



Young Electronics Group

Opto Training – Visible Light

What is an LED?

The essential element is a semiconductor P-N junction diode.

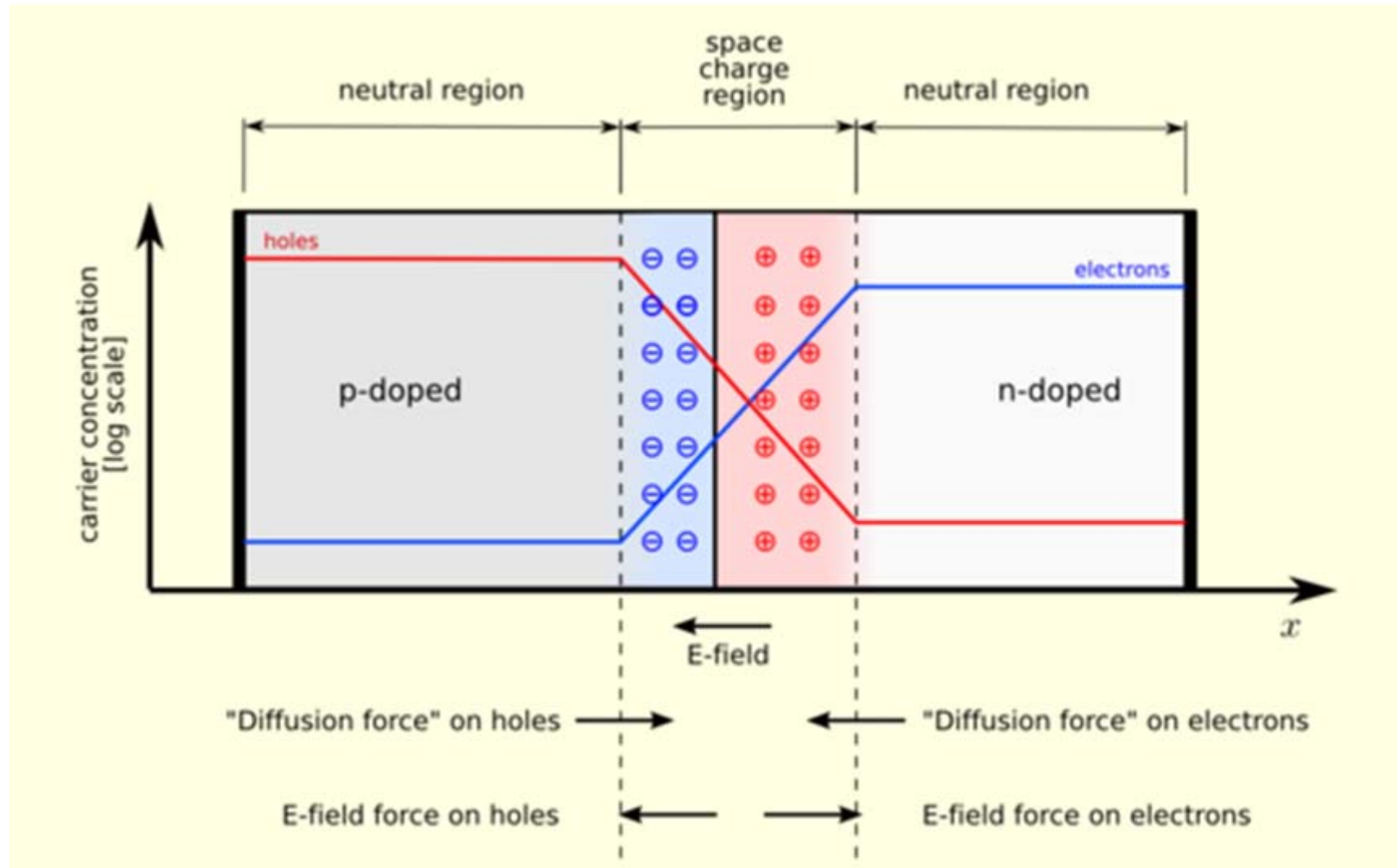
Impurities are added to the semiconductor to:

- (a) Greatly enhance the number of free charge carriers.
- (b) Generate photons of specific wavelengths, radiative recombination.

As the P-N junction is subjected to a voltage a very small drift current flows across the P-N junction by the injection of particles (electrons and holes) that are given sufficient energy to cross the junction, equilibrium. However, at the forward bias point the energy level of the junction reduces to allow the operating current to flow. The particles collide with each other and at the point of doing so generate energy, mostly phonon energy, as in a standard diode and this energy is dissipated into the semiconductor structure as vibration generating heat. But some energy forms photons or light and the LED base structure is designed to allow as many photons as possible to leave the P-N junction in the right directions.

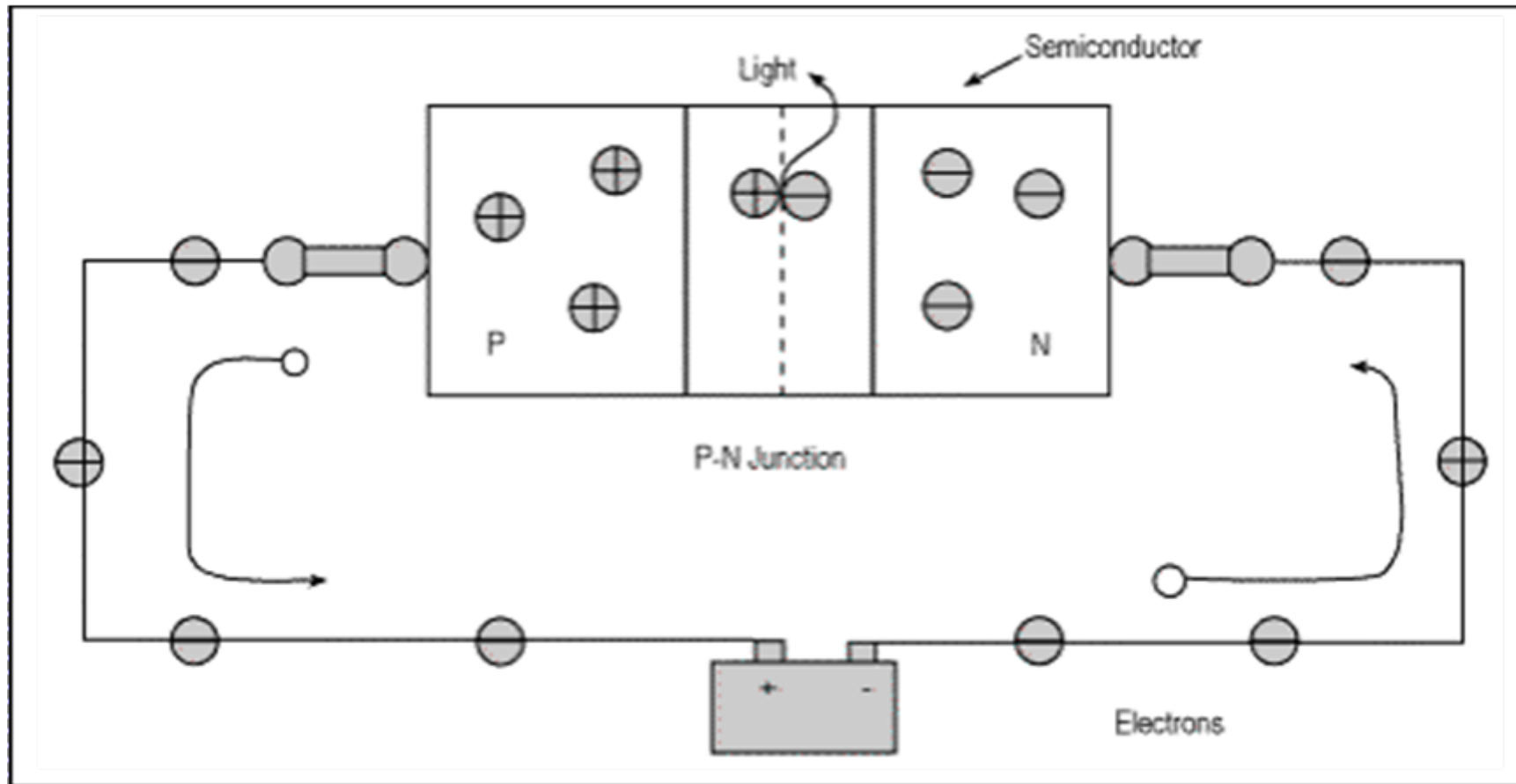
Newer generation of LEDs need so many collisions to occur so that the light emitted is maximised the heat this generates requires careful consideration, in essence a power diode.

P-N Junction

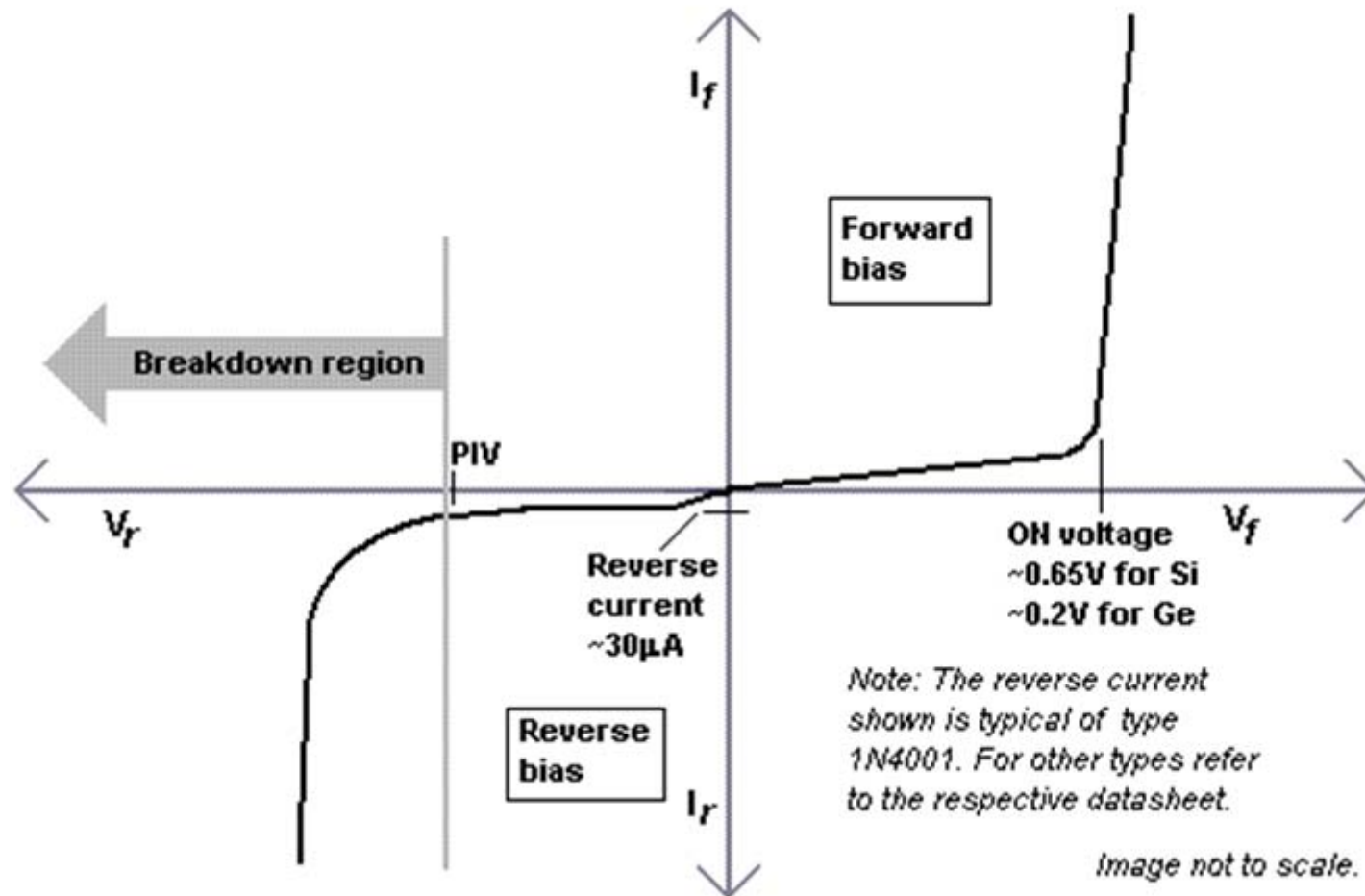


LED Forward Biased Circuit

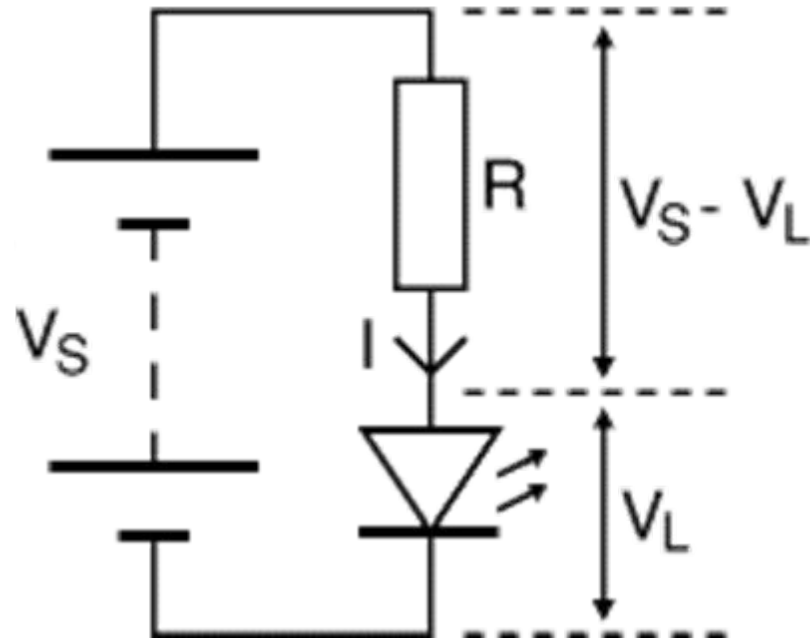
Block diagram of a biased LED P-N junction, there is no current limiting shown. The semiconductor substrate is transparent to allow the light to be reflected in the main axis direction of view.



P-N Junction Operating Curve



An LED will exhibit a V_f of between 1.8 to 4V depending upon the colour and hence the required P-N junction field voltage and the V_r of an LED is normally 5V



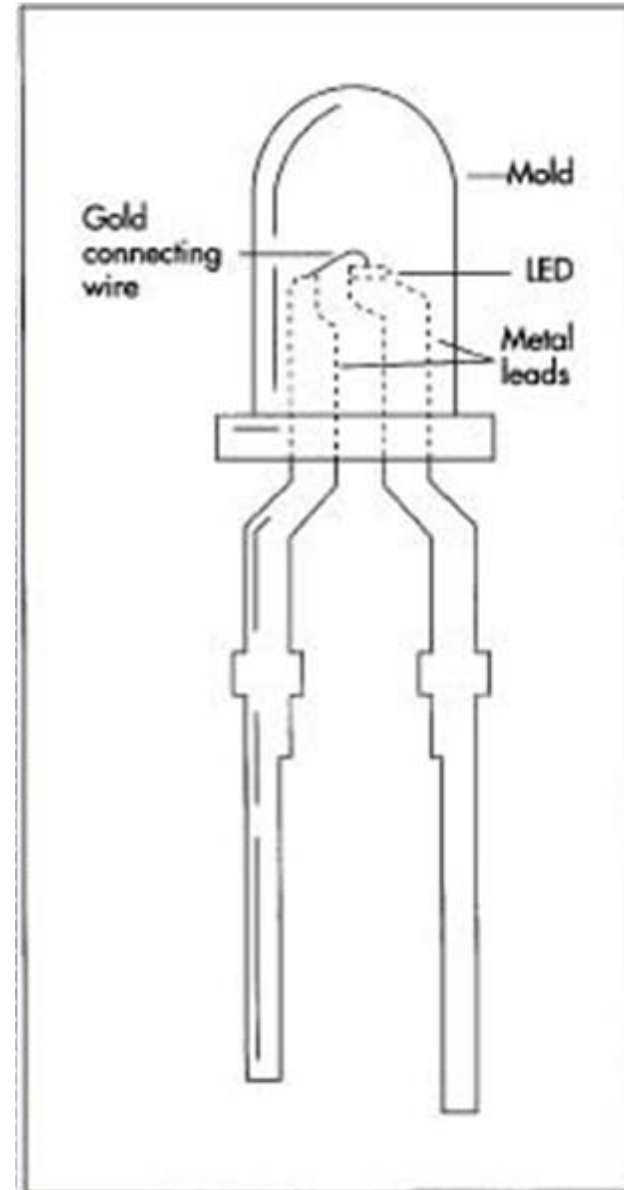
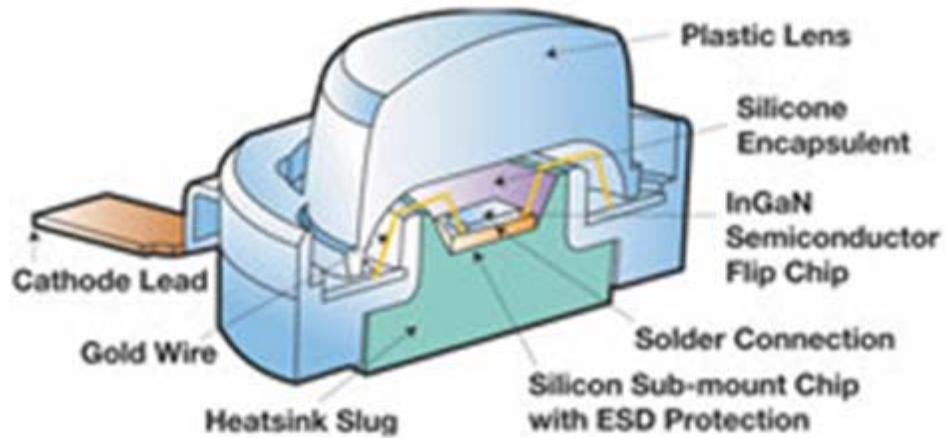
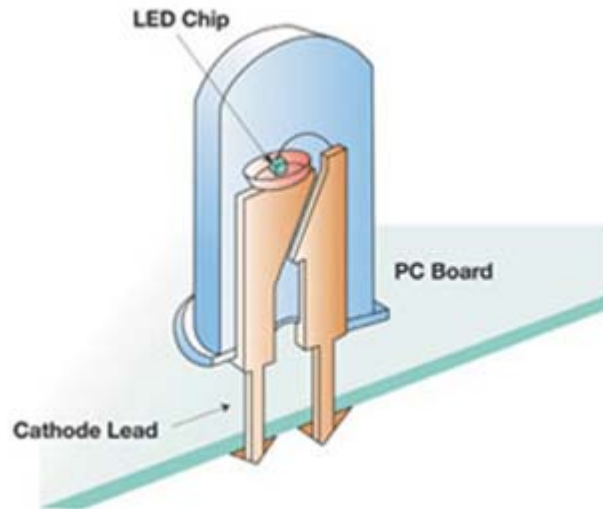
$$R = (V_S - V_L) \div I$$

where I must be less than the manufacturer's maximum dc or average (pulsed to a limit) value.

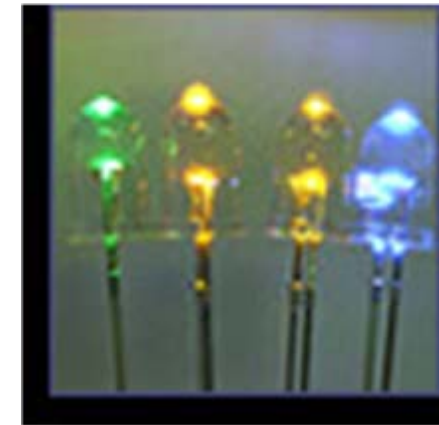
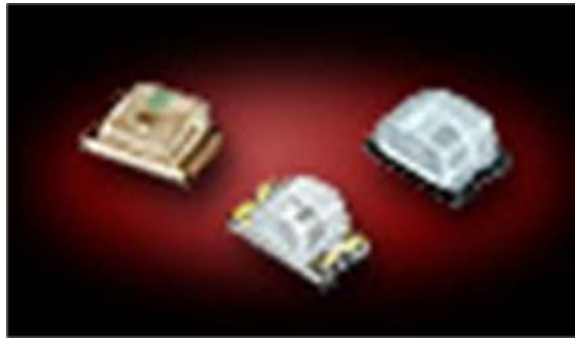
Multiple Connected LEDs



LED Construction



- **Indicators**



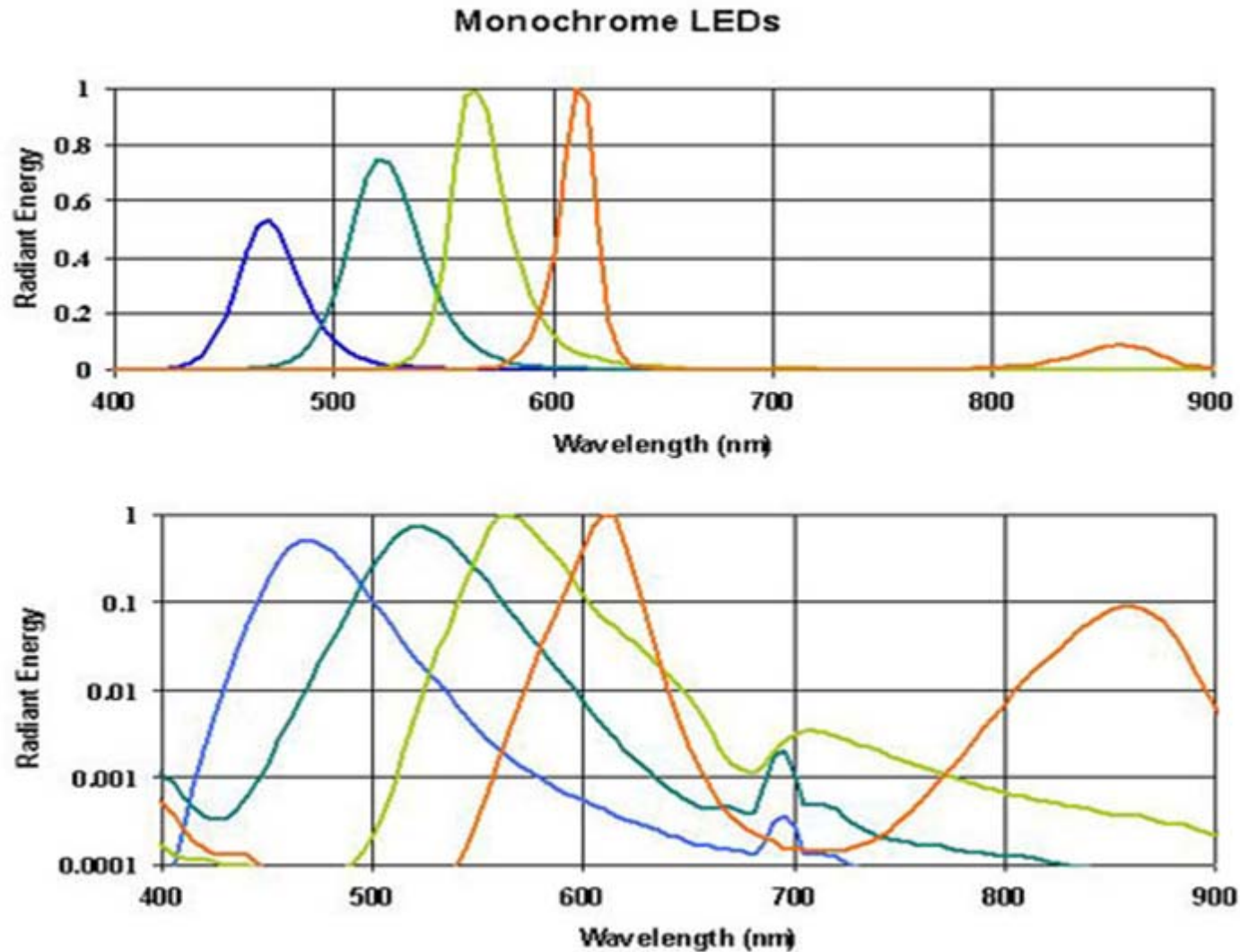
- **Module Displays**



- **Lighting**

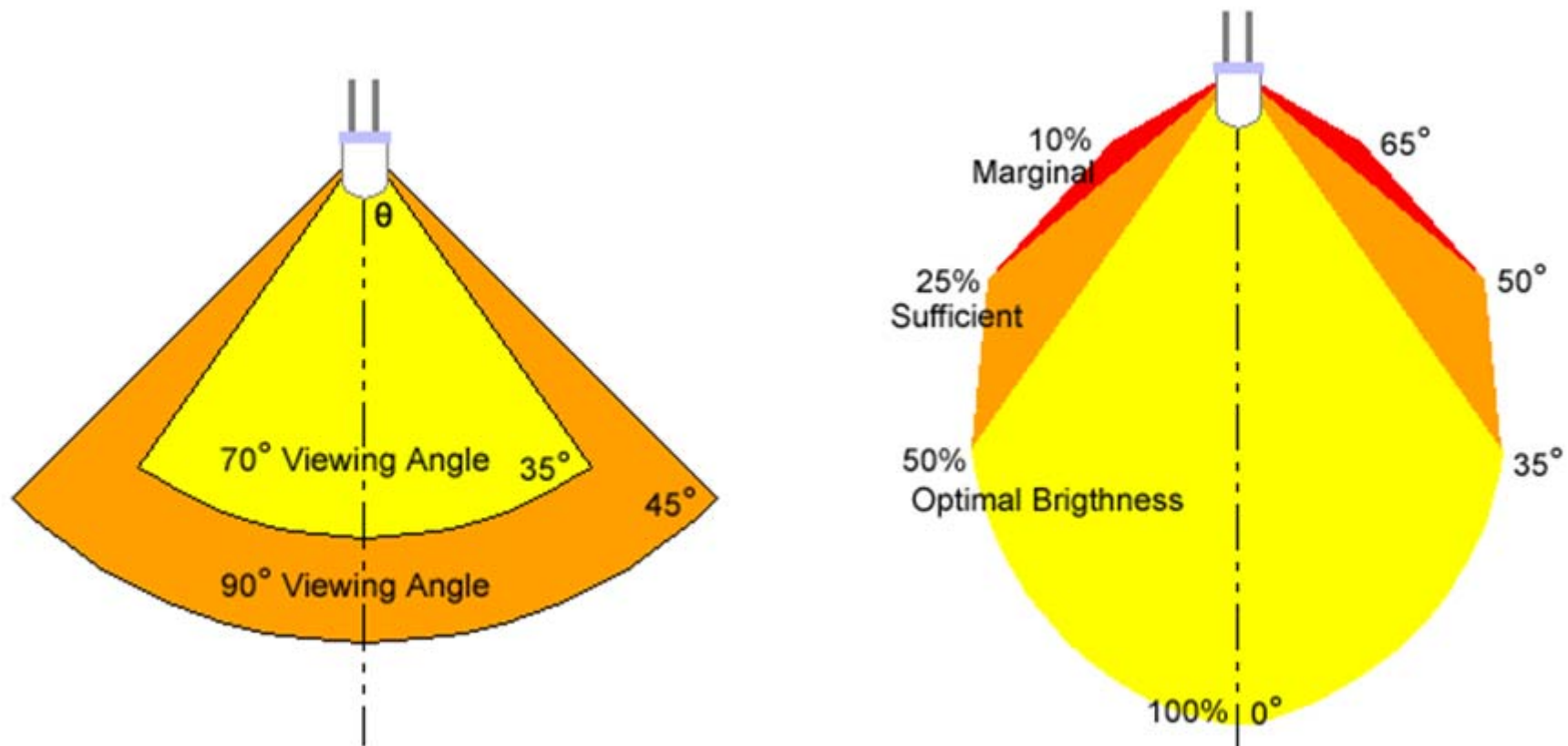


- Different materials are used in the P – N junction to provide the different dominant wavelengths and so give the required coloured light. LED light is non-coherent due to the manner of the photon emissions.



LED Viewing Angle and Intensity

Viewing angle is directly related to intensity (brightness). The LED industry defines viewing angle as the full angle at which brightness is half of the brightness from dead center. More scientifically, if ϕ (angle theta) is the angle from off center (0°) where the LED's brightness is half, the 2ϕ is defined as the full viewing angle. The entire yellow portion represents a 70° viewing angle, while the orange portion represents a 90° viewing angle



- **Radiation Angle**

At a narrower radiation angle the luminous intensity (clarity) becomes larger whereas the luminous flux (quantity of light) doesn't change.

For example: A 1000 mcd 30° LED radiates just as much light as a 4000 mcd 15° led. The radiation angle has been halved in both width and height multiplying the luminous intensity four times.

- **Luminous Flux**

Flux is a measure for the quantity of energy that is transmitted by a source in all directions. The SI unit of luminous flux is the lumen (lm). e.g. the luminous flux of a 40 Watt conventional light bulb is 450 lm. The human eye is most sensitive to radiation around 555nm. At this standard 1 Watt of radiation will produce a luminous flux of 683lm

- **Luminous intensity**

The luminous intensity of a light source is the density of that flux emitted in a given direction. For LEDs, this is expressed in millicandela (mcd) in that 1000 millicandelas equals 1 candela. E.g. the luminous intensity is 590,000 mcd.

Convert Millicandelas to Lumen

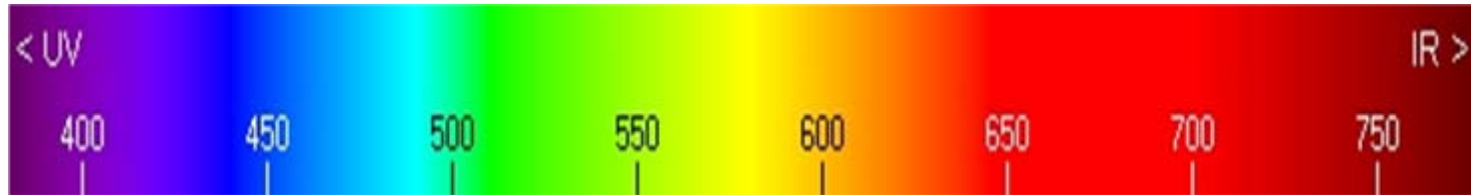
To calculate lumen from millicandelas, take the number of candelas, divide it with the number that belongs to the radiation angle of the lamp. Example:
590,000 mcd = 590 cd, a lamp with a radiation angle of 40°, $590/2.64 =$ approx. 223.48 Lumen.

Candela	Radiation Angle	Divide by
Y mcd ÷ 1000	5°	167.22
	10°	41.82
	15°	18.50
	20°	10.48
	25°	6.71
	30°	4.67
	35°	3.44
	40°	2.64
	45°	2.09

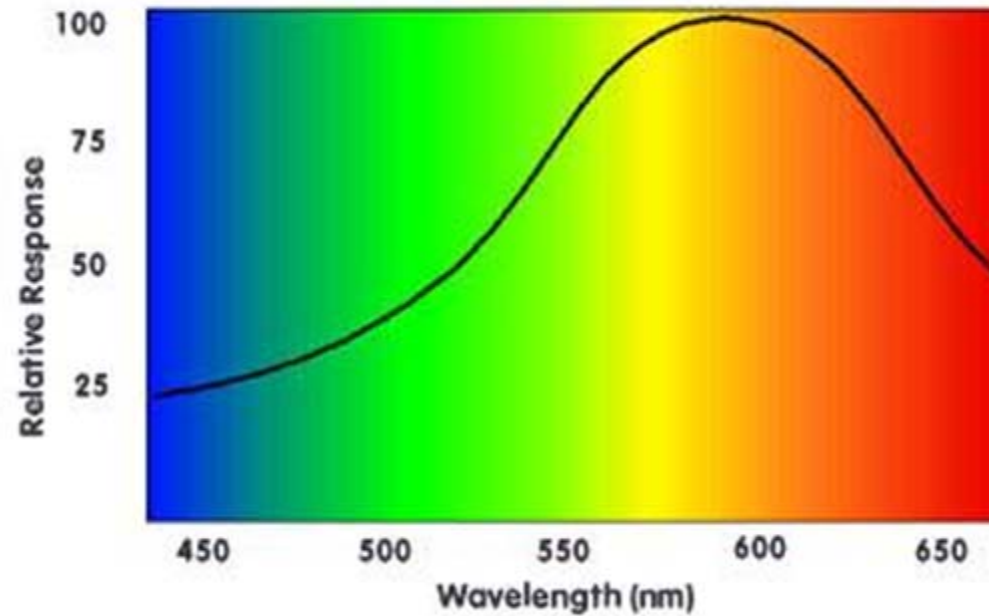
Various light sources exhibit different light output efficiencies. A old 60W incandescent bulb typically produces 500lm of luminous flux, less than 1W of pure radiation. Therefore the efficiency of this light source is $500 \div 60 = 8.3\text{lm/W}$.

- o A tungsten lamp is $1000 \div 100 = 10\text{lm/W}$ (up to 17lm/W)
 - o A fluorescent tube is $3000 \div 40 = 75\text{lm/W}$ (up to 100lm/W)
 - o Market Power LEDs today are reaching the 75lm/W point
 - o Power LEDs within next 2 years were expected to break 100lm/W
 - o Nichia (dti report) has reached $>100\text{lm/W}$ and Cree $>130\text{lm/W}$ now
 - o Power LEDs over the next 5 to 10 years will break 200lm/W
- **Market terminology**
 - Indicator LEDs and display module; Intensity = millicandela (mcd)
 - Power or lighting LEDs; Intensity = lumens (lm) and lumens/Watt

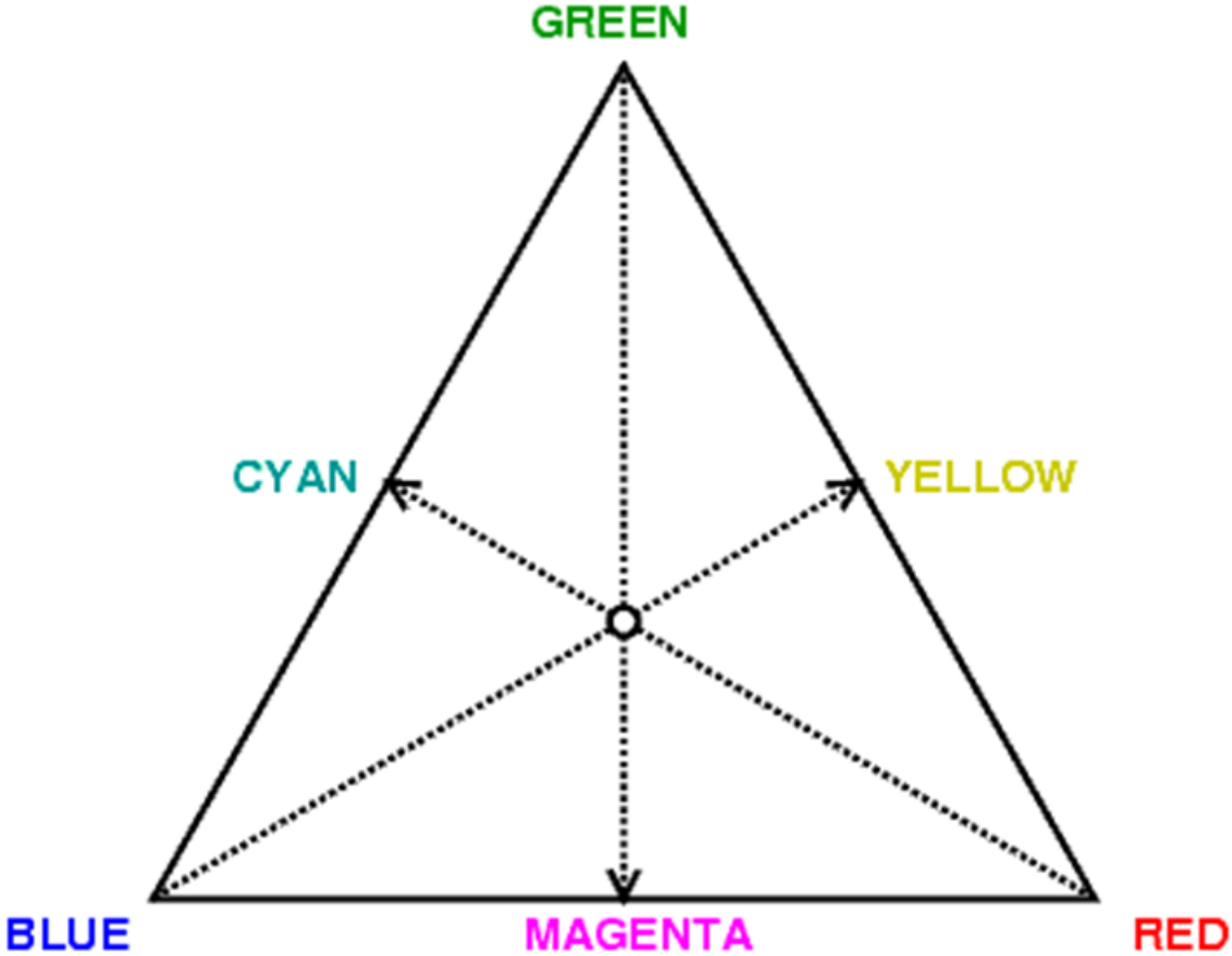
- **Visible Light Radiation**



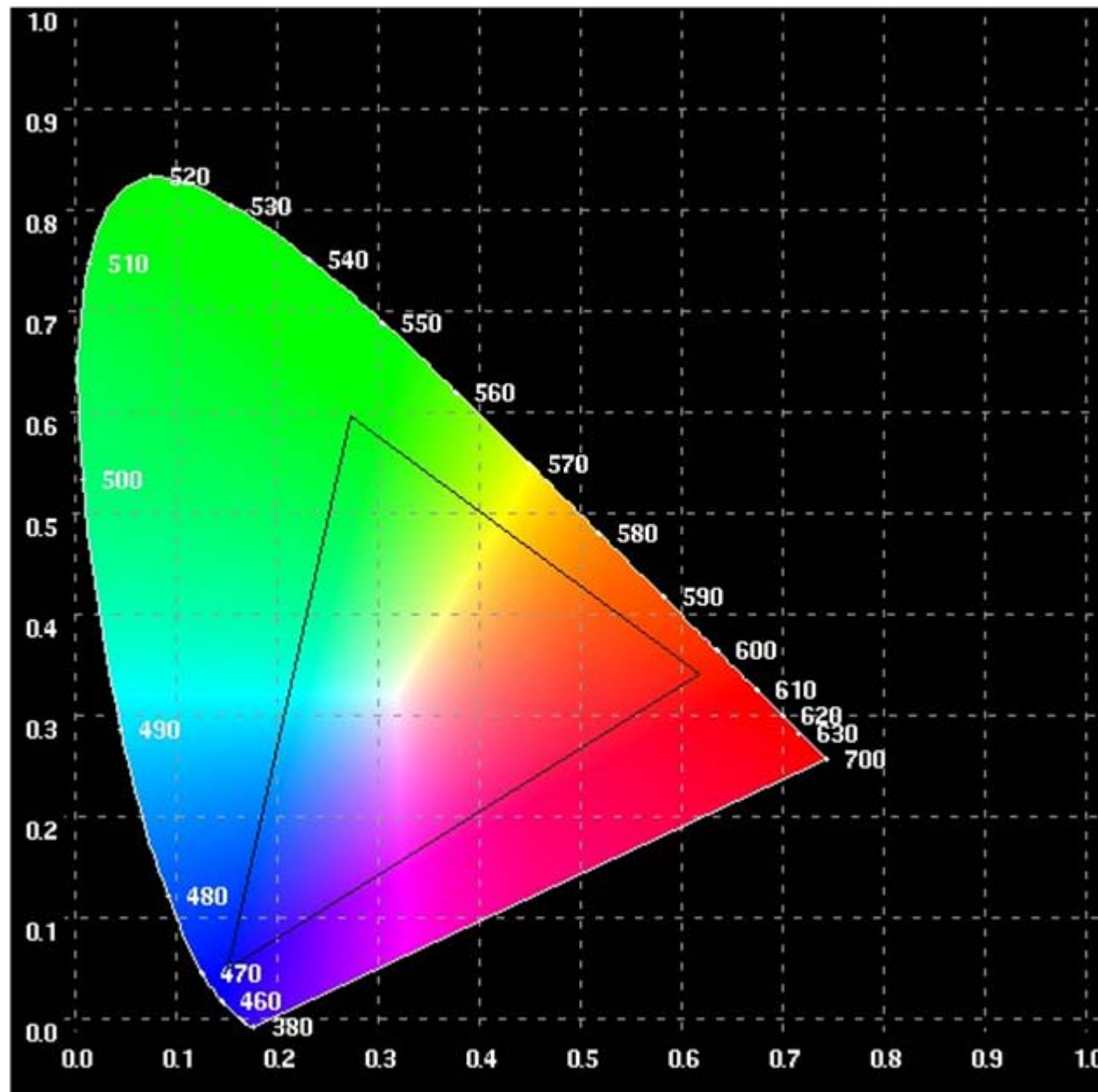
- **Human Eye Response to Visible Radiation**



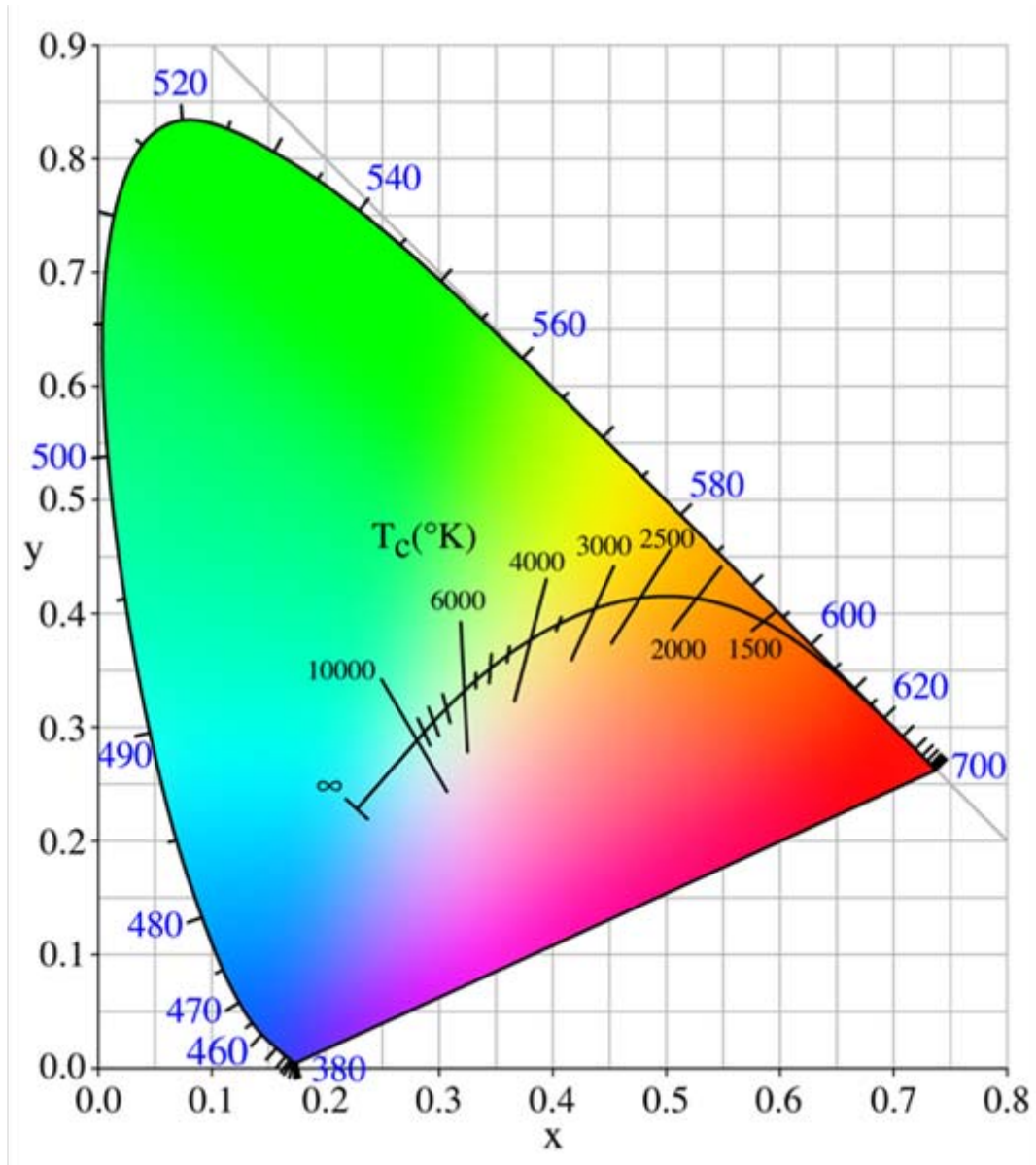
Maxwell Triangle

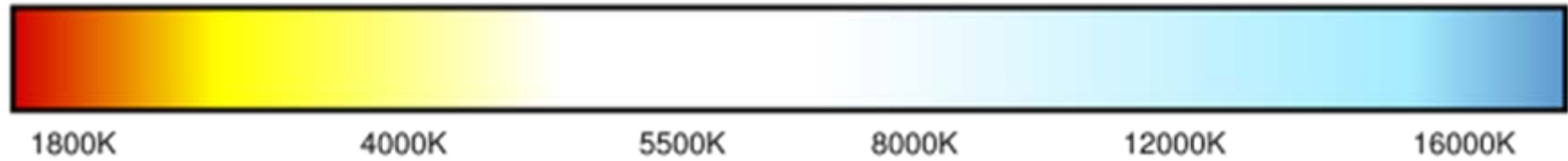


Chromaticity Chart



Visible Light Colour Temperature



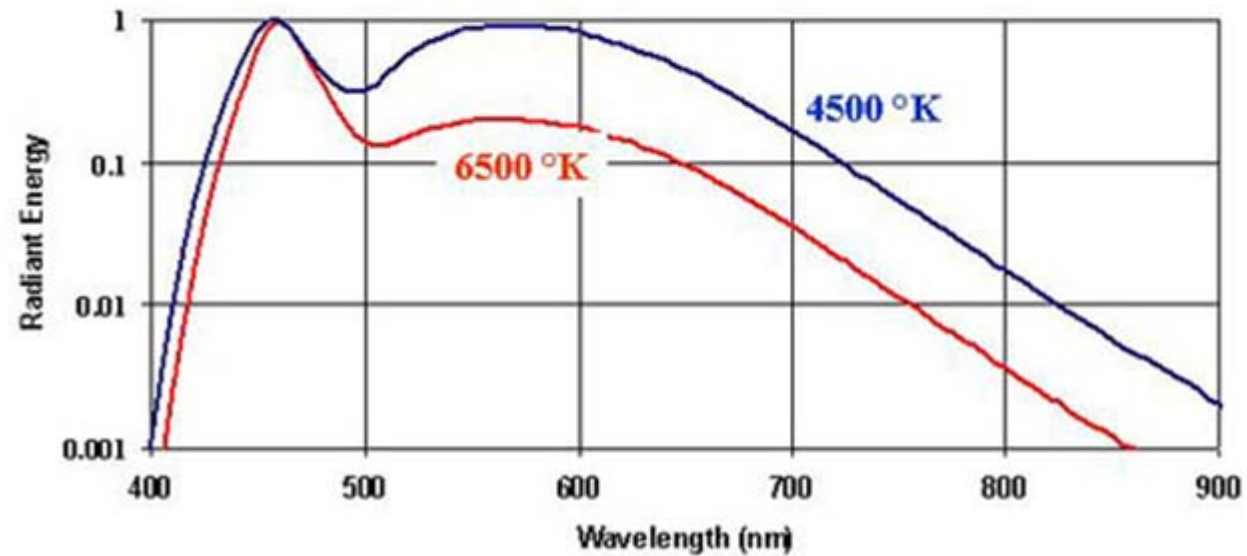
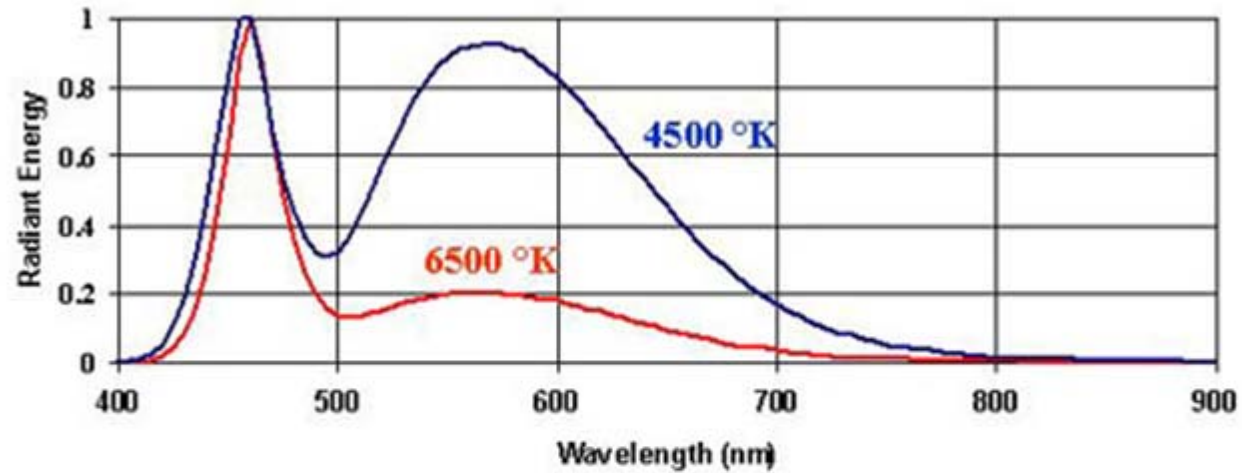


- **Typical Colour Temperatures**

- 1700K Match Flame
- 1850K Candle
- 2800K Tungsten Lamp
- 3400K Studio and Photoflood lamps
- 4100K Moonlight
- 5000K Warm Daylight
- 5500 to 6000K Cool Daylight
- 6420K Xenon lamp
- 6500K Daylight
- 9300K Analogue TV screen

White LED Peak and Spectral Wavelengths

White LEDs



- **Experience of Custom Indicator Modules**
 - Professional Audio Market
- **Experience of Large Indicator and Message Signage**
 - Highways, Urban Signs, Traffic Lights
- **Experience of White LEDs**
 - Backlighting, Advertising, Road Bollards
- **Experience of Power LED Based Lighting**
 - Domestic Lighting, Display and Large Advertising
- **YEG can Provide Concept Solutions to meet a Customer's Problem using LEDs.**
 - Design Circuit Layout, Build Prototype Solutions, Modify Customers' Products for LED Based Solutions