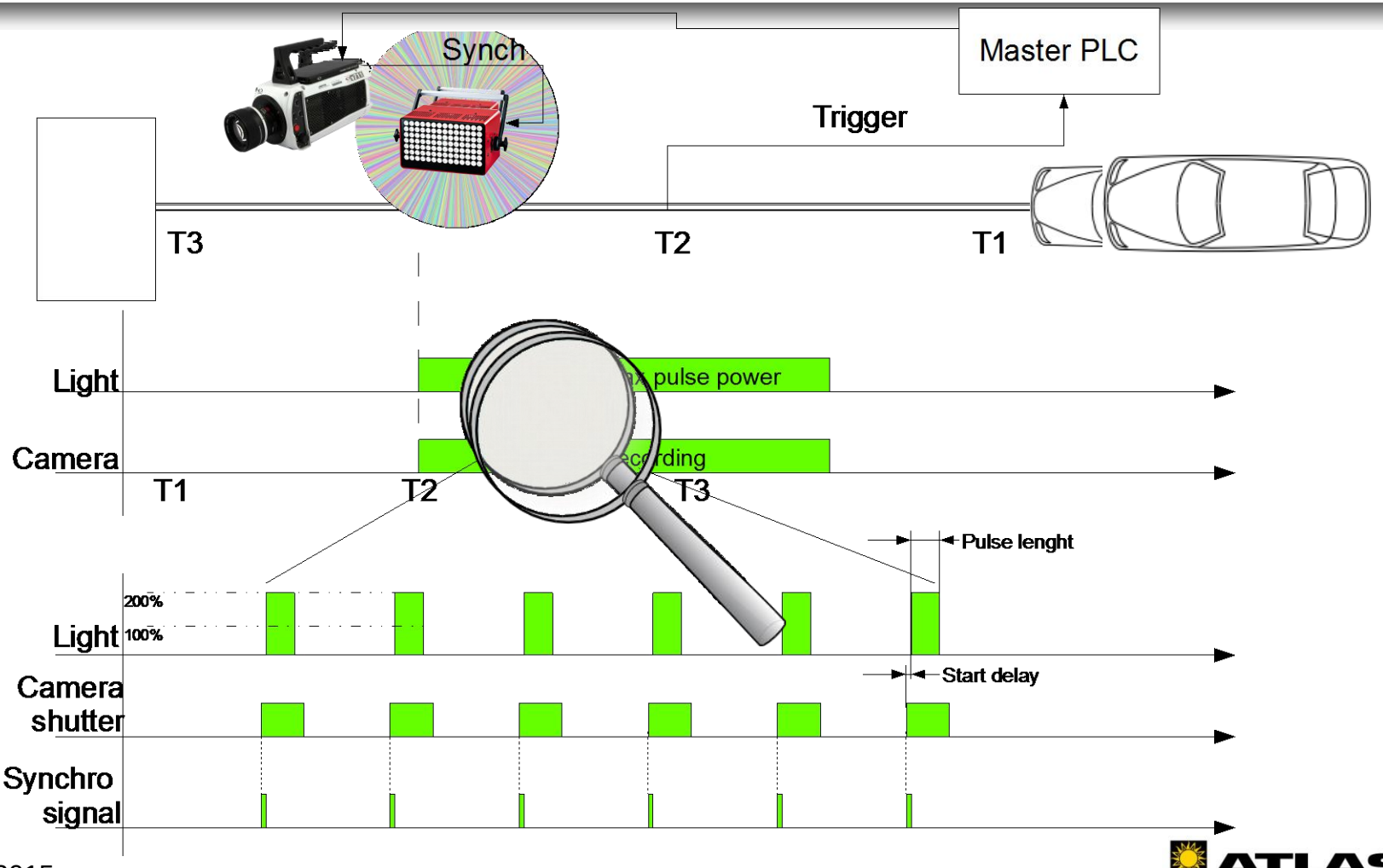


# Camera shutter Strobe mode

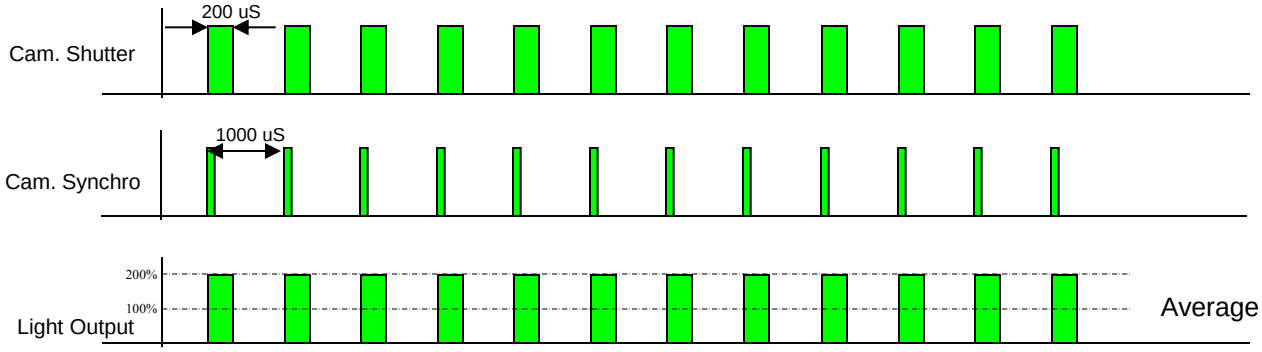


# Camera shutter synchronization mode



# Camera shutter synchronization mode (Setup)

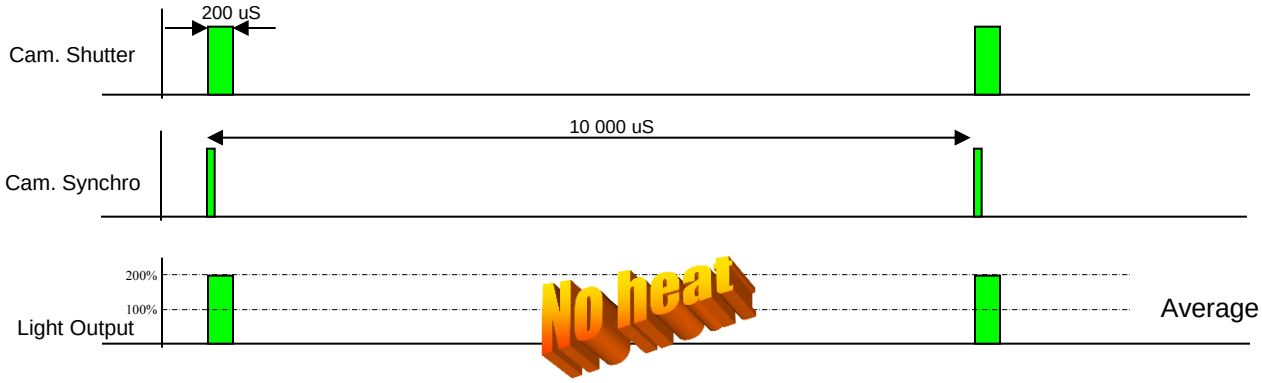
**Real test : 1000 FPS / Shutter time 200uS / Static luminaries M=Light**




Average power =500W / M=LED

Peak = 2500W

Setup : 100 FPS / Shutter time 200uS



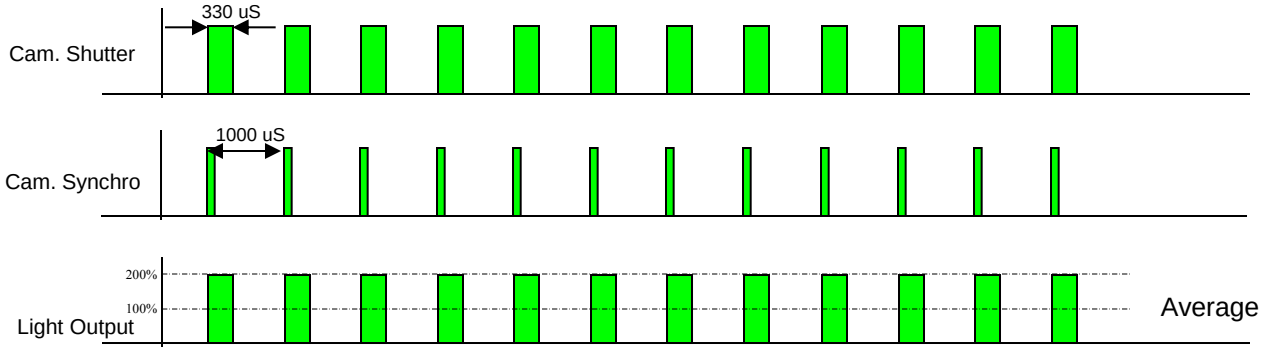

Average power = 50W / M=LED

Peak = 2500W

Same image quality

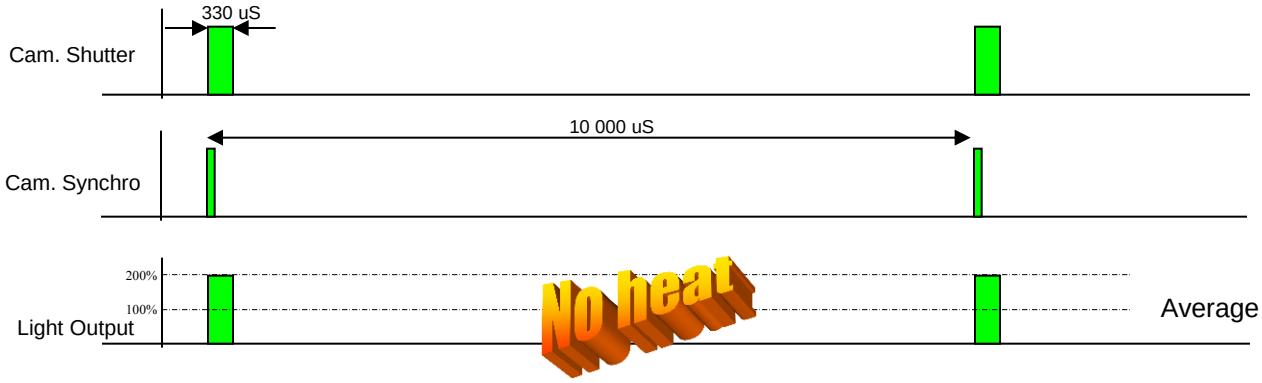
# Camera shutter synchronization mode (Setup)

**Real test : 1000 FPS / Shutter time 330uS / On board luminaries**




Average power = 40W / head
Peak = 120W

**Setup : 100 FPS / Shutter time 330uS**



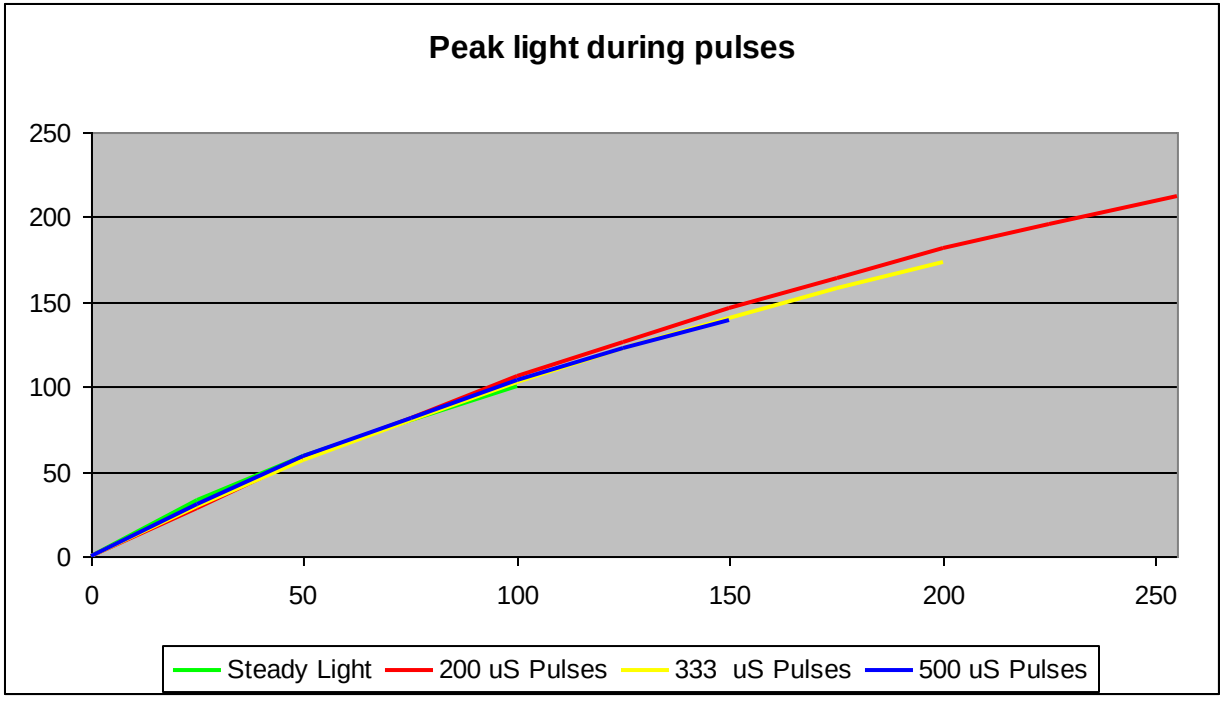

Average power = 4W / Head
Peak = 120W

Same image quality

# Light output vs Electrical power in pulsed mode

Test at 1000 fps

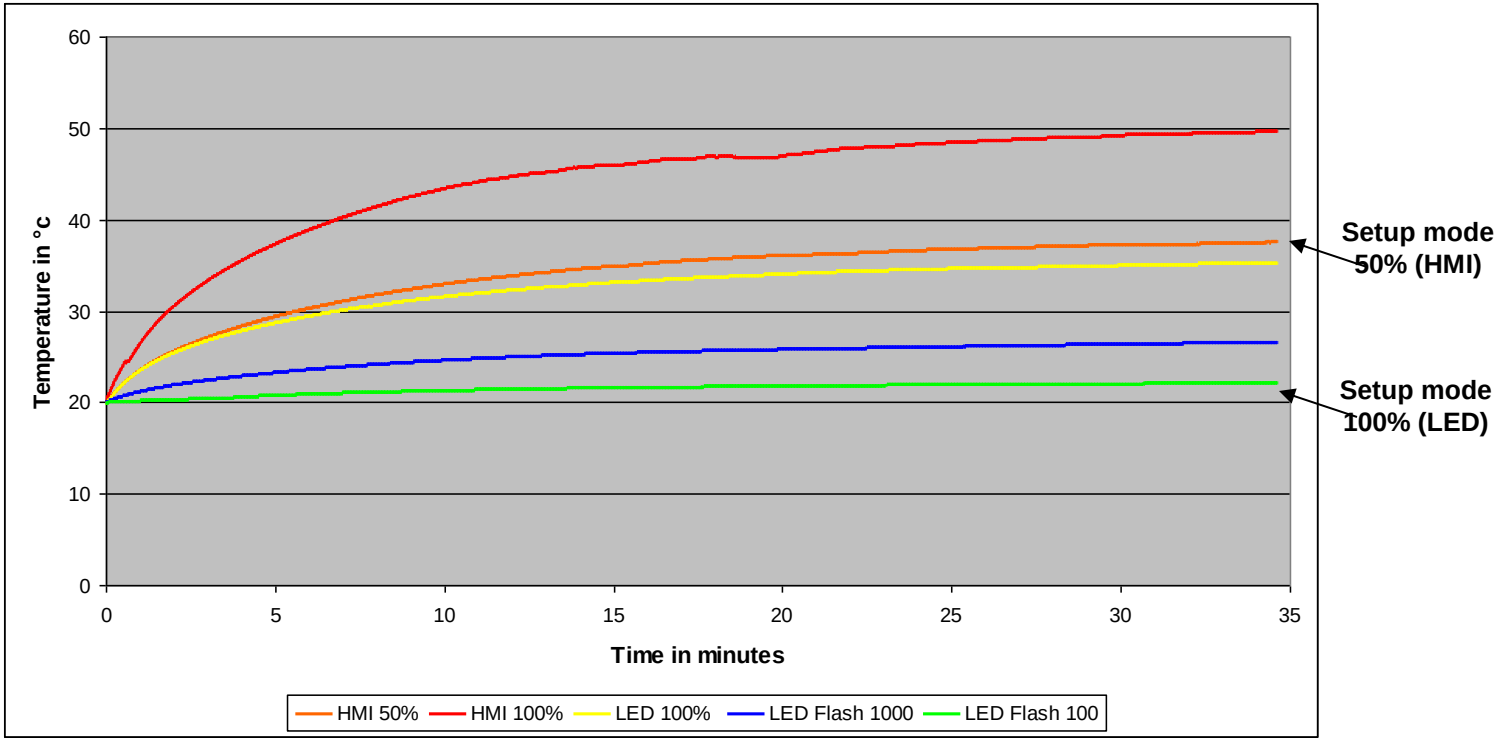
200uS = 1/5 of the cycle / 333uS= 1/3 of the cycle / 500uS= 1/2 of the cycle




Values are in relative unit (ref = 100% steady light)

# Temperature on exposed samples

Black body exposed at 100kLux @ 100%



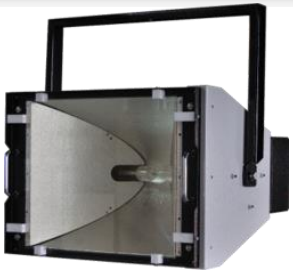
# LED Brand

M=LIGHT 1000W LED:

HIGH-G LED Onboard crash proof

All LED luminaries are with flash synchro functions

# Complete range



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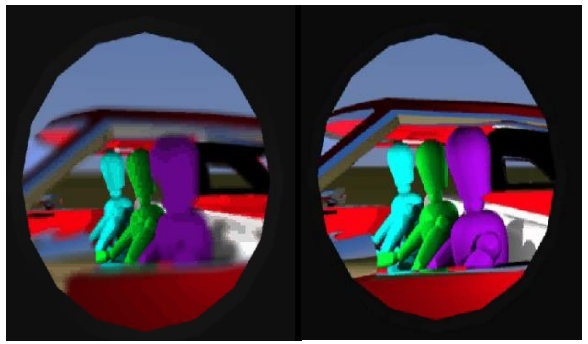
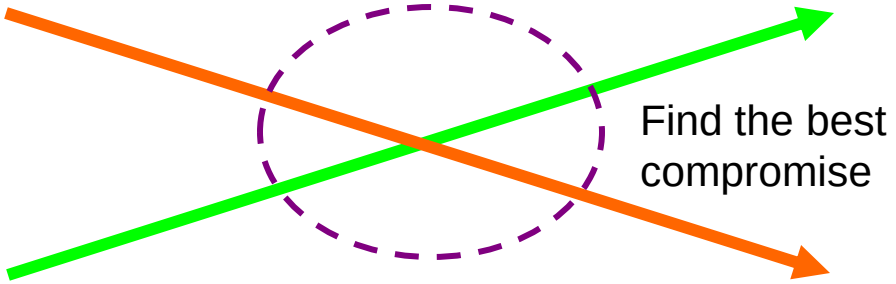
## Camera parameters for a good lighting

| | |
|---|---|
| **Objective quality** | **Need less light with better objective** |
| **CCD sensitivity** | **Need less light with better sensitivity (ISO equ. Number)** |
| **ISO adjustments** | **Need less light with greater ISO values but electrical noise induced.** |
| **F-Stop** | **Bigger F-stop, better depth of view**<br>**Smaller F-stop, less light needed**<br>**1xF-stop increase = twice more light**<br>**2xF-stop increase = 4 x more light** |
| **Shutter speed** | **Smaller time, sharper images**<br>**Longer time, less light needed** |



# Lighting quality

Photographs want more light for more accurate assessments




Economical constraints to limit prices

# Glossary

Lux : Quantity of light achieving a surface, and related to the human vision sensitivity.
Note : Using different light sources with the same Lux values can lead to variable pictures quality with a given camera.
This value should not directly be used to evaluate the quality of picture recording.

LED efficiency : Quantity of usable light emitted by the LED in function of the input power (unit : lumen / W)
Note : The Efficiency of a LED is highly dependent of the LED chip temperature. Without cooling, the efficiency is decreasing very fast.

Flicker : Negative effects on pictures (some pictures are underexposed) due to an instability of the light source.
Note : The flicker is only important in continuous mode and not in pulsed mode.

Continuous mode : The LEDs are powered with a constant DC current

Flash or pulse mode : The LEDs are powered with a square wave current and must be synchronized with camera frame rate

# Glossary

Synchro signal : Electrical pulse (very short time) that starts the light pulse on the LED. The lenght of this pulse must be programmed on the LED luminary. The electrical pulse starts usually at the same time as the camera shutter opening.

Strobe signal : Electrical signal generated during the camera shutter openning. The light on the LED luminary is on as long as the electrical signal is active.

LED Power : Max LED power given by the chip manufacturer in continuous mode lighting (for a period of time)

Pulse power : Max power allowed during a very short period of time (during camera open shutter time)
Note : Pulse power is depending on the luminary construction. Some LEDs can have up to 250% of the nominal power

Setup max power : Max power during the camera setup time (Typically several minutes) without damaging the LED or reducing efficiency. The setup time can be in continuous of pulsed mode.

Feed in power : Continuous electrical power needed to run the LEDs  luminaries.
Note : A luminary working in continuous mode at 1000W will need a feed in power of 1000W. A luminary working in pulsed mode at 2000W will also need a feed in power of 1000W