LED Technology for plants lighting

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INTRODUCTION

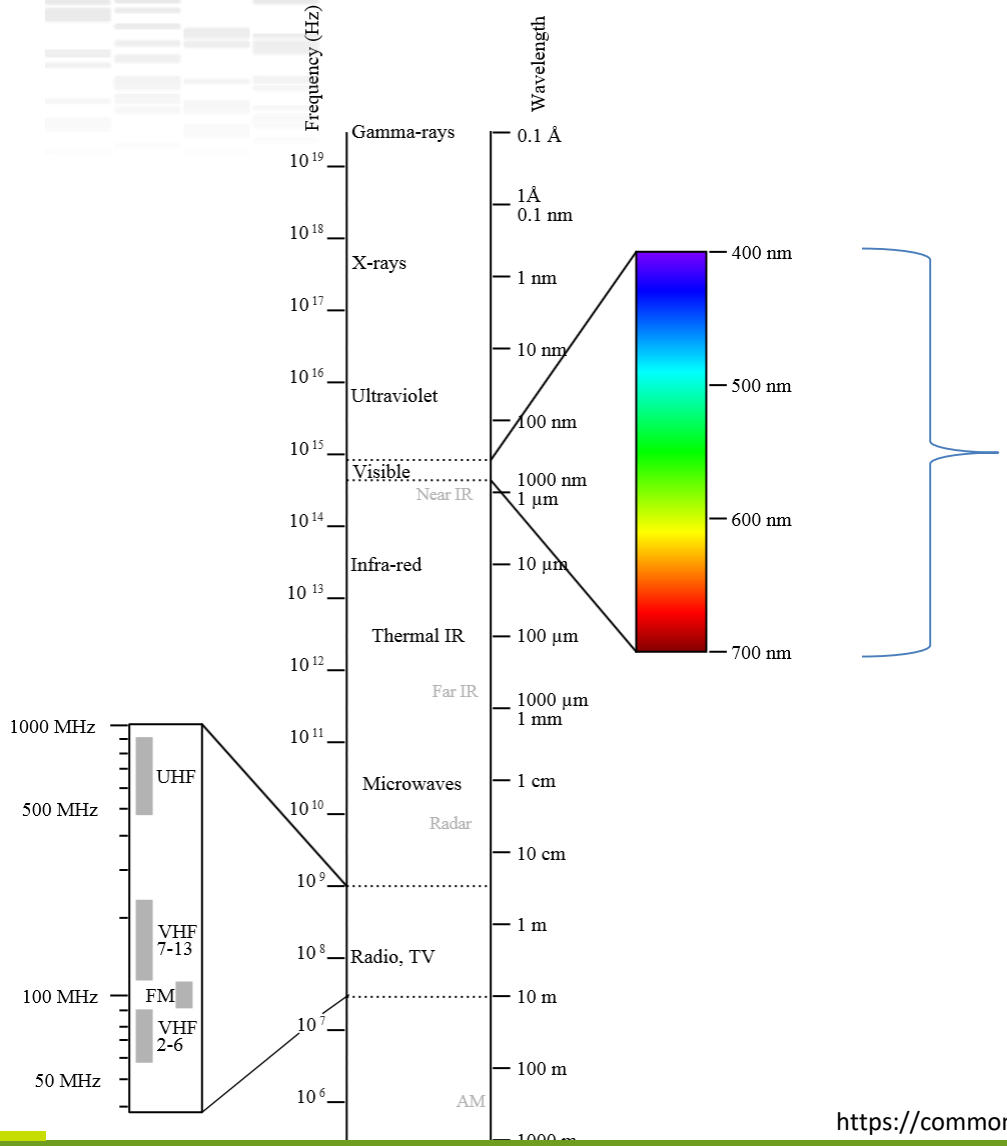
- **1907** : discovery of the phenomenon of electroluminescence by H. J. Round (**S**olid **S**tate **L**ighting)
- **1927** : creation of the first LED by O. Losev
- **1962** : first red light emitting was created by Nick Holonyak Jr. (Hewlett Packard)
- **1970 - 1980 :** LED technology used for traffic light, signalling, decoration, with only few colours (Red, Orange/ Yellow/ Green)
- **1990 - 2000** : creation of high power BLUE LED followed by WHITE LEDs by professor Nakamura (Nichia)
- **Since 2000 :** luminous efficiency and technology have progressed so much that LEDs are becoming sources of light in their own right

In the last 30 years, every 18-24 months, the luminous flux doubled!

SUMMARY

_01
Solar Radiation

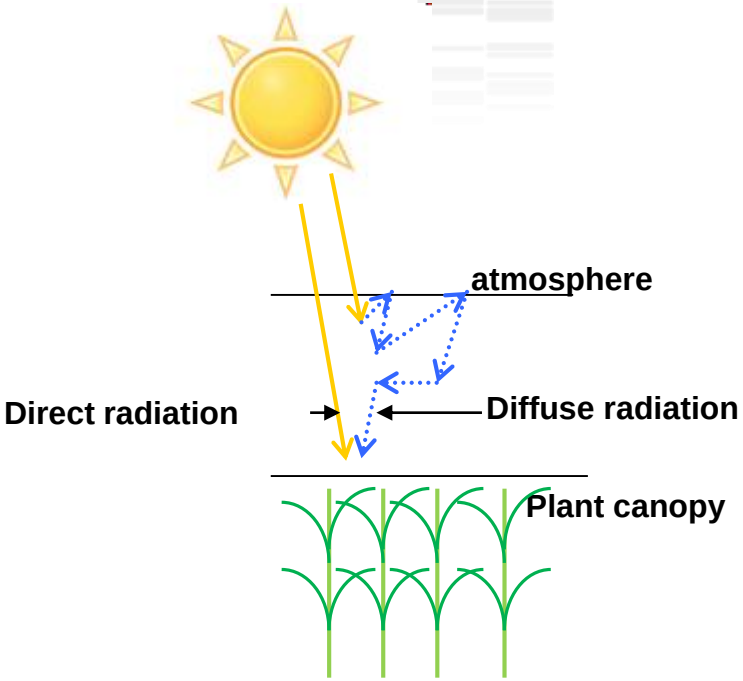
Solar radiation and electromagnetic spectrum

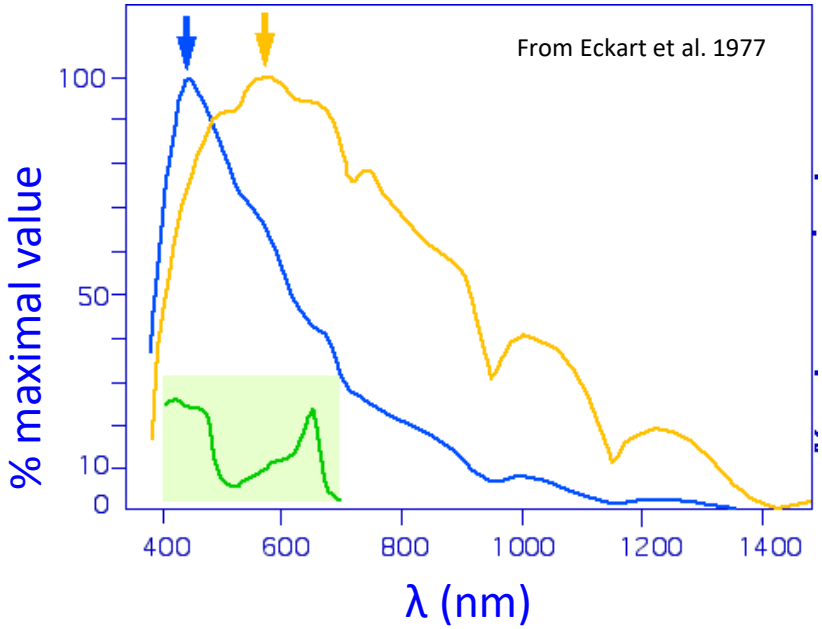


Plant and Human perception

https://commons.wikimedia.org/w/index.php?curid=22428451

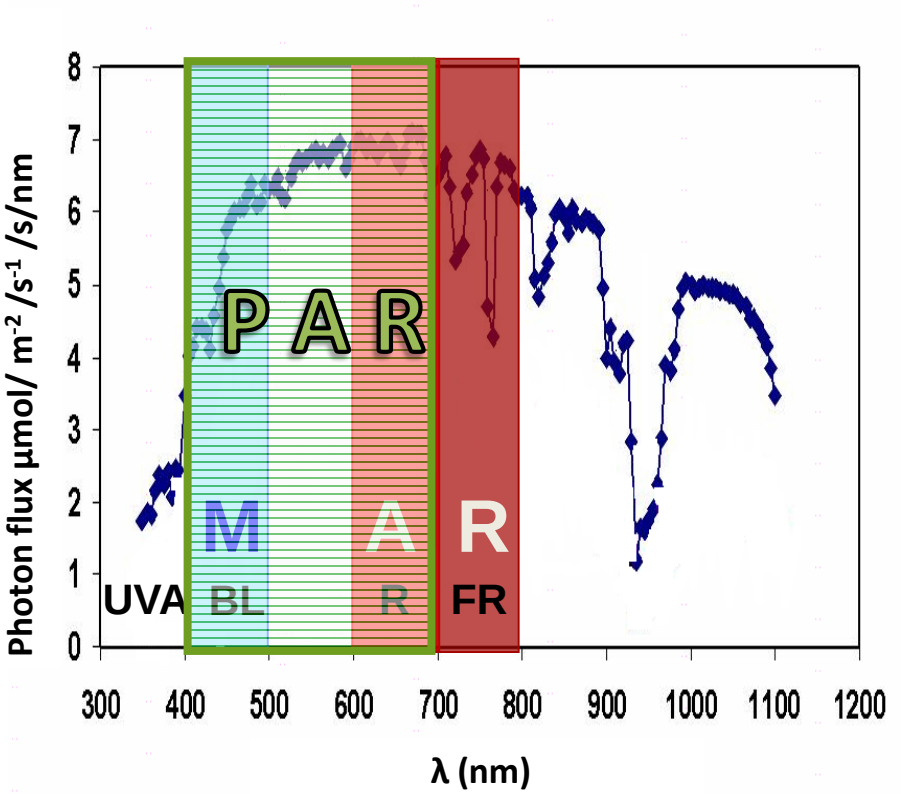
Solar radiation and electromagnetic spectrum





Spectral distribution of solar energy

Solar radiation and electromagnetic spectrum



PAR: Photosynthetically Active Radiation it as

MAR: Morphologically Active Radiation

↓

is a spectral domain not a flux!

PPFD: Photosynthetic Photon Flux Density ($\mu mol\ m^{-2}\ s^{-1}$)

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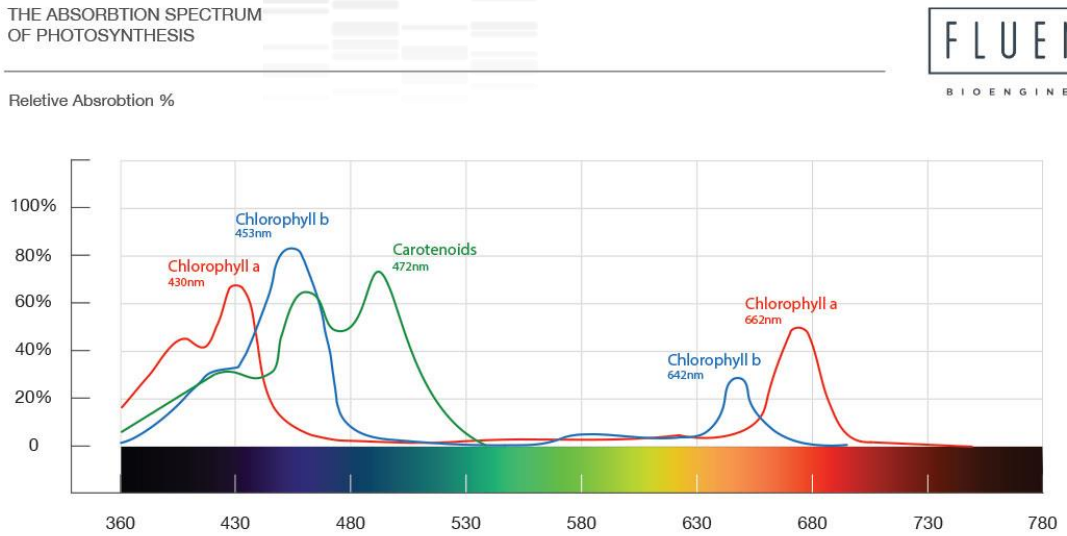
is a quantitative variable useful in plant biology

_02

Light driven biological processes

Light as source of energy for growth processes

Photosynthesis

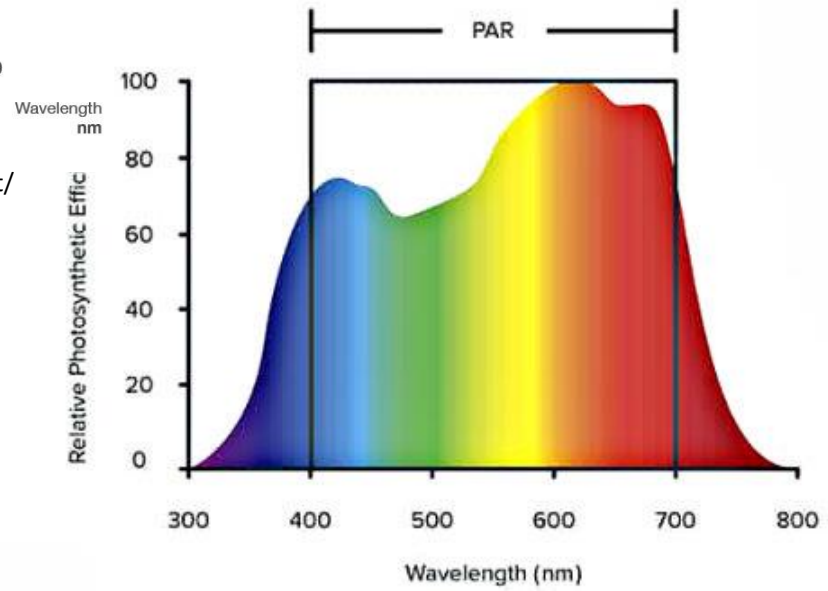


Light is absorbed by different photosynthetic pigments

Source: https://fluence.science/broad-spectrum-vs-narrow-spectrum-rediscovering-white-light/

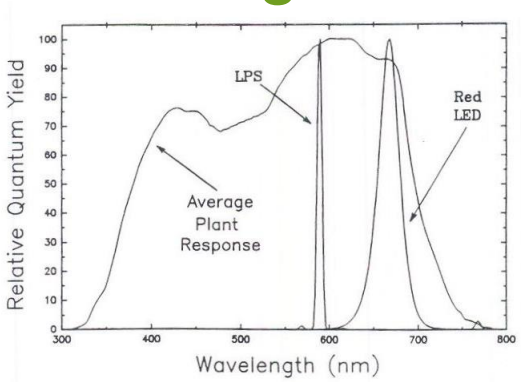
But absorption does not mean action !

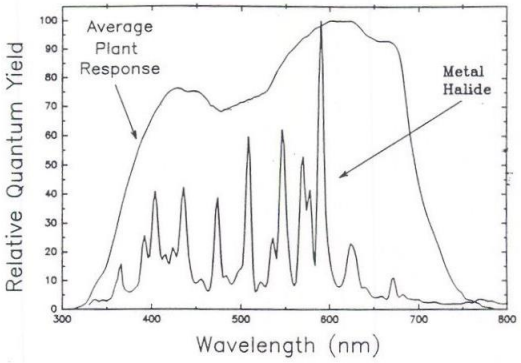
Photosynthetic efficiency differ within PAR domain

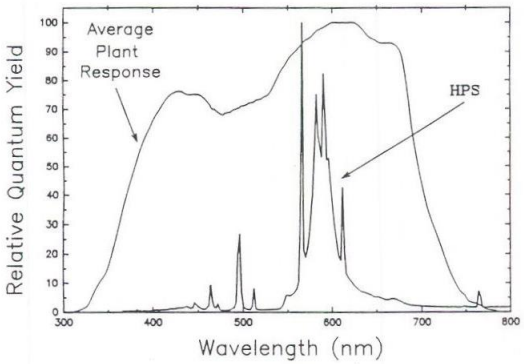


Source: https://fluence.science/science/photosynthesis-guide/

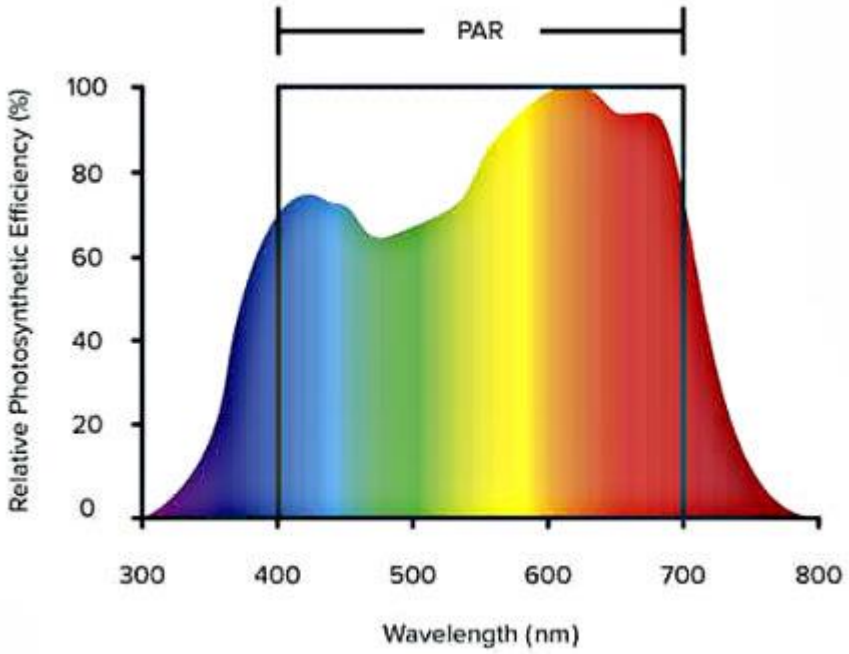
Light as source of energy for growth processes







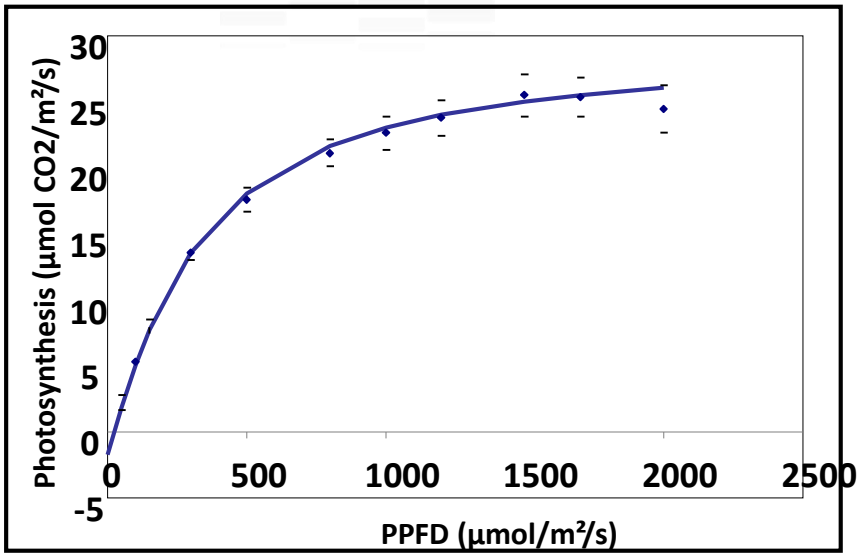
The spectral composition of artificial sources is of importance for photosynthetic efficiency



Source: https://fluence.science/science/photosynthesis-guide/

Light as source of energy for growth processes

Photosynthesis

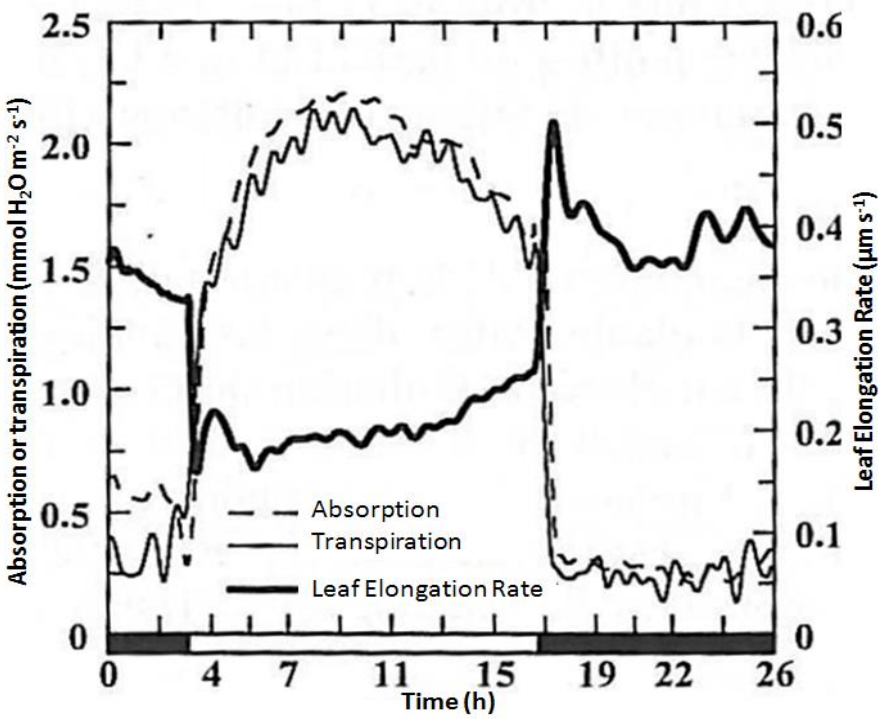


Non linear relationship between light quantity and photosynthesis.

Intensity of photosynthesis determines long term growth capacity

Light as source of energy for growth processes

Transpiration and Elongation



From Parrish and Wolf 1983

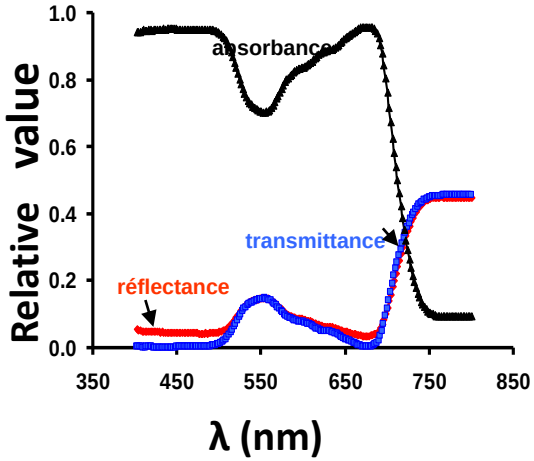
Light (IR domain) has also an effect on plant organ temperature

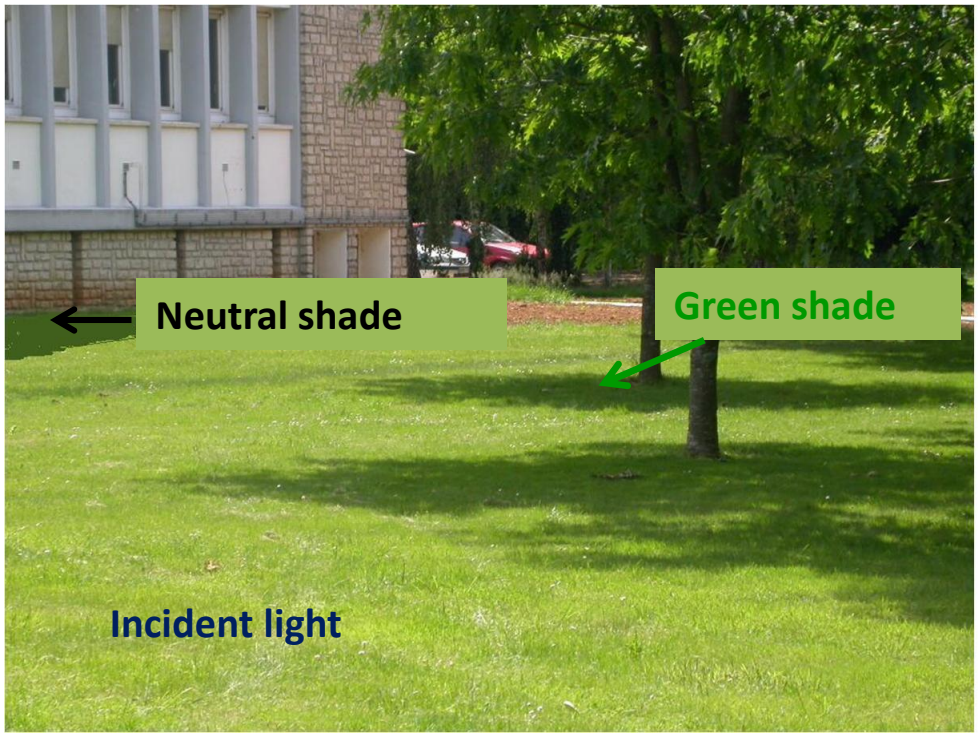
Effects on transpiration and elongation processes

Light as source of information

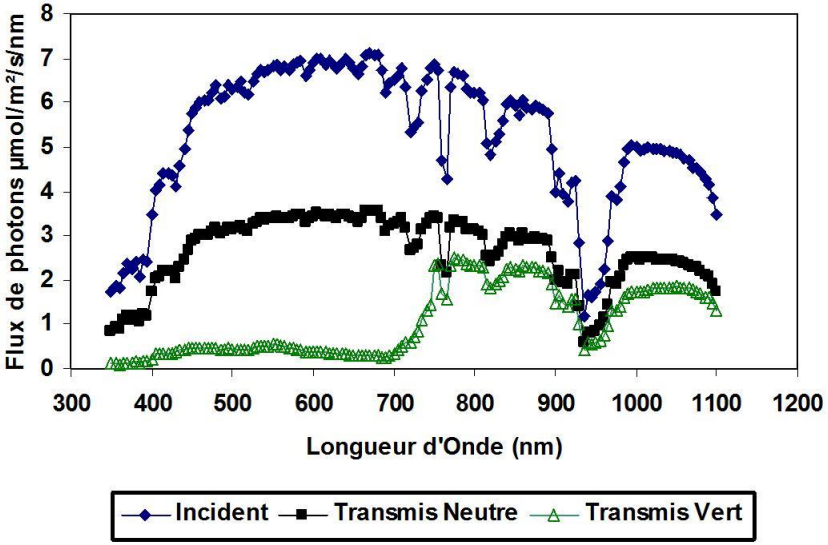
Via Changes in light spectral composition

- Light interception
- Optical properties of plant organs





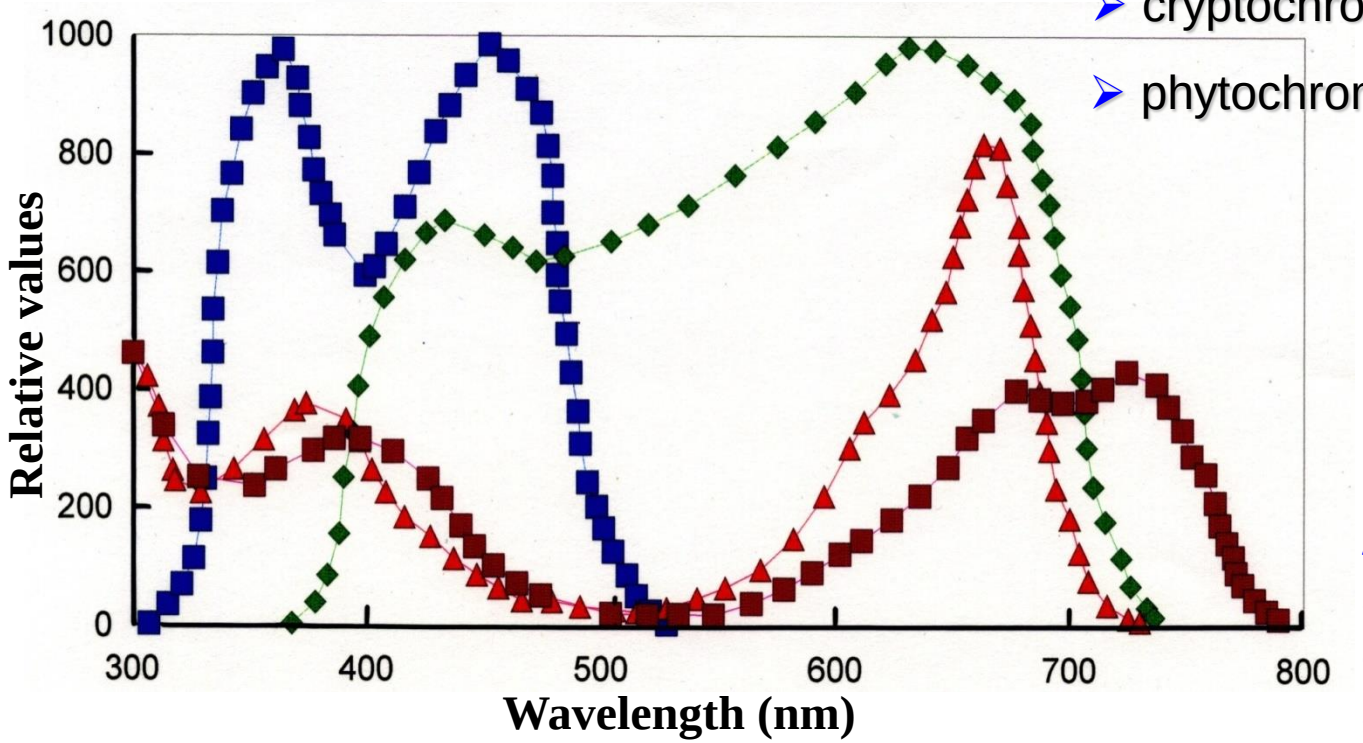
Records from Li-COR 1800 spectroradiometer



Light as source of information

Specific Photoreceptors

- cryptochromes for UVA-BL
- phytochromes for Red/Far red



Anticipation and/or adaption to light competition (shade avoidance responses)

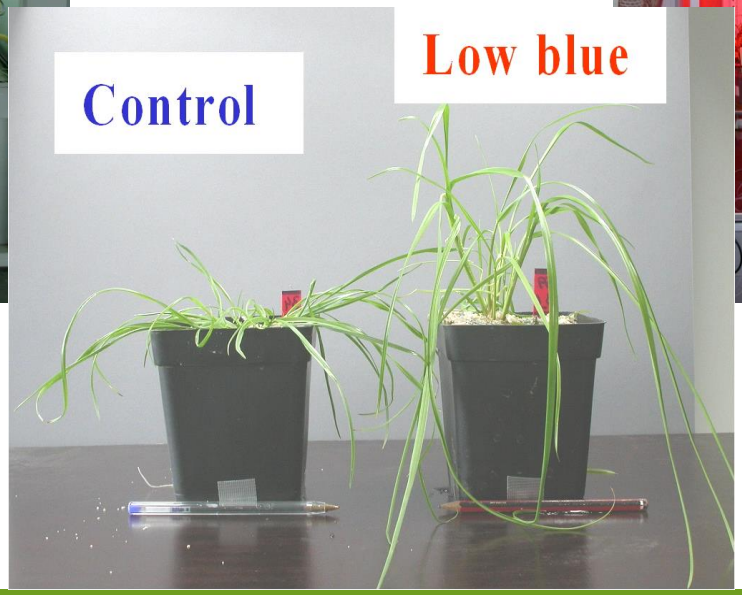
- Cryptochrome (abs Flavine)
- Leaf Photosynthesis
- Phytochrome Pfr
- Phytochrome Pr

Light driven biological processes

Badly chosen light source could have dramatic effects on plant growth!!!

PPFD = 350 µmol m^{-2} s^{-1}

Rc/Rs = 1.06



BL = 75 µmol m^{-2} s^{-1}

BL < 5 µmol m^{-2} s^{-1}

_03

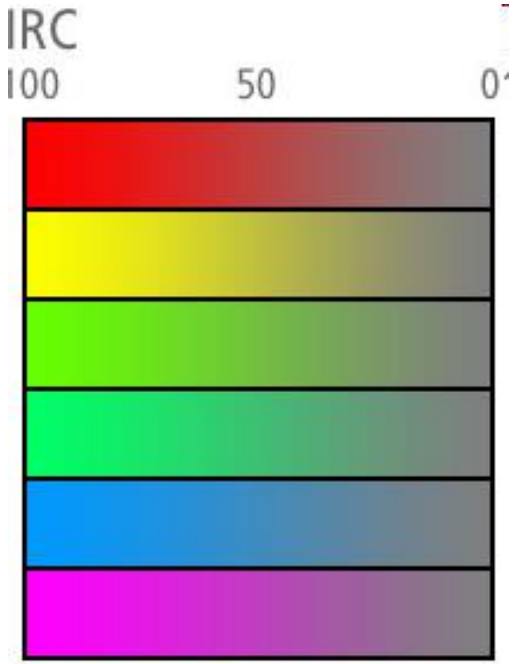
Artificial lighting: some technical specifications

Criteria to choose appropriate light source

- **Light Quality:**

Includes Correlated Color Temperature (CCT) and Color Rendering Index (CRI). These two measures offer a broad overview of most light sources

Code	Color Rendering Index (CRI)	Correlated Color Temperature (CCT)	
827	82 à 85	2700 K	Warm white
830	82 à 85	3000 K	Neutral white
840	82 à 85	4000 K	Cool white
930	92 à 98	3000 K	Neutral white
940	92 à 98	4000 K	Cool white



Criterion to choose appropriate light source

- **Efficacy**
  The efficacy of the light sources also matters a lot. This talks about their efficiency and how much light they generate as well as their energy input.

- **Timing**

Correspond to time of preheat necessary to achieve full light. The HID lamps don't usually turn on again after you put them off. You have to wait for about 10 to 15 minutes before you can put them on again. This can be very problematic especially when there's a sudden power outage. You may have to wait for several minutes to put the HID lamps on

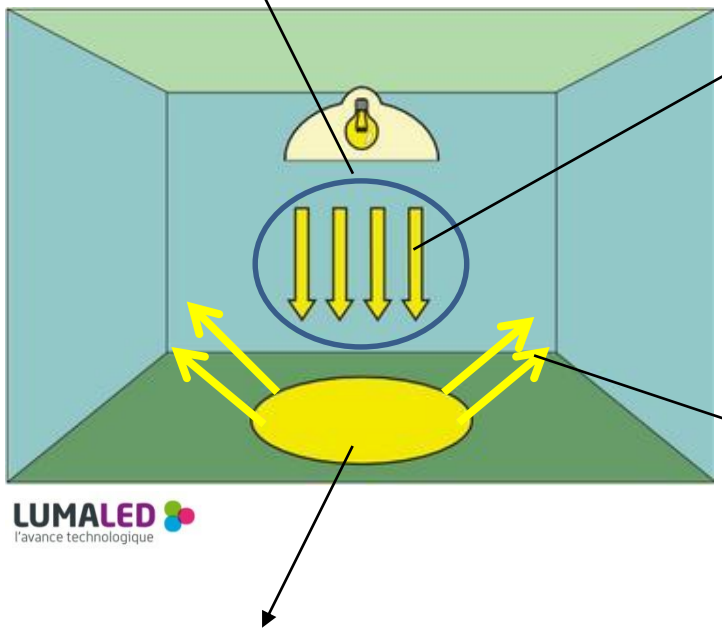
- **Dimming**
  Most of the light sources usually have dimming problems. Incandescent bulbs for instance drop their CCT levels as they dim. This usually makes them to look redder in color. LEDs also have dimming issues.

- **Aging**
  Aging issues also occur in most of the light sources.

The units used by manufacturers

Luminous flux F (lumen - lm) :

the total amount of visible **light** (to the human eye) emitted from a **lamp** or **light** source in all direction by time. The higher the **lumen** rating the “brighter” the **lamp** will appear.



Luminous intensity I (candela - cd) :

the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency 540 × 1012 hertz that has a radiant intensity in that direction of (1⁄683) watt per steradian.

Luminance L (cd/m²) :

a measure (in candelas per square metre) of the brightness of a point on a surface that is radiating or reflecting light. It is the luminous intensity in a given direction of a small element of surface area divided by the orthogonal projection of this area onto a plane at right angles to the direction.

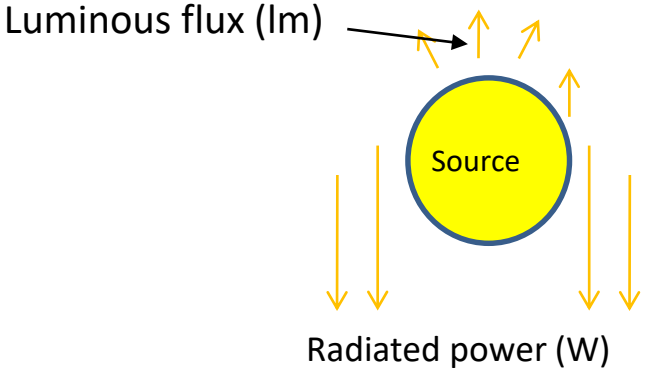
Illuminance E (lux - lx) :

the amount of luminous flux (F) per unit area
1 Lux = 1 lm/m²

The units used by manufacturers

Luminous efficiency (lm/W) :

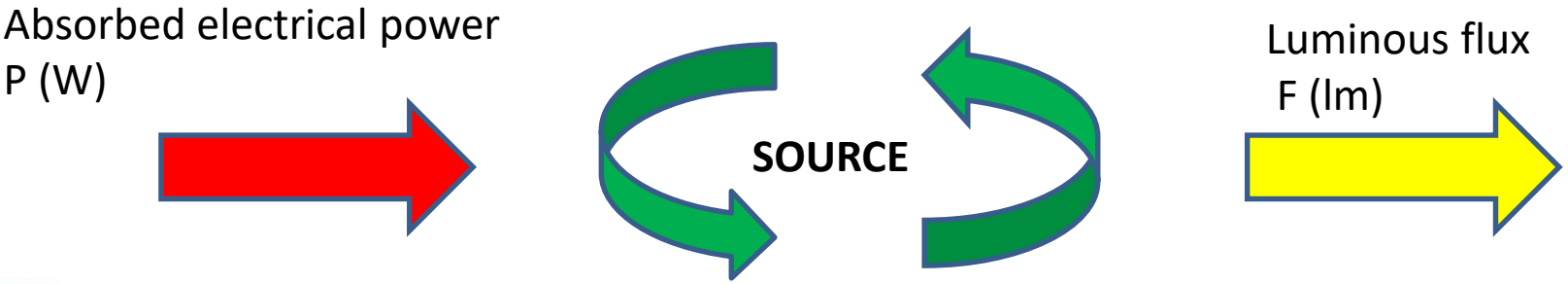
Luminous efficiency = Luminous flux/ Energetic flux



Electric efficiency (lm/W) :

Luminous flux emitted by a source (lamp) and it absorbed electrical power

$$\eta = \frac{F}{P}$$



LUMALED
l'avance technologique

Caution: Industrialists often confuse electric and luminous efficiency !

The units used by manufacturers

Electric efficiency (lm / W)

It defines the ability of a light to produce a flux from an absorbed Watt (W).

Three luminous efficiencies must be distinguished, depending on whether we take into account:

- the light source alone,
- the light source and its power supply (transformer, rectifier, ballast ...),
- the light source, its power supply and the optical losses of the installation (diffuser, reflector ...).

Note :

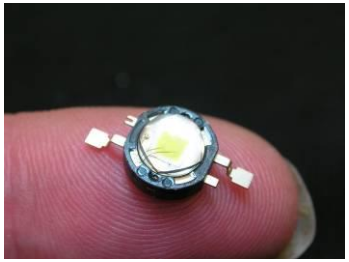
The lumen unit depends on the sensitivity of the eye to light. It is therefore easier to have high luminous efficiencies in the orange, wavelength at which humans are very sensitive.

Which is not the most judicious for the applications on the plants !!!

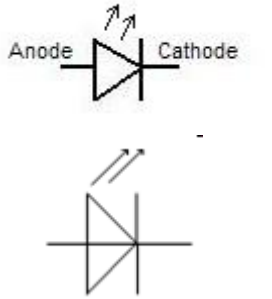
This criterion can therefore only make it possible to compare light sources with each other.

_04
LED Technology

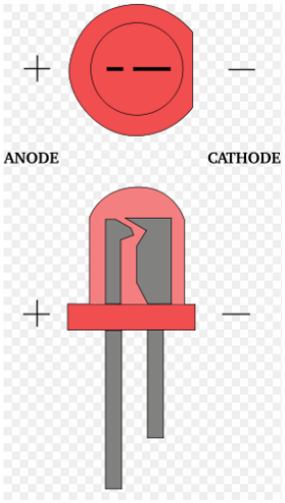
LED technology



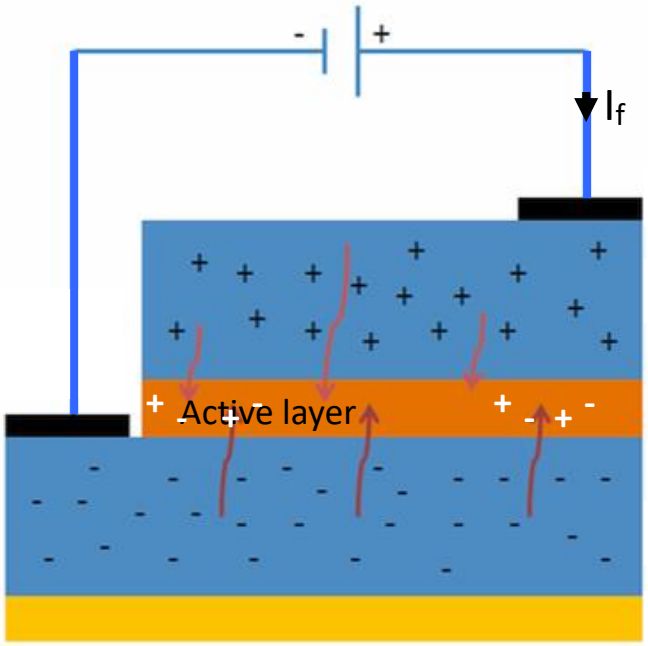
An LED is an optoelectronic component capable of emitting light when traversed by an electric current



Electric symbols



Principle



Metal electrode

Semiconductor type P (excess of whole - electron deficiency)

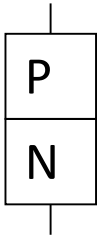
Photons

Semiconductor type N (excess of electrons)

Substrate

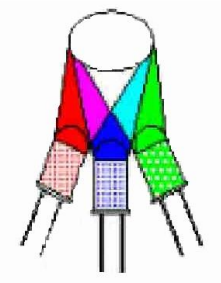
Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the bande gap of the semiconductor.

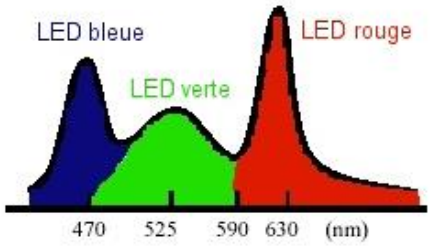
- We also talk about P-N junction



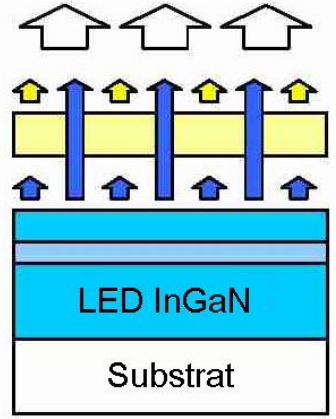
Different types of LED

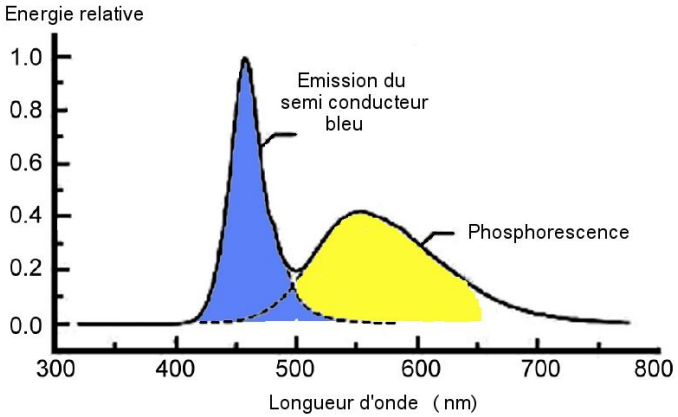
RGB





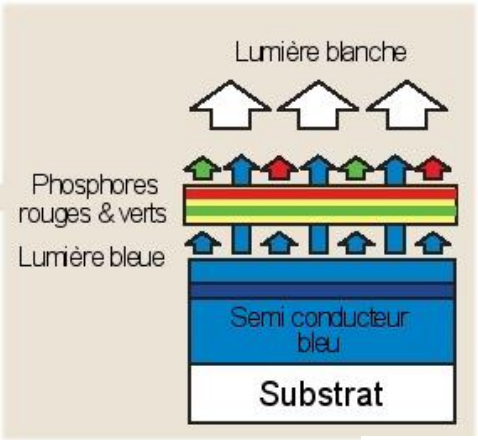
Blue LED + yellow phosphor

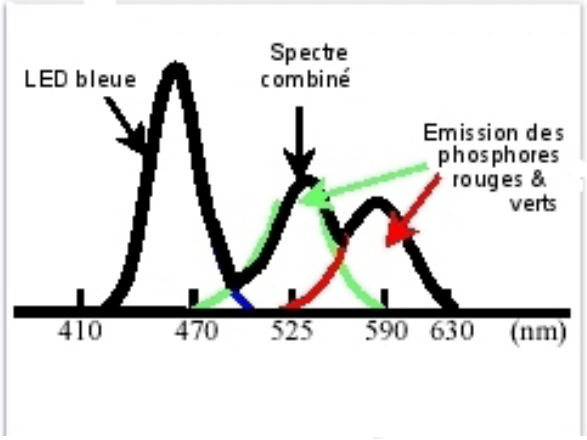




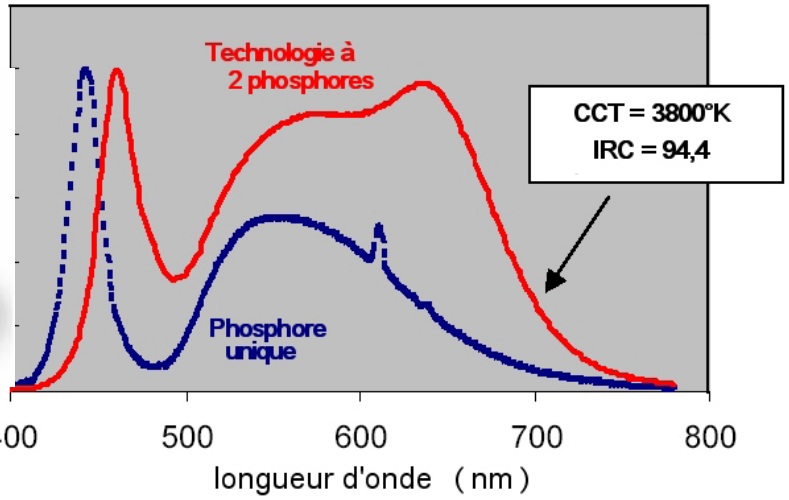
Different types of LED

Blue LED + Multi – Phosphor





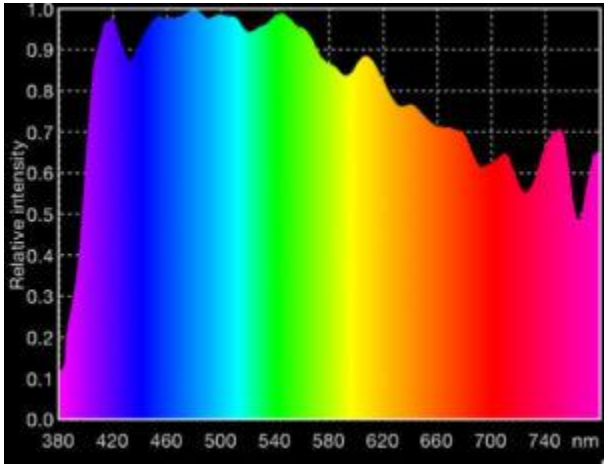
High luminosity LEDs



LED Spectrum

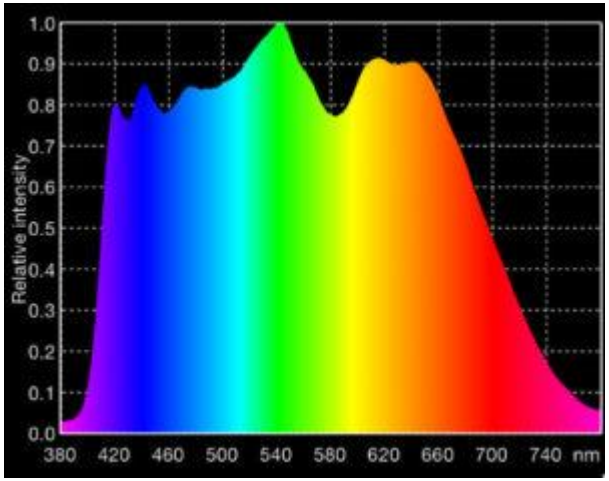
We are going to discuss more about biological effects of LED on plants and pathogen in working groups

Spectrum of sunlight



Source : Yuji LED

LED with phosphor coating



Source: Yuji LED

High potential of the new generation white LED!

05

International and national standards in the field of light and lighting

Many actors: rules are needed

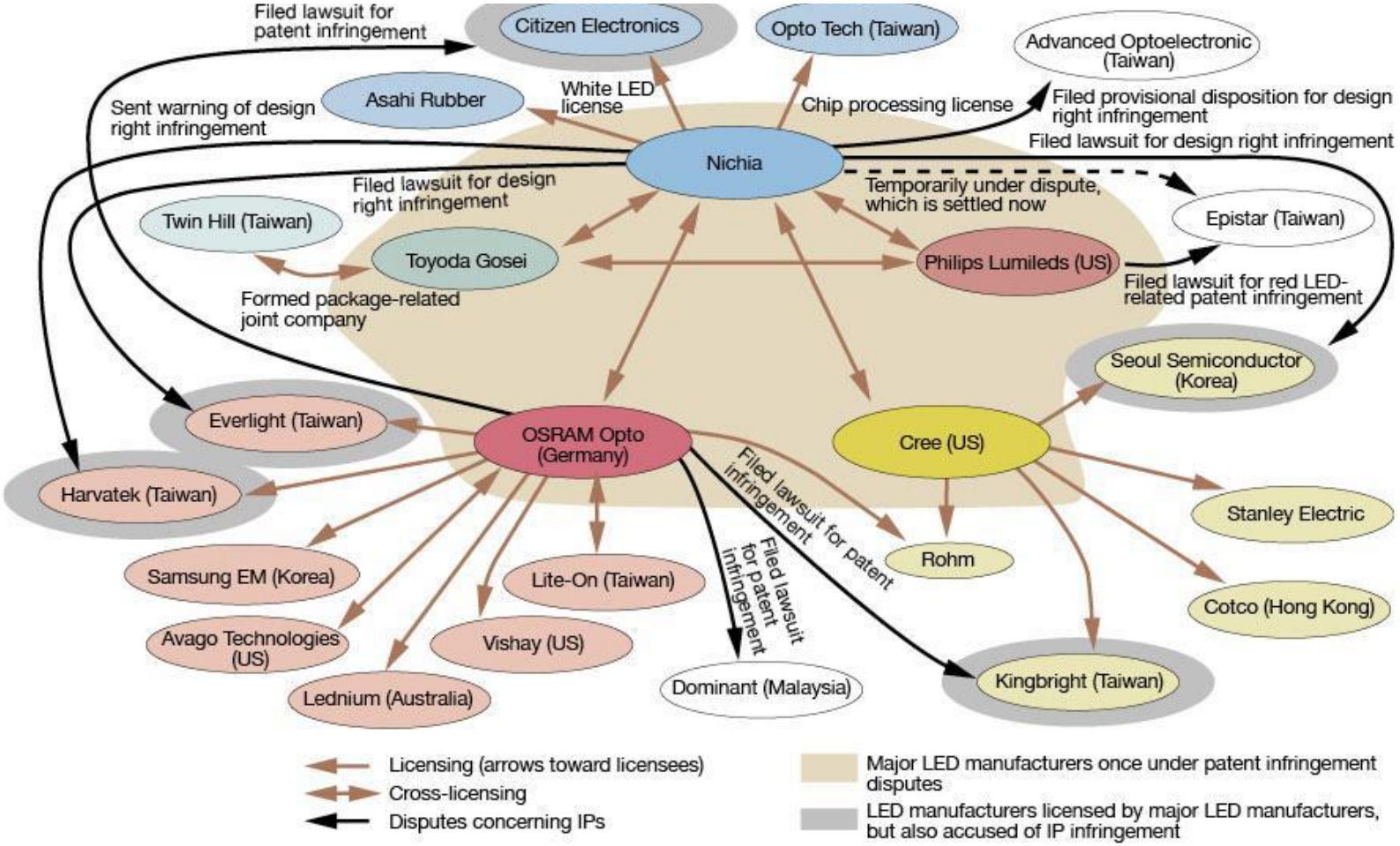


Fig 3 Major Manufacturers Conflicting Indirectly with Each Other This chart represents mutual relations between major LED manufacturers concerned with IP rights. In the GaN LED market, Nichia, first of all, Cree, OSRAM Opto, Philips Lumileds, and Toyoda Gosei, leading manufacturers of Japan, the US and Europe, are said to own primary patents. These five companies are not under IP disputes directly between each other. However, they are increasingly fighting each other indirectly by filing lawsuits against LED manufacturers licensed by one of these major manufacturers.

Links to important web sites

- http://www.cie.co.at/index_ie.html
- For France: http://www.afe-eclairage.fr/afe/cie-france-50.html
- The International Electrotechnical Commission (IEC) recently published two documents "Public Specifications" (english version not yet available) of performance requirements: CIEC / PAS 62717 -Performance requirements -LED modules for general lighting. CIEC / PAS 62722 - Performance requirements - LED lights for general lighting
- French web site:
www.syndicat-eclairage.com
- https://normalisation.afnor.org/

Links to learn more about LED lights

- https://fluence.science/science/influence-of-light-intensity/
- http://www.lighting.philips.com/main/products/horticulture

Thank you for your attention!!!