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Efficient of the Bulbs

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DESCRIPTION

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Abstract

In this thesis you can read about some of the different kind of bulb that you can found in the market and in it I gave to you an idea of what are their characteristics and other details of its working and also I explain how its work. I also mention the different application that they have now a days.

In this text I also mention the conclusion of some experiment that I had done during the made up of this thesis, about measurement of the electrics proprieties of the different bulbs and about the number of lumens that the lamps gave to us.

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CONTENTS

1 INCANDESCENT LIGHT BULB

The incandescent light bulb, incandescent lamp or incandescent light globe is a source of electric light that works by incandescence (a general term for heat-driven light emissions, which includes the simple case of black body radiation). An electric current passes through a thin filament, heating it until it produces light. The enclosing glass bulb contains either a vacuum or an inert gas to prevent oxidation of the hot filament. Incandescent bulbs are also sometimes called electric lamps, a term also applied to the original arc lamps.

Incandescent bulbs are made in a wide range of sizes and voltages, from 1.5 volts to about 300 volts. They require no external regulating equipment and have a low manufacturing cost, and work well on either alternating current or direct current. As a result the incandescent lamp is widely used in household and commercial lighting, for portable lighting, such as table lamps, car headlamps, flashlights, and for decorative and advertising lighting.

Some applications of the incandescent bulb make use of the heat generated, such as incubators, brooding boxes for poultry, heat lights for reptile tanks, infrared heating for industrial heating and drying processes, and the Easy-Bake Oven toy. In cold weather the heat shed by incandescent lamps contributes to building heating, but in hot climates lamp losses increase the energy used by air conditioning systems.

Incandescent light bulbs are gradually being replaced in many applications by other types of electric light such as (compact) fluorescent lamps, high-intensity discharge lamps, light-emitting diodes (LEDs), and other devices. These newer technologies give more visible light and less heat for the same amount of electrical energy input. Some jurisdictions, such as the European Union are in the process of phasing-out the use of incandescent light bulbs in favor of more energy-efficient lighting.

1.1.1 EFFICIENCY COMPARISONS

Approximately 90% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light.

The effectiveness of an electric lighting source is determined by two factors:

- The relative visibility of electromagnetic radiation
- The rate at which the source converts electric power into electromagnetic radiation.

Luminous efficacy of a light source is a ratio of the visible light energy emitted (the luminous flux) to the total power input to the lamp. Visible light is measured in lumens, a unit which is defined in part by the differing sensitivity of the human eye to different wavelengths of light. Not all wavelengths of visible electromagnetic energy are equally effective at stimulating the human eye; the luminous efficacy of radiant energy is a measure of how well the distribution of energy matches the perception of the eye. For white light, the maximum luminous efficacy is around 240 lumens per watt, but the exact value is not unique because the human eye can perceive many different mixtures of visible light as "white".

1.1.2 COST OF LIGHTING

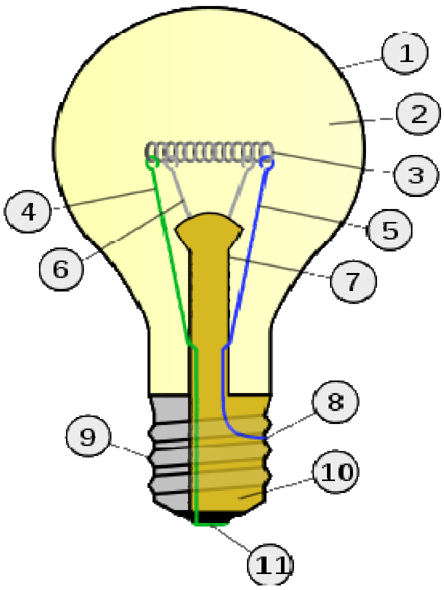
The desired product of any electric lighting system is light (lumens), not power (watts). To compare incandescent lamp operating cost with other light sources, the calculation must also consider the lumens produced by each lamp. For commercial and industrial lighting systems the comparison must also include the required illumination level, the capital cost of the lamp, the labor cost to replace lamps, the various depreciation factors for light output as the lamp ages, effect of lamp operation on heating and air conditioning systems, as well as the energy consumption. The initial cost of an incandescent bulb is small compared to the cost of the energy it will use.

Overall cost of lighting must also take into account light lost within the lamp holder fixture; internal reflectors and updated design of lighting fixtures can improve the amount of usable light delivered. Since human vision adapts to a wide range of light levels, a 10% or 20% decrease in lumens still may provide acceptable illumination, especially if the changeover is accompanied by cleaning of lighting equipment or improvements in fixtures.

1.2 CONSTRUCTION

Incandescent light bulbs consist of a glass enclosure (the envelope, or bulb) with a filament of tungsten wire inside the bulb, through which an electric current is passed. Contact wires and a base with two (or more) conductors provide electrical connections to the filament. Incandescent light bulbs usually contain a stem or glass mount anchored to the bulb's base which allows the electrical contacts to run through the envelope without gas/air leaks. Small wires embedded in the stem in turn support the filament and/or its lead wires. The bulb is filled with an inert gas such as argon to reduce evaporation of the filament.

An electrical current heats the filament to typically 2000 K to 3300 K, well below tungsten's melting point of 3695 K. Filament temperatures depend on the filament type, shape, size, and amount of current drawn. The heated filament emits light that approximates a continuous spectrum. The useful part of the emitted energy is visible light, but most energy is given off as heat in the near-infrared wavelengths.



1. Outline of Glass bulb
2. Low pressure inert gas (argon, neon, nitrogen)
3. Tungsten filament
4. Contact wire (goes out of stem)
5. Contact wire (goes into stem)
6. Support wires
7. Stem (glass mount)
8. Contact wire (goes out of stem)
9. Cap (sleeve)
10. Insulation (vitrite)
11. Electrical contact

Figure 1. Diagram of an incandescent lamp

1.3 ELECTRICAL CHARACTERISTICS

Incandescent lamps are nearly pure resistive loads with a power factor of 1. This means the actual power consumed (in watts) and the apparent power (in volt-amperes) are equal. The actual resistance of the filament is temperature-dependent. The cold resistance of tungsten-filament lamps is about 1/15 the hot-filament resistance when the lamp is operating. For example, a 100-watt, 120-volt lamp has a resistance of 144 ohms when lit, but the cold resistance is much lower (about 9.5 ohms). Since incandescent lamps are resistive loads, simple triac dimmers can be used to control brightness. Electrical contacts may carry a "T" rating symbol indicating that they are designed to control circuits with the high inrush current characteristic of tungsten lamps. For a 100-watt, 120 volt general-service lamp, the current stabilizes in about 0.10 seconds, and the lamp reaches 90% of its full brightness after about 0.13 seconds.

1.3.1 POWER

Incandescent light bulbs are usually marketed according to the electrical power consumed. This is measured in watts and depends mainly on the resistance of the filament, which in turn depends mainly on the filament's length, thickness, and material. For two bulbs of the same voltage, type, color, and clarity, the higher-powered bulb gives more light.

1.4 PHYSICAL CHARACTERISTICS

1.4.1 BULB SHAPES, SIZES, AND TERMS

Incandescent light bulbs come in a range of shapes and sizes. The names of the shapes may be slightly different in some regions. Many of these shapes have a designation consisting of one or more letters followed by one or more numbers, e.g. A55 or PAR38. The letters represent the shape of the bulb. The numbers represent the maximum diameter, either in eighths of an inch, or in millimeters, depending on the shape and the region. For example, 63 mm reflectors are designated R63, but in the U.S. they are known as R20 (2.5 inches). However, in both regions, a PAR38 reflector is known as PAR38.

Common shapes:

General Service

Light emitted in (nearly) all directions. Available either clear or frosted.

Types: General (A), Mushroom

High Wattage General Service

Lamps greater than 200 watts.

Types: Pear-shaped (PS)

Decorative

lamps used in chandeliers, etc.

Types: candle (B), twisted candle, bent-tip candle (CA & BA), flame (F), fancy round (P), globe (G)

Reflector (R)

Reflective coating inside the bulb directs light forward. Flood types (FL) spread light. Spot types (SP) concentrate the light. Reflector (R) bulbs put approximately double the amount of light (foot-candles) on the front central area as General Service (A) of same wattage.

Types: Standard reflector (R), elliptical reflector (ER), crown-silvered

Parabolic aluminized reflector (PAR)

Parabolic aluminized reflector (PAR) bulbs control light more precisely. They produce about four times the concentrated light intensity of general service (A), and are used in recessed and track lighting. Weatherproof casings are available for outdoor spot and flood fixtures.

120 V sizes: PAR 16, 20, 30, 38, 56 and 64

230 V sizes: Par 38, 56 and 64

Available in numerous spot and flood beam spreads. Like all light bulbs, the number represents the diameter of the bulb in 1/8ths of an inch. Therefore, a

PAR 16 is 2" in diameter, a PAR 20 is 2.5" in diameter, PAR 30 is 3.75" and a PAR 38 is 4.75" in diameter.

Multifaceted reflector (MR)

HIR

"HIR" is a GE designation for a lamp with an infrared reflective coating. Since less heat escapes, the filament burns hotter and more efficiently. The Osram designation for a similar coating is "IRC".

1.4.2 LAMP BASES

Very small lamps may have the filament support wires extended through the base of the lamp, and can be directly soldered to a printed circuit board for connections. Some reflector-type lamps include screw terminals for connection of wires. Most lamps have metal bases that fit in a socket to support the lamp and conduct current to the filament wires. In the late 19th century manufacturers introduced a multitude of incompatible lamp bases. General Electric introduced standard base sizes for tungsten incandescent lamps under the Mazda trademark in 1909. This standard was soon adopted across the United States, and the Mazda name was used by many manufacturers under license through 1945. Today most incandescent lamps for general lighting service use an Edison screw or double contact bayonet base. Bayonet base lamps are frequently used in automotive lamps to resist loosening due to vibration. A bipin base is often used for halogen or reflector lamps.

1.5 VOLTAGE, LIGHT OUTPUT, AND LIFETIME

Incandescent lamps are very sensitive to changes in the supply voltage. These characteristics are of great practical and economic importance.

For a supply voltage V near the rated voltage of the lamp:

- Light output is approximately proportional to $V^{3.4}$
- Power consumption is approximately proportional to $V^{1.6}$
- Lifetime is approximately proportional to V^{-16}
- Color temperature is approximately proportional to $V^{0.42}$

This means that a 5% reduction in operating voltage will more than double the life of the bulb, at the expense of reducing its light output by about 20%. This may be a very acceptable trade off for a light bulb that is in a difficult-to-access location (for example, traffic lights or fixtures hung from high ceilings). "Long-life" bulbs take advantage of this tradeoff. Since the value of the electric power they consume is much more than the value of the lamp, general service lamps emphasize efficiency over long operating life. The objective is to minimize the cost of light, not the cost of lamps.

The relationships above are valid for only a few percent change of voltage around rated conditions, but they do indicate that a lamp operated at much lower than rated voltage could last for hundreds of times longer than at rated conditions, albeit with greatly reduced light output. Lamps designed for different voltages have different luminous efficacy.

The wires used to support the filament make it mechanically stronger, but remove heat, creating another tradeoff between efficiency and long life. Many general-service 120-volt lamps use no additional support wires, but lamps designed for "rough service" or "vibration service" may have as many as five. Low-voltage lamps have filaments made of heavier wire and do not require additional support wires.

Very low voltages are inefficient since the lead wires would conduct too much heat away from the filament, so the practical lower limit for incandescent lamps is 1.5 volts.

Very long filaments for high voltages are fragile, and lamp bases become more difficult to insulate, so lamps for illumination are not made with rated voltages over 300 V.

2 HALOGEN LAMP

A halogen lamp is an incandescent lamp in which a tungsten filament is sealed into a compact transparent envelope filled with an inert gas and a small amount of halogen such as iodine or bromine. The combination of the halogen gas and the tungsten filament produces a chemical reaction known as a halogen cycle that increases the lifetime of the bulb and prevents its darkening by redepositing tungsten from the inside of the bulb back onto the filament. The halogen lamp can operate its filament at a higher temperature than a standard gas filled lamp of similar power without loss of operating life. This gives it a higher efficacy (10–30 lm/W). It also gives light of a higher color temperature compared to a non-halogen incandescent lamp. Alternatively, it may be designed to have perhaps twice the life with the same or slightly higher efficacy. Because of their smaller size, halogen lamps can advantageously be used with optical systems that are more efficient.

2.1 HALOGEN CYCLE

The function of the halogen is to set up a reversible chemical reaction with the tungsten evaporating from the filament. In ordinary incandescent lamps, this tungsten is mostly deposited on the bulb. The halogen cycle keeps the bulb clean and the light output remains almost constant throughout life. At moderate temperatures the halogen reacts with the evaporating tungsten, the halide formed being moved around in the inert gas filling. At some time it will reach higher temperature regions, where it dissociates, releasing tungsten and freeing the halogen to repeat the process. In order for the reaction to operate, the overall bulb temperature must be higher than in conventional incandescent lamps. The bulb must be made of fused silica (quartz) or a high melting point glass (such as aluminosilicate glass). Quartz being very strong, the gas pressure can be higher, which reduces the rate of evaporation of the filament, permitting it to run a higher temperature (and so efficacy) for the same average life. The tungsten released in hotter regions does not generally redeposit where it came from, so the hotter parts of the filament eventually thin out and fail. Regeneration of the filament is also possible with fluorine, but its chemical activity is so great that other parts of the lamp are attacked.

High temperature filaments emit some energy in the UV region. Small amounts of other elements can be mixed into the quartz, so that the doped quartz (or selective optical coating) blocks harmful UV radiation. Hard glass blocks UV and has been used extensively for the bulbs of car headlights. Alternatively, the halogen lamp can be mounted inside an outer bulb, similar to an ordinary incandescent lamp, which also reduces the risks from the high bulb temperature. Undoped quartz halogen lamps are used in some scientific, medical and dental instruments as a UV-B source.

For a fixed power and life, the efficacy of all incandescent lamps is greatest at a particular design voltage. Halogen lamps made for 12 to 24 volt operation have good light outputs, and the very compact filaments are particularly beneficial for optical control. The range of MR-16 (50 mm diameter) reflector lamps of 20 W to 50 W were originally conceived for the projection of 8 mm film, but are now widely used for display lighting and in the home. More recently, wider beam versions are available designed for direct use on supply voltages of 120 or 230 V.

2.2 EFFECT OF VOLTAGE ON PERFORMANCE

Tungsten halogen lamps behave in a similar manner to other incandescent lamps when run on a different voltage. However the light output is reported as proportional to voltage to the power of 3, and the efficacy proportional to the power of 1.3. The normal relationship regarding life is that it is proportional to voltage to the power of −14. For example, a bulb operated at 5% higher than its design voltage would produce about 15% more light, and the efficacy would be about 6.5% higher, but would be expected to have only half the rated life.

Halogen lamps are manufactured with enough halogen to match the rate of tungsten evaporation at their design voltage. Increasing the applied voltage increases the rate of evaporation, so at some point there may be insufficient halogen and the lamp goes black. Over-voltage operation is not generally recommended. With a reduced voltage the evaporation is lower and there may be too much halogen, which can lead to abnormal failure. At much lower voltages, the bulb temperature may be too low to support the halogen cycle, but by this time the evaporation rate is too low for the bulb to blacken significantly. There are many situations where halogen lamps are dimmed successfully. However, lamp life may not be extended as much as predicted. The life span on dimming depends on lamp construction, the halogen additive used and whether dimming is normally expected for this type.

2.3 SPECTRUM

Like all incandescent light bulbs, a halogen lamp produces a continuous spectrum of light, from near ultraviolet to deep into the infrared. Since the lamp filament can operate at a higher temperature than a non-halogen lamp, the spectrum is shifted toward blue, producing light with a higher effective color temperature.

2.4 SAFETY

Halogen lamps get hotter than regular incandescent lamps because the heat is concentrated on a smaller envelope surface, and because the surface is closer to the filament. This high temperature is essential to their operation. Because the halogen lamp operates at very high temperatures, it can pose fire and burn hazards. Some safety codes now require halogen bulbs to be protected by a grid or grille, especially for high power (1–2 kW) bulbs used in commercial theatre, or by the glass and metal housing of the fixture to prevent ignition of draperies or flammable objects in contact with the lamp.

Additionally, it is possible to get a sunburn from excess exposure to the UV emitted by an undoped quartz halogen lamp. To reduce unintentional UV exposure, and to contain hot bulb fragments in the event of explosive bulb failure, general-purpose lamps usually have a UV-absorbing glass filter over or around the bulb. Alternatively, lamp bulbs may be doped or coated to filter out the UV radiation. When this is done correctly, a halogen lamp with UV inhibitors will produce less UV than its standard incandescent counterpart.

2.5 HANDLING PRECAUTIONS

Any surface contamination, notably fingerprints, can damage the quartz envelope when it is heated. Contaminants will create a hot spot on the bulb surface when the bulb is turned on. This extreme, localized heat causes the quartz to change from its vitreous form into a weaker, crystalline form that leaks gas. This weakening may also cause the bulb to rapidly form a bubble, thereby weakening the bulb and leading to its failure or explosion, and creating a serious safety hazard. Consequently, manufacturers recommend that quartz lamps should be handled without touching the clear quartz, either by using a clean paper towel or carefully holding the porcelain base. If the quartz is contaminated in any way, it must be thoroughly cleaned with rubbing alcohol and dried before use.

2.6 APPLICATIONS

Halogen headlamps were widely implemented in many automobiles. Halogen floodlights for home outdoor lighting systems as well as for watercraft are also manufactured for commercial and recreational use. They are now also used in desktop lamps. With the help of some companies such as Philips and Osram Sylvania, halogen bulbs have been fitted for use with standardized household fittings, and can be another choice as a replacement for incandescent light bulbs.

Tungsten-halogen lamps are frequently used as a near-infrared light source in Infrared spectroscopy.

3 FLUORESCENT LAMP

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp is more costly because it requires a ballast to regulate the flow of current through the lamp.

While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes as incandescents and is used as an energy-saving alternative in homes.

3.1 PRINCIPLES OF OPERATION

The fundamental means for conversion of electrical energy into radiant energy in a fluorescent lamp relies on inelastic scattering of electrons. An incident electron collides with an atom in the gas. If the free electron has enough kinetic energy, it transfers energy to the atom's outer electron, causing that electron to temporarily jump up to a higher energy level. The collision is 'inelastic' because a loss of energy occurs.

This higher energy state is unstable, and the atom will emit an ultraviolet photon as the atom's electron reverts to a lower, more stable, energy level. Most of the photons that are released from the mercury atoms have wavelengths in the ultraviolet (UV) region of the spectrum predominantly at wavelengths of 253.7 nm and 185 nm. These are not visible to the human eye, so they must be converted into visible light. This is done by making use of fluorescence. Ultraviolet photons are absorbed by electrons in the atoms of the lamp's interior fluorescent coating, causing a similar energy jump, then drop, with emission of a further photon. The photon that is emitted from this second interaction has a lower energy than the one that caused it. The chemicals that make up the phosphor are chosen so that these emitted photons are at wavelengths visible to the human eye. The difference in energy between the absorbed ultra-violet photon and the emitted visible light photon goes toward heating up the phosphor coating.

When the light is turned on, the electric power heats up the cathode enough for it to emit electrons. These electrons collide with and ionize noble gas atoms inside the bulb surrounding the filament to form a plasma by a process of impact ionization. As a result of avalanche ionization, the conductivity of the ionized gas rapidly rises, allowing higher currents to flow through the lamp.

3.1.1 CONSTRUCTION

A fluorescent lamp tube is filled with a gas containing low pressure mercury vapor and argon, xenon, neon, or krypton. The pressure inside the lamp is around 0.3% of atmospheric pressure. The inner surface of the bulb is coated with a fluorescent (and often slightly phosphorescent) coating made of varying blends of metallic and rare-earth phosphor salts. The bulb's cathode is typically made of coiled tungsten that is coated with a mixture of barium, strontium and calcium oxides (chosen to have a relatively low thermionic emission temperature).

3.1.2 ELECTRICAL ASPECTS OF OPERATION

Fluorescent lamps are negative differential resistance devices, so as more current flows through them, the electrical resistance of the fluorescent lamp drops, allowing even more current to flow. Connected directly to a constant-voltage mains power supply, a fluorescent lamp would rapidly self-destruct due to the uncontrolled current flow. To prevent this, fluorescent lamps must use an auxiliary device, a ballast, to regulate the current flow through the tube.

The terminal voltage across an operating lamp varies depending on the arc current, tube diameter, temperature, and fill gas. A fixed part of the voltage drop is due to the electrodes.

The simplest ballast for alternating current use is a series coil or choke, consisting of a winding on a laminated magnetic core. The inductance of this winding limits the flow of AC current. Ballasts are rated for the size of lamp and power frequency. Where the mains voltage is insufficient to start long fluorescent lamps, the ballast is often a step-up autotransformer with substantial leakage inductance (so as to limit the current flow). Either form of inductive ballast may also include a capacitor for power factor correction.

Fluorescent lamps can run directly from a DC supply of sufficient voltage to strike an arc. The ballast must be resistive, and would consume about as much power as the lamp. When operated from DC, the starting switch is often arranged to reverse the polarity of the supply to the lamp each time it is started; otherwise, the mercury accumulates at one end of the tube. Fluorescent lamps are (almost) never operated directly from DC for those reasons. Instead, an inverter converts the DC into AC and provides the current-limiting function as described below for electronic ballasts.

3.1.3 EFFECT OF TEMPERATURE

The light output and performance of fluorescent lamps is critically affected by the temperature of the bulb wall and its effect on the partial pressure of mercury vapor within the lamp. Each lamp contains a small amount of mercury, which must vaporize to support the lamp current and generate light. At low temperatures the mercury is in the form of dispersed liquid droplets. As the lamp warms, more of the mercury is in vapor form. At higher temperatures, self-absorption in the vapor reduces the yield of UV and visible light. Since mercury condenses at the coolest spot in the lamp, careful design is required to maintain that spot at the optimum temperature, around 40 °C.

3.1.4 LOSSES

The efficiency of fluorescent lighting owes much to the fact that low pressure mercury discharges emit about 65% of their total light in the 254 nm line (another 10–20% of the light is emitted in the 185 nm line). The UV light is absorbed by the bulb's fluorescent coating, which re-radiates the energy at longer wavelengths to emit visible light. The blend of phosphors controls the color of the light, and along with the bulb's glass prevents the harmful UV light from escaping.

Only a fraction of the electrical energy input into a lamp gets turned into useful light. The ballast dissipates some heat; electronic ballasts may be around 90% efficient. A fixed voltage drop occurs at the electrodes. Some of the energy in the mercury vapor column is also dissipated, but about 85% is turned into visible and ultraviolet light.

Not all the UV energy on the phosphor gets converted into visible light. In a modern lamp, for every 100 incident photons of UV impacting the phosphor, only 86 visible light photons are emitted (a quantum efficiency of 86%). The largest single loss in modern lamps is due to the lower energy of each photon of visible light, compared to the energy of the UV photons that generated them. Incident photons have an energy of 5.5 electron volts but produces visible light photons with energy around 2.5 electron volts, so only 45% of the UV energy is used. If a so-called "two-photon" phosphor could be developed, this would improve the efficiency but much research has not yet found such a system.

3.1.5 STARTING

The mercury atoms in the fluorescent tube must be ionized before the arc can "strike" within the tube. For small lamps, it does not take much voltage to strike the arc and starting the lamp presents no problem, but larger tubes require a substantial voltage (in the range of a thousand volts).

3.1.5.1 SWITCHSTART

This technique uses a combination filament/cathode at each end of the lamp in conjunction with a mechanical or automatic switch that initially connect the filaments in series with the ballast and thereby preheat the filaments prior to striking the arc.

Electronic starters use a more complex method to preheat the cathodes of a fluorescent lamp. They commonly use a specially designed semiconductor switch called a Fluoractor. They are programmed with a predefined preheat time to ensure that the cathodes are fully heated and reduce the amount of sputtered emission mix to prolong the life of the lamp. Electronic starters contain a series of capacitors that are capable of producing a high voltage pulse of electricity across the lamp to ensure that it strikes correctly. Electronic starters only attempt to start a lamp for a short time when power is initially applied and will not repeatedly attempt to restrike a lamp that is dead and cannot sustain an arc. This eliminates the re-striking of a lamp and the cycle of flashing that a failing lamp installed with a glow starter can produce.

When starting the lamp, a glow discharge will appear over the electrodes of the starter. This glow discharge will heat the gas in the starter and cause the bi-metallic electrode to bend towards the other electrode. When the electrodes touch, the two filaments of the fluorescent lamp and the ballast will effectively be switched in series to the supply voltage. This causes the filaments to glow and emit electrons into the gas column by thermionic emission. In the starter's tube, the touching electrodes have stopped the glow discharge, causing the gas to cool down again. The bi-metallic electrode also cools down and starts to move back. When the electrodes separate, the inductive kick from the ballast provides the high voltage to start the lamp. The starter additionally has a capacitor wired in parallel to its gas-discharge tube, in order to prolong the electrode life.

Once the tube is struck, the impinging main discharge then keeps the cathode hot, permitting continued emission without the need for the starter to close. The starter does not close again because the voltage across the starter is reduced by the resistance in the cathodes and ballast. The glow discharge in the starter will not happen at the lower voltage so it will not warm and thus close the starter.

Tube strike is reliable in these systems, but glow starters will often cycle a few times before allowing the tube to stay lit, which causes undesirable flashing during starting. (The older thermal starters behaved better in this respect.)

3.1.5.2 BALLAST ELECTRONICS

This may occur in compact fluorescent lamps with integral electrical ballasts or in linear lamps. Ballast electronics failure is a somewhat random process that follows the standard failure profile for any electronic device. There is an initial small peak of early failures, followed by a drop and steady increase over lamp life. Life of electronics is heavily dependent on operating temperature—it typically halves for each 10 °C temperature rise. The quoted average life of a lamp is usually at 25 °C ambient (this may vary by country). The average life of the electronics at this temperature is normally greater than this, so at this temperature, not many lamps will fail due to failure of the electronics. In some fittings, the ambient temperature could be well above this, in which case failure of the electronics may become the predominant failure mechanism. Similarly, running a compact fluorescent lamp base-up will result in hotter electronics, which can cause shorter average life (particularly with higher power rated ones). Electronic ballasts should be designed to shut down the tube when the emission mix runs out as described above. In the case of integral electronic ballasts, since they never have to work again, this is sometimes done by having them deliberately burn out some component to permanently cease operation.

3.2 PHOSPHOR

The phosphor drops off in efficiency during use. By around 25,000 operating hours, it will typically be half the brightness of a new lamp (although some manufacturers claim much longer half-lives for their lamps). Lamps that do not suffer failures of the emission mix or integral ballast electronics will eventually develop this failure mode. They still work, but have become dim and inefficient. The process is slow, and often only becomes obvious when a new lamp is operating next to an old one.

3.3 LOSS OF MERCURY

Mercury is slowly absorbed into glass, phosphor, and tube electrodes throughout the lamp life, where it can no longer function. Newer lamps now have just enough mercury to last the expected life of the lamp. Loss of mercury will take over from failure of the phosphor in some lamps. The failure symptoms are similar, except loss of mercury initially causes an extended run-up time to full light output, and finally causes the lamp to glow a dim pink when the mercury runs out and the argon base gas takes over as the primary discharge.

3.4 PHOSPHORS AND THE SPECTRUM OF EMITTED LIGHT

The spectrum of light emitted from a fluorescent lamp is the combination of light directly emitted by the mercury vapor, and light emitted by the phosphorescent coating. The spectral lines from the mercury emission and the phosphorescence effect give a combined spectral distribution of light that is different than those produced by incandescent sources. The relative intensity of light emitted in each narrow band of wavelengths over the visible spectrum is in different proportions compared to that of an incandescent source. Colored objects are perceived differently under light sources with differing spectral distributions. For example, some people find the color rendition produced by some fluorescent lamps to be harsh and displeasing. A healthy person can sometimes appear to have an unhealthy skin tone under fluorescent lighting. The extent to which this phenomenon occurs is related to the light's spectral composition, and may be gauged by its color rendering index (CRI).

3.5 USAGE

Residential use of fluorescent lighting remains low (generally limited to kitchens, basements, garages, and other areas), but schools and businesses find the cost savings of fluorescents to be significant and rarely use incandescent lights.

3.6 ADVANTAGES

- **Luminous efficacy:** Fluorescent lamps convert more of the input power to visible light than incandescent lamps. A typical 100 watt tungsten filament incandescent lamp may convert only 2% of its power input to visible white light, whereas typical fluorescent lamps convert about 22% of the power input to visible white light.

- **Life:** Typically a fluorescent lamp will last between 10 to 20 times as long as an equivalent incandescent lamp when operated several hours at a time.

- **Lower luminosity:** Compared with an incandescent lamp, a fluorescent tube is a more diffuse and physically larger light source.

- **Lower heat:** About two-thirds to three-quarters less heat is given off by fluorescent lamps compared to an equivalent installation of incandescent lamps. This greatly reduces the size, cost, and energy consumption of air-conditioning equipment.

3.7 DISADVANTAGES

- **Frequent switching:** If the lamp is installed where it is frequently switched on and off, it will age rapidly. Under extreme conditions, its lifespan may be much shorter than a cheap incandescent lamp.

- **Health and safety issues:** If a fluorescent lamp is broken, a very small amount of mercury can contaminate the surrounding environment. The EPA recommends airing out the location of a fluorescent tube break and using wet paper towels to help pick up the broken glass and fine particles. Any glass and used towels should be disposed of in a sealed plastic bag. Vacuum cleaners can cause the particles to become airborne, and should not be used. Fluorescent lamps emit a small amount of ultraviolet (UV) light. UV light can affect sensitive paintings, especially watercolors and many textiles. Valuable art work must be protected from light by additional glass or transparent acrylic sheets put between the lamp(s) and the painting.

- **Ballast:** Fluorescent lamps require a ballast to stabilize the current through the lamp, and to provide the initial striking voltage required to start the arc discharge. This increases the cost of fluorescent light fixtures, though often one ballast is shared between two or more lamps. Electromagnetic ballasts with a minor fault can produce an audible humming or buzzing noise.

- **Power quality and radio interference:** Simple inductive fluorescent lamp ballasts have a power factor of less than unity. Inductive ballasts include power factor correction capacitors. Simple electronic ballasts may also have low power factor due to their rectifier input stage.

  Fluorescent lamps are a non-linear load and generate harmonic currents in the electrical power supply. The arc within the lamp may generate radio frequency noise, which can be conducted through power wiring. Suppression of radio interference is possible. Very good suppression is possible, but adds to the cost of the fluorescent fixtures.

- **Operating temperature:** Fluorescent lamps operate best around room temperature. At much lower or higher temperatures, efficiency decreases.

- **Lamp shape:** Fluorescent tubes are long, low-luminance sources compared with high pressure arc lamps and incandescent lamps. However, low luminous intensity of the emitting surface is useful because it reduces glare. Lamp fixture design must control light from a long tube instead of a compact globe.

  The compact fluorescent lamp (CFL) replaces regular incandescent bulbs. However, some CFLs will not fit some lamps, because the harp (heavy wire shade support bracket) is shaped for the narrow neck of an incandescent lamp. CFLs tend to have a wide housing for their electronic ballast close to the bulb's base, and so may not fit some lamps.

- **Flicker problems:** Fluorescent lamps using a magnetic mains frequency ballast do not give out a steady light; instead, they flicker at twice the supply frequency. This effect is eliminated by paired lamps operating on a lead-lag ballast. Unlike a true strobe lamp, the light level drops in appreciable time and so substantial "blurring" of the moving part would be evident.

- **Dimming:** Fluorescent light fixtures cannot be connected to the same dimmer switch used for incandescent lamps. Two effects are responsible for this: the waveshape of the voltage emitted by a standard phase-control dimmer interacts badly with many types of ballast, and it becomes difficult to sustain an arc in the fluorescent tube at low power levels. Dimming installations require a compatible dimming ballast. These systems keep the cathodes of the fluorescent tube fully heated even as the arc current is reduced, promoting easy thermionic emission of electrons into the arc stream. CFLs are available that work in a dimmer circuit.

3.8 DISPOSAL AND RECYCLING

The disposal of phosphor and particularly the toxic mercury in the tubes is an environmental issue. Governmental regulations in many areas require special disposal of fluorescent lamps separate from general and household wastes. For large commercial or industrial users of fluorescent lights, recycling services are available in many nations, and may be required by regulation. In some areas, recycling is also available to consumers.

3.9 COLORS

Color is usually indicated by WW for warm white, EW for enhanced (neutral) white, CW for cool white (the most common), and DW for the bluish daylight white. BLB is used for blacklight-blue lamps commonly used in bug zappers. BL is used for blacklight lamps commonly used in nightclubs. Other non-standard designations apply for plant lights or grow lights.

Philips and Osram use numeric color codes for the colors. On tri-phosphor and multi-phosphor tubes, the first digit indicates the color rendition index of the lamp. If the first digit on a lamp says 8, then the CRI of that lamp will be approximately 85. The last two digits indicate the color temperature of the lamp in kelvins (K). For example, if the last two digits on a lamp say 41, that lamp's color temperature will be 4100 K, which is a common tri-phosphor cool white fluorescent lamp.

4 COMPACT FLUORESCENT LAMP

A compact fluorescent lamp (CFL), also known as a compact fluorescent light or energy saving light (or less commonly as a compact fluorescent tube [CFT]), is a type of fluorescent lamp. Many CFLs are designed to replace an incandescent lamp and can fit into most existing light fixtures formerly used for incandescents.

Compared to general service incandescent lamps giving the same amount of visible light, CFLs use less power and have a longer rated life. Like all fluorescent lamps, CFLs contain mercury, which complicates their disposal.

CFLs radiate a different light spectrum from that of incandescent lamps. Improved phosphor formulations have improved the subjective color of the light emitted by CFLs such that some sources rate the best 'soft white' CFLs as subjectively similar in color to standard incandescent lamps.

4.1 CONSTRUCTION

4.1.1 PARTS

There are two main parts in a CFL: the gas-filled tube (also called bulb or burner) and the magnetic or electronic ballast. An electrical current from the ballast flows through the gas (mercury vapour), causing it to emit ultraviolet light. The ultraviolet light then excites a phosphor coating on the inside of the tube. This coating emits visible light.

Electronic ballasts contain a small circuit board with rectifiers, a filter capacitor and usually two switching transistors connected as a high-frequency resonant series DC to AC inverter.

There are two types of CFLs: integrated and non-integrated lamps.

4.1.1.1. INTEGRATED CFLS

Integrated lamps combine a tube, an electronic ballast and either an Edison screw or bayonet fitting in a single CFL unit. These lamps allow consumers to replace incandescent lamps easily with CFLs.

Integrated CFLs work well in many standard incandescent light fixtures, which lowers the cost of CFL conversion.

Special 3-way models and dimmable models with standard bases are available for use when those features are needed.

4.1.1.2. NON-INTEGRATED CFLS

There are two types of bulbs: bi-pin tubes designed for conventional ballasts and quad-pin tubes designed for electronic ballasts and conventional ballasts with an external starter.

The bi-pin tubes contain an integrated starter in the base, which obviates the need for external heating pins, but causes incompatibility with electronic ballasts.

There are different standard shapes of tubes: single-turn, double-turn, triple-turn, quad-turn, circular, and butterfly.

Since the ballasts are placed in the light fixture they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the bulb reaches its end-of-life. Non-integrated CFL housings can be both more expensive and sophisticated.

4.2 COMPARISON WITH INCANDESCENT LAMPS

4.2.1 LIFESPAN

The average rated life of a CFL is between 8 and 15 times that of incandescents. CFLs typically have a rated lifespan of between 6,000 and 15,000 hours, whereas incandescent lamps are usually manufactured to have a lifespan of 750 hours or 1,000 hours.

The lifetime of any lamp depends on many factors including operating voltage, manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off, lamp orientation and ambient operating temperature, among other factors. The life of a CFL is significantly shorter if it is only turned on for a few minutes.

CFLs produce less light later in their life than when they are new. CFLs can be expected to produce 70–80% of their original light output.

4.2.2. HEATING

If a building's indoor incandescent lamps are replaced by CFLs, the heat produced due to lighting will be reduced. At times when the building requires both heating and lighting, the heating system will make up the heat.

4.2.3. EFFICACY AND EFFICIENCY

A typical CFL is in the range of 17 to 21% efficient at converting electric power to radiant power based on 60 to 72 lumens per watt source efficacy, and 347 lumens per radiant watt luminous efficacy of radiation for a tri-phosphor spectrum

4.2.4. COST

While the purchase price of an integrated CFL is typically 3 to 10 times greater than that of an equivalent incandescent lamp, the extended lifetime and lower energy use will more than compensate for the higher initial cost.

4.2.5. STARTING TIME

Incandescents reach full brightness a fraction of a second after being switched on. As of 2009, CFLs turn on within a second, but may still take time to warm up to full brightness. Some CFLs are marketed as "instant on" and have no noticeable warm-up period, but others can take up to a minute to reach full brightness, or longer in very cold temperatures.

4.3. SPECTRUM OF LIGHT

The light of CFLs is emitted by a mix of phosphors on the inside of the tube, which each emit one color. Modern phosphor designs are a compromise between the shade of the emitted light, energy efficiency, and cost.

Every extra phosphor added to the coating mix causes a loss of efficiency and increased cost. Good quality consumer CFLs use three or four phosphors to achieve a 'white' light with a CRI (color rendering index) of around 80, where 100 represents the appearance of colors under daylight or a black-body (depending on the correlated color temperature).

Color temperature is a quantitative measure. The higher the number in kelvins, the 'cooler' (i.e., bluer) the shade. Color names associated with a particular color temperature are not standardized for modern CFLs and other triphosphor lamps like they were for the older-style halophosphate fluorescent lamps.

4.4. HEALTH ISSUES

According to the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) in 2008, the only property of compact fluorescent lamps that could pose an added health risk is the ultraviolet and blue light emitted by such devices. The worst that can happen is that this radiation could aggravate symptoms in people who already suffer rare skin conditions that make them exceptionally sensitive to light. They also stated that more research is needed to establish whether compact fluorescent lamps constitute any higher risk than incandescent lamps.

If individuals are exposed to the light produced by some single-envelope compact fluorescent lamps for long periods of time at distances of less than 20 cm, it could lead to ultraviolet exposures approaching the current workplace limit set to protect workers from skin and retinal damage.

The UV received from CFLs is too small to contribute to skin cancer and the use of double-envelope CFL lamps "largely or entirely" mitigates any other risks, they say.

4.5. ENVIRONMENTAL ISSUES

4.5.2. MERCURY EMISSIONS

CFLs, like all fluorescent lamps, contain small amounts of mercury as vapor inside the glass tubing. Most CFLs contain 3 – 5 mg per bulb, with some brands containing as little as 1 mg. Because mercury is poisonous, even these small amounts are a concern for landfills and waste incinerators where the mercury from lamps may be released and contribute to air and water pollution.

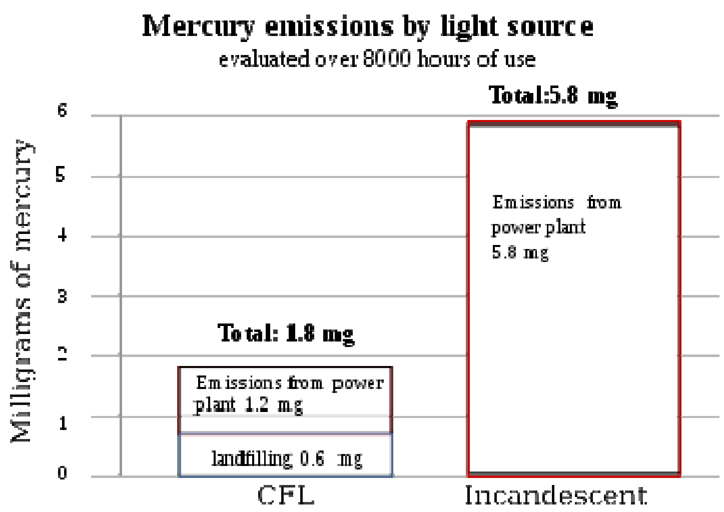


Figure 2. Mercury emissions by light source

Net mercury emissions for CFL and incandescent lamps, based on EPA FAQ sheet, assuming average US emission of 0.012 mg of mercury per kilowatthour and 14% of CFL mercury contents escapes to environment after land fill disposal.

In the United States, the U.S. Environmental Protection Agency estimated that if all 270 million compact fluorescent lamps sold in 2007 were sent to landfill sites, that this would represent around 0.13 tons (US), or 0.1% of all U.S. emissions of mercury (around 104 tons (US)) that year.

4.5.2.1.BROKEN AND DISCARDED LAMPS

Spent lamps should be properly disposed of, or recycled, to contain the small amount of mercury in each lamp, in preference to disposal in landfills. In the European Union, CFLs are one of many products subject to the WEEE recycling scheme. The retail price includes an amount to pay for recycling, and manufacturers and importers have an obligation to collect and recycle CFLs. Safe disposal requires storing the bulbs unbroken until they can be processed. In the US, The Home Depot is the first retailer to make CFL recycling options widely available.

Special handling instructions for breakage are currently not printed on the packaging of household CFL bulbs in many countries. The amount of mercury released by one bulb can temporarily exceed U.S. federal guidelines for chronic exposure. Chronic however, implies that the exposure continues constantly over a long period of time and the Maine DEP study noted that it remains unclear what the health risks are from short-term exposure to low levels of elemental mercury. The Maine DEP study also confirmed that, despite following EPA best-practice cleanup guidelines on broken CFLs, researchers were unable to remove mercury from carpet, and agitation of the carpet—such as by young children playing—created spikes as high as 25,000 ng/m^3 in air close to the carpet, even weeks after the initial breakage. Conventional tubular fluorescent lamps have been in commercial and domestic use since the 1930s with little public concern about their handling; these and other domestic products such as thermometers contain far more mercury than modern CFLs.

The U.S. Environmental Protection Agency (EPA) recommends that, in the absence of local guidelines, fluorescent bulbs be double-bagged in plastic before disposal. The Maine DEP study of 2008 compared clean-up methods, and warned that the EPA recommendation of plastic bags was the worst choice, as vapours well above safe levels continued to leach from the bags. The Maine DEP now recommends a sealed glass jar as the best repository for a broken bulb.

The first step of processing CFLs involves crushing the bulbs in a machine that uses negative pressure ventilation and a mercury-absorbing filter or cold trap to contain mercury vapor. Many municipalities are purchasing such machines. The crushed glass and metal is stored in drums, ready for shipping to recycling factories.

According to the Northwest Compact Fluorescent Lamp Recycling Project, because household users in the U.S. Northwest have the option of disposing of these products in the same way they dispose of other solid waste, in Oregon "a large majority of household CFLs are going to municipal solid waste". They also note the EPA's estimates for the percentage of fluorescent lamps' total mercury released when they are disposed of in the following ways: municipal waste landfill 3.2%, recycling 3%, municipal waste incineration 17.55% and hazardous waste disposal 0.2%.

4.6. DESIGN AND APPLICATION ISSUES

The primary objectives of CFL design are high electrical efficiency and durability. However, there are some other areas of CFL design and operation that are problematic:

Size

CFL light output is roughly proportional to phosphor surface area, and high output CFLs are often larger than their incandescent equivalents. This means that the CFL may not fit well in existing light fixtures.

End of life

In addition to the wear-out failure modes common to all fluorescent lamps, the electronic ballast may fail since it has a number of component parts. The lamps are internally protected and are meant to fail safely at the end of their lives.

Incandescent replacement wattage inflation

An August 2009 newspaper report described that some manufacturers claim the CFL replaces a higher wattage incandescent lamp than justified by the light produced by the CFL. Equivalent wattage claims can be replaced by comparison of the lumens produced by the lamp.

Dimming

Only some CF lamps are labeled for dimming control. Using regular CFLs with a dimmer is ineffective at dimming, can shorten bulb life and will void the warranty of certain manufacturers. Dimmable CFLs are available. The dimming range of CFLs is usually between 20% and 90%.

Perceived coldness of low intensity CFL

When a CFL is dimmed the colour temperature (warmth) stays the same. This is counter to most other light sources (such as the sun or incandescents) where colour gets warmer as the light source gets dimmer.

Heat

Some CFLs are labeled not to be run base up, since heat will shorten the ballast's life. Such CFLs are unsuitable for use in pendant lamps and especially unsuitable for recessed light fixtures. CFLs for use in such fixtures are available.

Power quality

The introduction of CFLs may affect power quality appreciably, particularly in large-scale installations.

Time to achieve full brightness

Compact fluorescent lamps may provide as little as 50–80% of their rated light output at initial switch on and can take up to three minutes to warm up, and color cast may be slightly different immediately after being turned on.

Infrared signals

Electronic devices operated by infrared remote control can interpret the infrared light emitted by CFLs as a signal, this limits the use of CFLs near televisions, radios, remote controls, or mobile phones.

Audible noise

CFLs, much as other fluorescent lights, may emit a buzzing sound, where incandescents normally do not. The noise can be generated by the ballast circuit in the CFL.

Iridescence

Fluorescent lamps can cause window film to exhibit iridescence. This phenomenon usually occurs at night. The amount of iridescence may vary from almost imperceptible, to very visible and most frequently occurs when the film is constructed using one or more layers of sputtered metal.

Use with timers, motion sensors, and other electronic controls

Electronic (but not mechanical) timers can interfere with the electronic ballast in CFLs and can shorten their lifespan. Some timers rely on a connection to neutral through the bulb and so pass a tiny current through the bulb, charging the capacitors in the electronic ballast. They may not work with a CFL connected, unless an incandescent bulb is also connected. They may also cause the CFL to flash when off. This can also be true for illuminated wall switches and motion sensors.

Fire hazard

When the base of the bulb is not made to be flame-retardant then the electrical components in the bulb can overheat which poses a fire hazard.

Outdoor use

CFLs not designed for outdoor use will not start in cold weather. CFLs are available with cold-weather ballasts, which may be rated to as low as −23 °C. Light output drops at low temperatures.

Differences among manufacturers

There are large differences among quality of light, cost, and turn-on time among different manufacturers, even for lamps that appear identical and have the same color temperature.

Lifetime brightness

Fluorescent lamps get dimmer over their lifetime, so what starts out as an adequate luminosity may become inadequate. In one test by the US Department of Energy of 'Energy Star' products in 2003–04, one quarter of tested CFLs no longer met their rated output after 40% of their rated service life.

UV emissions

Fluorescent bulbs can damage paintings and textiles which have light-sensitive dyes and pigments. Strong colours will tend to fade on exposure to UV light.

5. LIGHT-EMITTING DIODE

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

The LED is based on the semiconductor diode. When a diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. An LED is usually small in area (less than 1 mm^2), and integrated optical components are used to shape its radiation pattern and assist in reflection. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. However, they are relatively expensive and require more precise current and heat management than traditional light sources. Current LED products for general lighting are more expensive to buy than fluorescent lamp sources of comparable output.

5.1. TECHNOLOGY

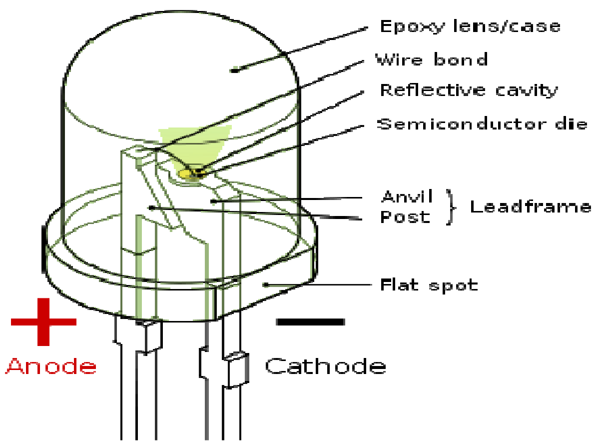


Figure 3. Parts of LED

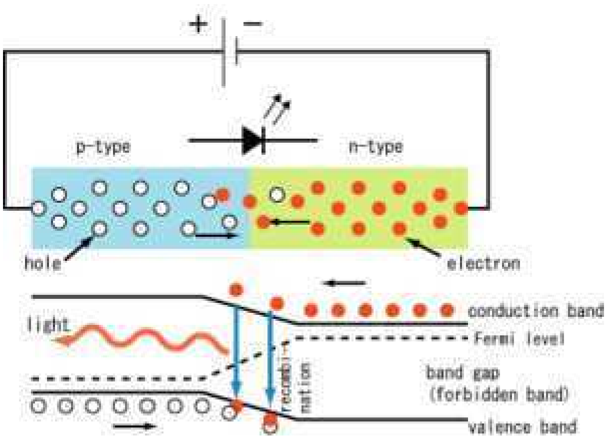


Figure 4. The inner workings of an LED

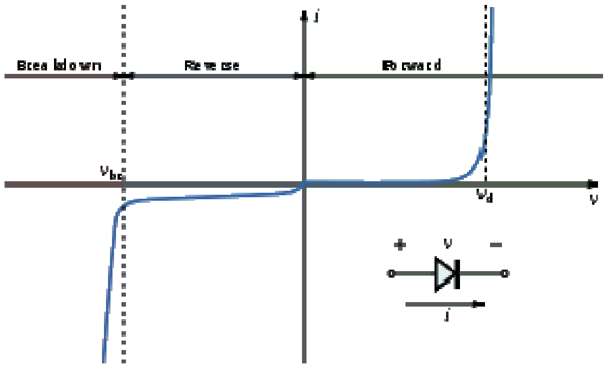


Figure 5. I-V diagram for a diode an LED will begin to emit light when the on-voltage is exceeded. Typical on voltages are 2-3 Volt

5.1.1. PHYSICS

Like a normal diode, the LED consists of a chip of semiconducting material impregnated, or doped, with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and therefore its color, depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

5.1.2. EFFICIENCY AND OPERATIONAL PARAMETERS

Typical indicator LEDs are designed to operate with no more than 30–60 milliwatts [mW] of electrical power. Around 1999, Philips Lumileds introduced power LEDs capable of continuous use at one watt [W].

One of the key advantages of LED-based lighting is its high efficiency, as measured by its light output per unit power input. White LEDs quickly matched and overtook the efficiency of standard incandescent lighting systems. For comparison, a conventional 60–100 W incandescent lightbulb produces around 15 lm/W, and standard fluorescent lights produce up to 100 lm/W. A recurring problem is that efficiency will fall dramatically for increased current. This effect is known as droop and effectively limits the light output of a given LED, increasing heating more than light output for increased current.

It should be noted that high-power (≥ 1 W) LEDs are necessary for practical general lighting applications. Typical operating currents for these devices begin at 350 mA. The highest efficiency high-power white LED is claimed by Philips Lumileds Lighting Co. with a luminous efficacy of 115 lm/W (350 mA)

Note that these efficiencies are for the LED chip only, held at low temperature in a lab. In a lighting application, operating at higher temperature and with drive circuit losses, efficiencies are much lower. United States Department of Energy (DOE) testing of commercial LED lamps designed to replace incandescent or CFL lamps showed that average efficacy was still about 31 lm/W in 2008 (tested performance ranged from 4 lm/W to 62 lm/W).

5.1.3. LIFETIME AND FAILURE

LEDs are subject to very limited wear and tear if operated at low currents and at low temperatures. Typical lifetimes quoted are 25,000 to 100,000 hours but heat and current settings can extend or shorten this time significantly.

The most common symptom of LED failure is the gradual lowering of light output and loss of efficiency. To quantitatively classify lifetime in a standardized manner it has been suggested to use the terms L75 and L50 which is the time it will take a given LED to reach 75% and 50% light output respectively. L50 is equivalent to the half-life of the LED.

5.2.COLORS AND MATERIALS

Conventional LEDs are made from a variety of inorganic semiconductor materials, the following table shows the available colors with wavelength range, voltage drop and material. (See table in annex)

5.2.1. WHITE LIGHT

There are two primary ways of producing high intensity white-light using LEDs. One is to use individual LEDs that emit three primary colors – red, green, and blue, and then mix all the colors to produce white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works. Due to metamerism, it is possible to have quite different spectra which appear white.

5.2.1.1. RGB SYSTEMS

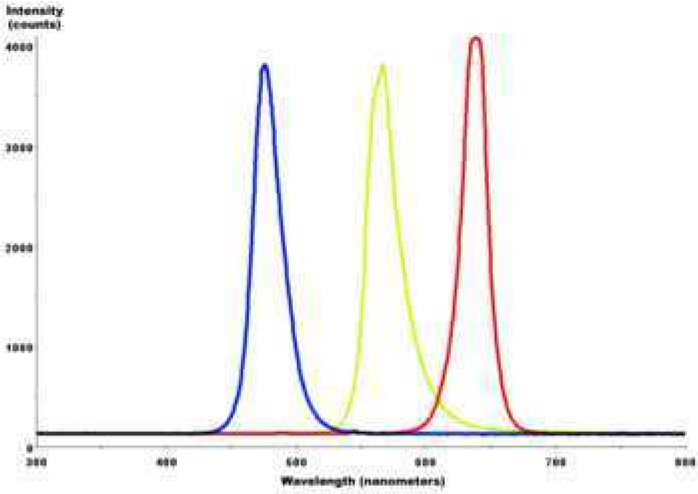


Figure 6. Combined spectral curves for blue, yellow-green, and high brightness red solid-state semiconductor LEDs. FWHM spectral bandwidth is approximately 24–27 nm for all three colors.

White light can be produced by mixing differently colored light, the most common method is to use red, green and blue (RGB). Hence the method is called multi-colored white LEDs (sometimes referred to as RGB LEDs). Because its mechanism is involved with sophisticated electro-optical design to control the blending and diffusion of different colors, this approach has rarely been used to mass produce white LEDs in the industry. Nevertheless this method is particularly interesting to many researchers and scientists because of the flexibility of mixing different colors. In principle, this mechanism also has higher quantum efficiency in producing white light.

There are several types of multi-colored white LEDs: di-, tri-, and tetrachromatic white LEDs. Several key factors that play among these different approaches include color stability, color rendering capability, and luminous efficacy. Often higher efficiency will mean lower color rendering, presenting a trade off between the luminous efficiency and color rendering. For example, the dichromatic white LEDs have the best luminous efficacy(120 lm/W), but the lowest color rendering capability. Conversely, although tetrachromatic white LEDs have excellent color rendering capability, they often have poor luminous efficiency. Trichromatic white LEDs are in between, having both good luminous efficacy(>70 lm/W) and fair color rendering capability.

What multi-color LEDs offer is not merely another solution of producing white light, but is a whole new technique of producing light of different colors. In principle, most perceivable colors can be produced by mixing different amounts of three primary colors, and this makes it possible to produce precise dynamic color control as well. As more effort is devoted to investigating this technique, multi-color LEDs should have profound influence on the fundamental method which we use to produce and control light color. However, before this type of LED can truly play a role on the market, several technical problems need to be solved. These certainly include that this type of LED's emission power decays exponentially with increasing temperature, resulting in a substantial change in color stability. Such problems are not acceptable for industrial usage. Therefore, many new package designs aimed at solving this problem have been proposed and their results are now being reproduced by researchers and scientists.

5.2.1.2.PHOSPHOR BASED LEDS

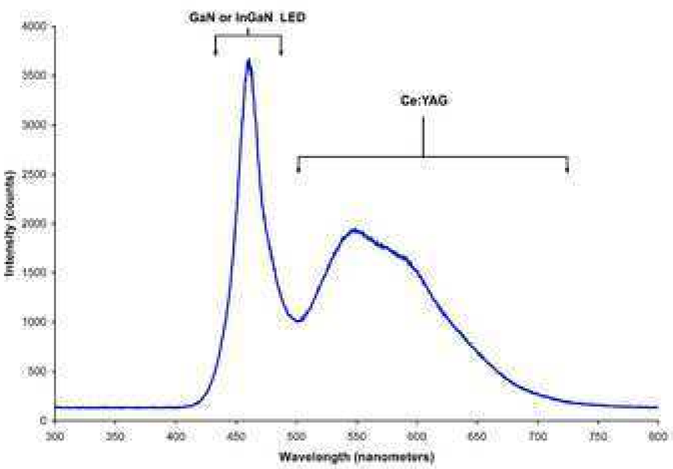


Figure 7. Spectrum of a “white” LED clearly showing blue light which is directly emitted by the GaN-based LED (peak at about 465 nm) and the more broadband Stokes-shifted light emitted by the Ce^{3+}:YAG phosphor which emits at roughly 500–700 nm.

This method involves coating an LED of one color (mostly blue LED made of InGaN) with phosphor of different colors to produce white light, the resultant LEDs are called phosphor based white LEDs. A fraction of the blue light undergoes the Stokes shift being transformed from shorter wavelengths to longer. Depending on the color of the original LED, phosphors of different colors can be employed. If several phosphor layers of distinct colors are applied, the emitted spectrum is broadened, effectively increasing the color rendering index (CRI) value of a given LED.

Phosphor based LEDs have a lower efficiency than normal LEDs due to the heat loss from the Stokes shift and also other phosphor-related degradation issues. However, the phosphor method is still the most popular technique for manufacturing high intensity white LEDs. The design and production of a light source or light fixture using a monochrome emitter with phosphor conversion is simpler and cheaper than a complex RGB system, and the majority of high intensity white LEDs presently on the market are manufactured using phosphor light conversion.

The greatest barrier to high efficiency is the seemingly unavoidable Stokes energy loss. However, much effort is being spent on optimizing these devices to higher light output and higher operation temperatures. For instance, the efficiency can be increased by adapting better package design or by using a more suitable type of phosphor. Philips Lumileds' patented conformal coating process addresses the issue of varying phosphor thickness, giving the white LEDs a more homogeneous white light. With development ongoing, the efficiency of phosphor based LEDs is generally increased with every new product announcement.

Technically the phosphor based white LEDs encapsulate InGaN blue LEDs inside of a phosphor coated epoxy. A common yellow phosphor material is cerium-doped yttrium aluminium garnet (Ce^{3+}:YAG).

White LEDs can also be made by coating near ultraviolet (NUV) emitting LEDs with a mixture of high efficiency europium-based red and blue emitting phosphors plus green emitting copper and aluminium doped zinc sulfide (ZnS:Cu, Al). This is a method analogous to the way fluorescent lamps work. This method is less efficient than the blue LED with YAG:Ce phosphor, as the Stokes shift is larger and more energy is therefore converted to heat, but yields light with better spectral characteristics, which render color better. Due to the higher radiative output of the ultraviolet LEDs than of the blue ones, both approaches offer comparable brightness. Another concern is that UV light may leak from a malfunctioning light source and cause harm to human eyes or skin.

5.2.1.3. OTHER WHITE LEDS

Another method used to produce experimental white light LEDs used no phosphors at all and was based on homoepitaxially grown zinc selenide (ZnSe) on a ZnSe substrate which simultaneously emitted blue light from its active region and yellow light from the substrate.

5.3.TYPES

The main types of LEDs are miniature, high power devices and custom designs such as alphanumeric or multi-color.

5.3.1. MINIATURE LEDS

These are mostly single-die LEDs used as indicators, and they come in various-sizes from 2 mm to 8 mm, through-hole and surface mount packages. They are usually simple in design, not requiring any separate cooling body. Typical current ratings ranges from around 1 mA to above 20 mA. The small scale sets a natural upper boundary on power consumption due to heat caused by the high current density and need for heat sinking.

5.3.2. HIGH POWER LEDS

High power LEDs (HPLED) can be driven at currents from hundreds of mA to more than an ampere, compared with the tens of mA for other LEDs. They produce up to over a thousand lumens. Since overheating is destructive, the HPLEDs must be mounted on a heat sink to allow for heat dissipation. If the heat from a HPLED is not removed, the device will burn out in seconds. A single HPLED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.

5.3.3. APPLICATION-SPECIFIC VARIATIONS

- Flashing LEDs are used as attention seeking indicators without requiring external electronics.

- Bi-color LEDs are actually two different LEDs in one case. They consist of two dies connected to the same two leads but in opposite directions. Current flow in one direction produces one color, and current in the opposite direction produces the other color. Alternating the two colors with sufficient frequency causes the appearance of a blended third color.

- Tri-color LEDs are two LEDs in one case, but the two LEDs are connected to separate leads so that the two LEDs can be controlled independently and lit simultaneously. A three-lead arrangement is typical with one common lead (anode or cathode).

- RGB LEDs contain red, green and blue emitters, generally using a four-wire connection with one common lead (anode or cathode). These LEDs can have either common positive or common negative leads. Others however, have only two leads (positive and negative) and have a built in tiny electronic control unit.

- Alphanumeric LED displays are available in seven-segment and starburst format. Seven-segment displays handle all numbers and a limited set of letters. Starburst displays can display all letters. Seven-segment LED displays were in widespread use in the 1970s and 1980s, but increasing use of liquid crystal displays, with their lower power consumption and greater display flexibility, has reduced the popularity of numeric and alphanumeric LED displays.

5.4. ADVANTAGES

- **Efficiency:** LEDs produce more light per watt than incandescent bulbs.

- **Color:** LEDs can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs.

- **Size:** LEDs can be very small (smaller than 2 mm^2) and are easily populated onto printed circuit boards.

- **On/Off time:** LEDs light up very quickly. A typical red indicator LED will achieve full brightness in microseconds. LEDs used in communications devices can have even faster response times.

- **Cycling:** LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.

- **Dimming:** LEDs can very easily be dimmed either by Pulse-width modulation or lowering the forward current.

- **Cool light:** In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.

- **Slow failure:** LEDs mostly fail by dimming over time, rather than the abrupt burn-out of incandescent bulbs.

- **Lifetime:** LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer. Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000–2,000 hours.

- **Shock resistance:** LEDs, being solid state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs which are fragile.

- **Focus:** The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner.

- **Toxicity:** LEDs do not contain mercury, unlike fluorescent lamps.

5.5. DISADVANTAGES

- **High initial price:** LEDs are currently more expensive, price per lumen, on an initial capital cost basis, than most conventional lighting technologies.

- **Temperature dependence:** LED performance largely depends on the ambient temperature of the operating environment. Over-driving the LED in high ambient temperatures may result in overheating of the LED package, eventually leading to device failure. Adequate heat-sinking is required to maintain long life.

- **Voltage sensitivity:** LEDs must be supplied with the voltage above the threshold and a current below the rating. This can involve series resistors or current-regulated power supplies.

- **Light quality:** Most cool-white LEDs have spectra that differ significantly from a black body radiator like the sun or an incandescent light. The spike at 460 nm and dip at 500 nm can cause the color of objects to be perceived differently under cool-white LED illumination than sunlight or incandescent sources, due to metamerism, red surfaces being rendered particularly badly by typical phosphor based cool-white LEDs. However, the color rendering properties of common fluorescent lamps are often inferior to what is now available in state-of-art white LEDs.

- **Area light source:** LEDs do not approximate a "point source" of light, but rather a lambertian distribution. So LEDs are difficult to use in applications requiring a spherical light field.

- **Blue hazard:** There is a concern that blue LEDs and cool-white LEDs are now capable of exceeding safe limits of the so-called blue-light hazard as defined in eye safety specifications such as ANSI/IESNA RP-27.1-05: Recommended Practice for Photobiological Safety for Lamp and Lamp Systems.

- **Blue pollution:** Because cool-white LEDs emit proportionally more blue light than conventional outdoor light sources such as high-pressure sodium lamps, the strong wavelength dependence of Rayleigh scattering means that cool-white LEDs can cause more light pollution than other light sources.

5.6. APPLICATION

Application of LEDs falls into three major categories:

- Visual signal.
- Generate light for measuring and interacting with processes that do not involve the human visual system.
- Illumination.

5.6.1. INDICATORS AND SIGNS

The low energy consumption, low maintenance and small size of modern LEDs has led to applications as status indicators and displays on a variety of equipment and installations. Large area LED displays are used as stadium displays and as dynamic decorative displays.

The single color light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting, ships' lanterns and LED-based Christmas lights.

Because of their long life and fast switching times, LEDs have been used for automotive high-mounted brake lights and truck and bus brake lights and turn signals for some time, but many vehicles now use LEDs for their rear light clusters. The use of LEDs also has styling advantages because LEDs are capable of forming much thinner lights than incandescent lamps with parabolic reflectors. The significant improvement in the time taken to light up (perhaps 0.5s faster than an incandescent bulb) improves safety by giving drivers more time to react.

5.6.2. NON-VISUAL APPLICATIONS

Light has many other uses besides for seeing. LEDs are used for some of these applications. The uses fall in three groups: Communication, sensors and light matter interaction.

The light from LEDs can be modulated very quickly so they are used extensively in optical fiber and Free Space Optics communications. This include remote controls, such as for TVs and VCRs, where infrared LEDs are often used.

Many sensor systems rely on light as the signal source. LEDs are often ideal as a light source due to the requirements of the sensors. LEDs are used as movement sensors, for example in optical computer mice.

Many materials and biological systems are sensitive to, or dependent on light. Grow lights use LEDs to increase photosynthesis in plants and bacteria and viruses can be removed from water and other substances using UV LEDs for sterilization. Other uses are as UV curing devices for some ink and coating applications as well as LED printers.

5.6.3. LIGHTING

With the development of high efficiency and high power LEDs it has become possible to incorporate LEDs in lighting and illumination. Replacement light bulbs have been made as well as dedicated fixtures and LED lamps. LEDs are used as street lights and in other architectural lighting where color changing is used. The mechanical robustness and long lifetime is used in automotive lighting on cars, motorcycles and on bicycle lights. LEDs have been used for lighting of streets and of parking garages.

The lack of IR/heat radiation makes LEDs ideal for stage lights using banks of RGB LEDs that can easily change color and decrease heating from traditional stage lighting, as well as medical lighting where IR-radiation can be harmful.

Since LEDs are small, durable and require little power they are used in hand held devices such as flashlights. LED strobe lights or camera flashes operate at a safe, low voltage, as opposed to the 250+ volts commonly found in xenon flashlamp-based lighting. This is particularly applicable to cameras on mobile phones, where space is at a premium and bulky voltage-increasing circuitry is undesirable. LEDs are used for infrared illumination in night vision applications including security cameras. A ring of LEDs around a video camera, aimed forward into a retroreflective background, allows chroma keying in video productions.

LEDs are used for decorative lighting as well. Uses include but are not limited to indoor/outdoor decor, limousines, cargo trailers, conversion vans, cruise ships, RVs, boats, automobiles, and utility trucks. Decorative LED lighting can also come in the form of lighted company signage and step and aisle lighting in theaters and auditoriums.

6. LED LAMP

A Light-Emitting-Diode lamp is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. Since the light output of individual light-emitting diodes is small compared to incandescent and compact fluorescent lamps, multiple diodes are used together. LED lamps can be made interchangeable with other types, but presently at a higher cost. Most LED lamps must also include internal circuits to operate from standard AC voltages. LED lamps offer long life and high efficiency, but initial costs are higher than that of fluorescent lamps.

6.1.TECHNOLOGY OVERVIEW

General purpose lighting requires white light. To create white light from LEDs requires either mixing light from red, green, and blue LEDs, or using a phosphor to convert some of the light to other colors.

- The first method (RGB-LEDs).
- The second method, phosphor converted LEDs (pcLEDs).

6.2.APPLICATION

LED lamps are used for both general lighting and special purpose lighting. Where colored light is required, LEDs come in multiple colors, which are produced without the need for filters. This improves the energy efficiency over a white light source that generates all colors of light then discards some of the visible energy in a filter.

White-light light-emitting diode lamps have the characteristics of long life expectancy and relatively low energy consumption. The LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. LED lamps have no glass tubes to break, and their internal parts are rigidly supported, making them resistant to vibration and impact. With proper driver electronics design, an LED lamp can be made dimmable over a wide range; there is no minimum current needed to sustain lamp operation.LED lamps contain no mercury.

However, some current models are not compatible with standard dimmers. As a result, current LED screw-in light bulbs offer either low levels of light at a moderate cost, or moderate levels of light at a high cost. In contrast to other lighting technologies, LED light tends to be directional. This is a disadvantage for most general lighting applications, but can be an advantage for spot or flood lighting.

6.3. USING LED LAMPS ON HOUSEHOLD AC POWER

A single LED is a low-voltage solid state device and cannot be directly operated on household AC current without some circuit to control current flow through the lamp. A series resistor could be used to limit current, but this is inefficient since most of the applied voltage would be wasted on the resistor. A single series string would minimize dropper losses, but one LED failure would extinguish the whole string. Paralleled strings increase reliability. In practice usually 3 strings or more are used.

6.3.1. LAMP SIZES AND BASES

LED lamps intended to be interchangeable with incandescent lamps are made in standard light bulb shapes, such as an Edison screw base, an MR16 shape with a bi-pin base, or a GU5.3 (Bipin cap) or GU10 (bayonet socket). LED lamps are made in low voltage (typically 12 V halogen-like) varieties and replacements for regular AC (e.g. 120 or 240 VAC) lighting. Currently the latter are less widely available but this is changing rapidly.

6.4. ENVIRONMENTALLY FRIENDLY OPTIONS

A single kilowatt-hour of electricity will generate 1.34 pounds (610 g) of CO_2 emissions. Assuming the average light bulb is on for 10 hours a day, a single 40-watt incandescent bulb will generate 196 pounds (89 kg) of CO_2 every year. The 13-watt LED equivalent will only be responsible for 63 pounds (29 kg) of CO_2 over the same time span. A building's carbon footprint from lighting can be reduced by 68% by exchanging all incandescent bulbs for new LEDs in warm climates. In cold climates, the energy saving may be lower, since more heating would be needed to compensate for the lower temperature.

LEDs are also non-toxic unlike the more popular energy efficient bulb option: the compact florescent a.k.a. CFL which contains traces of harmful mercury. While the amount of mercury in a CFL is small, introducing less into the environment is preferable.

6.5. ECONOMICALLY SUSTAINABLE

LED light bulbs could be a cost effective option for lighting a home or office space because of their very long lifetimes. Consumer use of LEDs as a replacement for conventional lighting system is currently hampered by the high cost and low efficiency of available products. The high initial cost of the commercial LED bulb is due to the expensive sapphire substrate which is key to the production process. The sapphire apparatus must be coupled with a mirror-like collector to reflect light that would otherwise be wasted.

6.6. REMAINING PROBLEMS

The current manufacturing process of white LEDs has not matured enough for them to be produced at low enough cost for widespread use. There are multiple manufacturing hurdles that must be overcome. The process used to deposit the active semiconductor layers of the LED must be improved to increase yields and manufacturing throughput. Problems with phosphors, which are needed for their ability to emit a broader wavelength spectrum of light, have also been an issue. In particular, the inability to tune the absorption and emission, and inflexibility of form have been issues in taking advantage of the phosphors spectral capabilities.

Variations of CCT (color correlated temperature) at different viewing angles present another obstacle against widespread use of white LED. It has been shown, that CCT variations can exceed 500 K, which is clearly noticeable by human observer, who is normally capable of distinguishing CCT differences of 50 to 100 K in range from 2000 K to 6000 K, which is the range of CCT variations of daylight.

LEDs also have limited temperature tolerance and falling efficiency as temperature rises. This limits the total LED power that can practically be fitted into lamps that physically replace existing filament & compact fluorescent types. R&D is needed to improve thermal characteristics. Thermal management of high-power LEDs is a significant factor in design of lighting equipment.

The long life of solid-state lighting products, expected to be about 50 times the most common incandescent bulbs, poses a problem for bulb makers, whose current customers buy frequent replacements.

7. MEASURAMENT OF THE NUMBER OF LUMS

In this exercise I am going to measure the number of Lum that the bulb gives to us in different distances and then I am going to write one conclusion about the behaviours of the bulbs focusing in the result obtain of the different measures that I have done.

For do this experiment I am going to use one lamp which is situated 1.40 meter of the floor, several types of bulbs with different power, measuring tape, paper, and one luxmeter to measure the number of lumens. The type and the power of the bulb that I had used are this:

- Incandescent
    - 25w (Airman)
    - 40w (Airman)
    - 60w (Airman)
- Halogen
    - 28w (Elexi)
    - 42w (Elexi)
- CFL
    - Spiral
        - 5w (Megaman)
        - 11w (Elexi)
        - 15w (Elexi)
    - Long life
        - 7w (Airman)
        - 23w (Airman)
    - Décor
        - 11w (Elexi)
        - 11w (WIRTA)
    - Stick
        - 11w (Elman)
- LED
    - 3.7w (WIRTA)

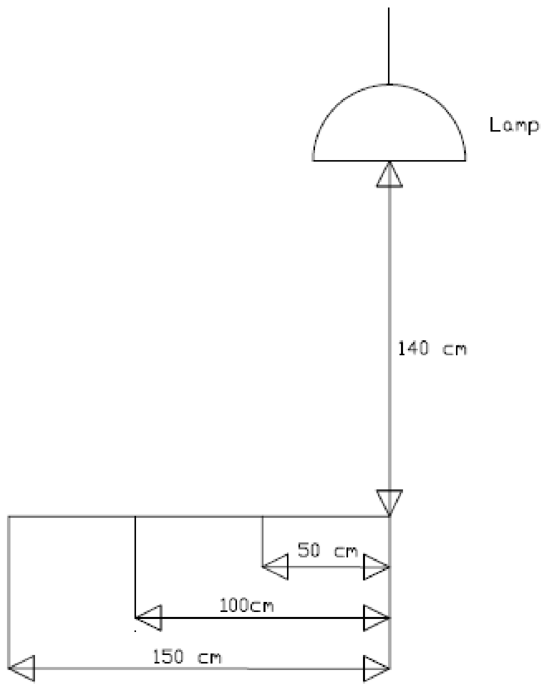


Figure 8. Diagram of the experiment

Table 1. Measurement of the number of Lum of incandescent bulbs

Power (w) \ Distance (m)	Lum		
	25	40	60
0	41.3	66.5	135.6
0.5	26.5	47.4	82.2
1	12.39	23.7	36.7
1.5	6.44	10.7	19.52
Brand	Airman		

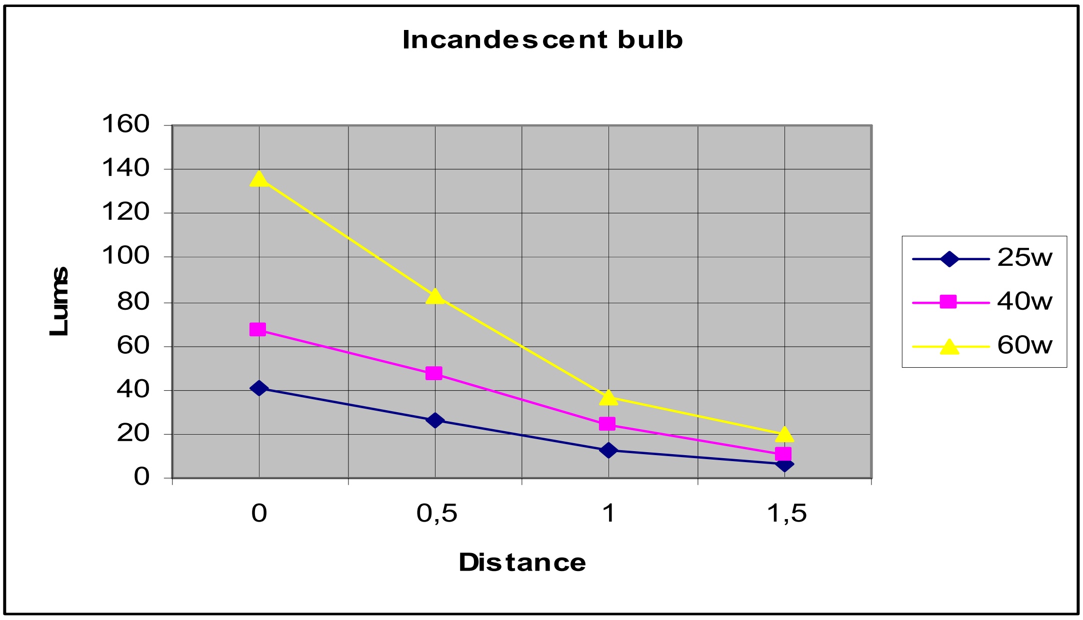


Figure 9. Representation of the number of lums of the incandescent bulbs

Table 2. Measurement of the number of Lum of halogen lamps

Power (W) \ Distance (m)	Lum	
	28	42
0	67,1	112,3
0,5	41,7	74,2
1	21,6	37,4
1,5	10,8	18,82
Equivalence incandescent	40 w	60 w

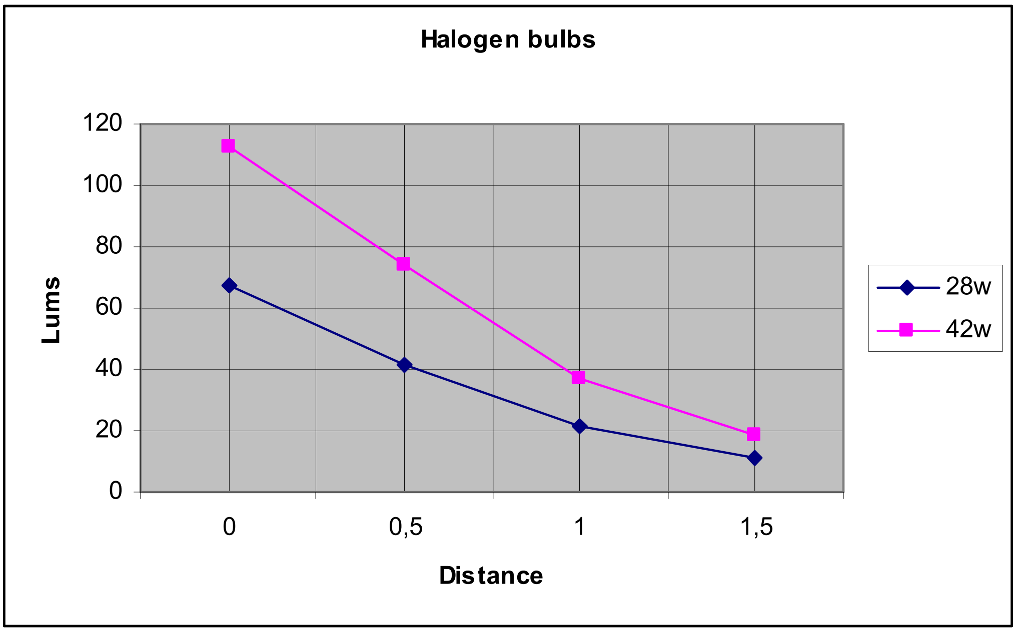


Figure 10. Representation of the number of lums of the halogen bulbs

Table 3. Measurement of the number of Lum of CFL

Power (W) \ Distance (m)	Lum							
	Spiral			Decor		Long life		Stick
	5	11	15	11	11	7	23	11
0	63.8	108.3	144.3	101.2	86.7	67	197.4	85.8
0.5	43	76.4	103.2	75.7	62.3	53.7	168.3	81.1
1	20.3	42.6	61	43.7	29.5	32.1	113.2	60.3
1.5	9.75	20.2	27.6	20.6	10.54	15.35	65.1	34.5
Equivalence incandescent	25 w	47 w	65 w	47 w	60 w	35 w	125 w	55 w
Brand	Megaman	Elexi			WIRTA	Airam		Elman

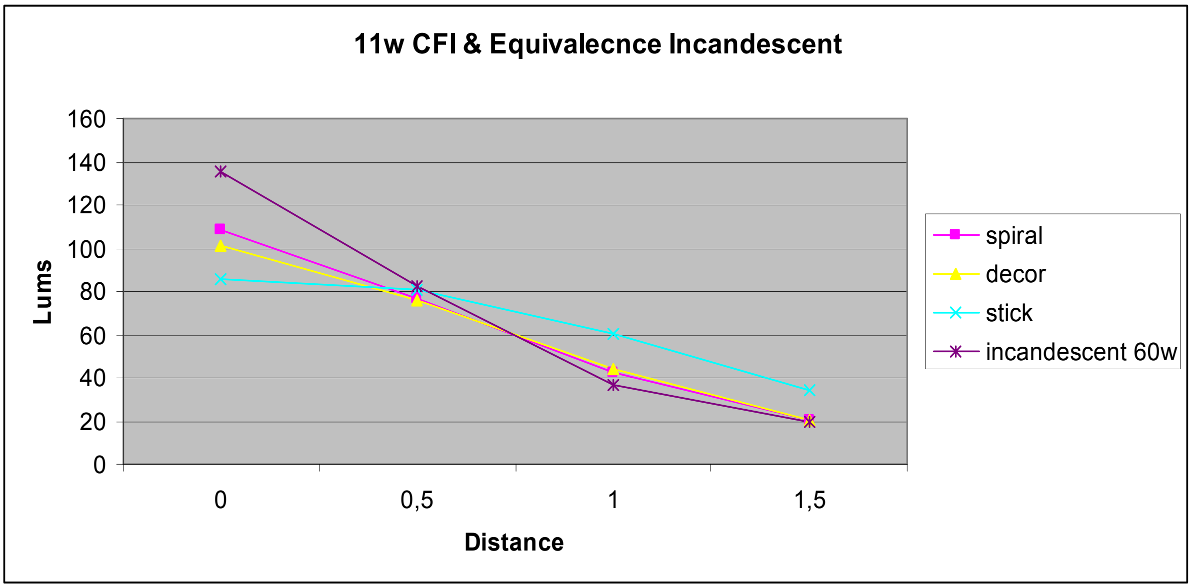


Figure 11. Comparison of the number of lums from the CFL bulb of 11w with one incandescent bulb of 60w.

Table 4. Measurement of the number of Lum of LED lamp

Power (W) \ Distance (m)	Lum 3.7
0	255
Brand	WIRTA

Table 5. Measurement of the number of Lum per watt.

Type	Selector	Power (w)	Lums max	Lum/w max	Brand
Incandescent	GLS	25	41.3	1.65	Airman
		40	66.5	1.66	
		60	135.6	2.26	
Halogen	Single ended halogen capsules	28	67.1	2.4	Elexi
		42	112.3	2.67	
CFL	Spiral	5	63.8	12.76	Megaman
		11	108.3	9.84	Elexi
		15	144.3	9.62	
	Decor	11	101.2	9.2	
		11	86.7	7.88	WRTA
	Long life	7	67	9.57	Airman
		23	197.4	8.58	
	Stick	11	85.8	7.8	Elman
LED	Decor	3.7	255	68.92	WIRTA

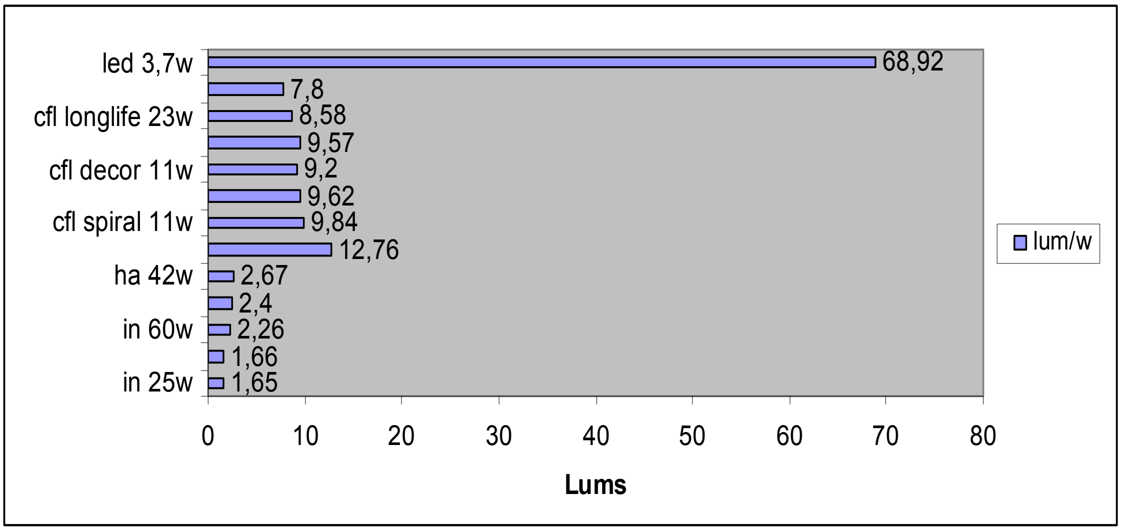


Figure 12. Representation of the maximum number of lums per watt in the point 0.

CONCLUSIONS

After had done this exercise we can take the next notes:

- Light intensity of the led lamps that were texted was focus in one point this is the reason because there is only one measurement on he table referred to the led lamps.

- We also can appreciate that if we compared the maximum number of lums that offer us the different bulb that in theory are equivalent to one incandescent bulb of 60 w, the maximum value in the point 0 is the one of the incandescent bulb, but as we go away of the central point the behaviour of the different bulb are getting very similar being almost the same value for the distance of 1.5 metres.

- Other thing that realise after doing this text is that the efficient of one bulb of the same power and of the same company is the same regardless to the design of the bulb that we are using.

- We observe that there is a quite big difference between the products of the bulb makers, for example if we compare the CFL of 11w of the brand Elexi and WRTA we appreciate one difference of lums of 14.5 in the point 0 and one different of 10.06 lums to 1.5 meter from the lamp.

- Seeing the result of the experiment we can say that one approximate equivalence between the bulbs could be that one incandescent bulb of 40 w is similar to one halogen bulb of 28w and the one of 60 should be similar to the one of 42. These approximations are more difficult to make with the CFL bulbs.

- One thing that you can notice seeing the result of this prove is that you have to be careful when you are going to chose the brand of the bulb spite of some of the brand are quite extract with the equivalence between his bulb and the incandescent one, other are not so strict.

8. MEASUREMENTS OF THE ELECTRIC PROPRIETIES

In this practice exercise we are going to measure the different electric proprieties of the bulbs, to make sure that the real values are the same value which the maker said. The factor that we are going to measure are the power, maximum current the power factor and the harmonic distortion of the voltage and current.

For do this experiment we need one lamp, one clamp, we use the fluke 41b, and the bulbs. The bulbs those we texts are:

- Incandescent
    - 25w (Airman)
    - 40w (Airman)
    - 60w (Airman)
- Halogen
    - 28w (Elexi)
    - 42w (Elexi)
- CFL
    - Spiral
        - 5w (Megaman)
        - 11w (Elexi)
        - 15w (Elexi)
    - Long life
        - 7w (Airman)
        - 23w (Airman)
    - Décor
        - 11w (Elexi)
        - 11w (WIRTA)
    - Stick
        - 11w (Elman)

Due to the clamp only work well with values higher than one amp we had to roll a lot of time the wire on the clamp, depending of the power of the bulb we roll the wire 10, 20 or 30 times. This made that the values that we had are a little bit approximated, this is also he reason because in this exercise we did not text the led lamp, its power was to low 3.7w so we need at list 45 rolls and with this amount of rolls the oscillation of the measurement were to big, so we could not approximated a correct value.

Table 6. Values of the measurements of the electrical proprieties.

Type	Selector	W (theory)	W (real)	I (ma)	PF	THDv	THDi	Brand
Incandescent	GLS	25	25	110	1	2.3	4.4	Airman
		40	37	161	1	2.3	3.4	
		60	55	242	1	2.2	2.6	
Halogen	Single ended halogen capsules	28	28	124	1	2	3.8	Elexi
		42	42	185	1	2	2.6	
CFL	Spiral	5	5.3	40	0.57	2.3	74.1	Megaman
		11	10.5	74	0.62	2.1	68.1	Elexi
		15	14	101	0.61	2.1	69.4	
	Decor	11	10.5	73.5	0.61	2.5	70.2	
		11	9	66.5	0.61	2.5	70.9	WIRTA
	Longlife	7	7	52	0.60	2.4	67.8	Airman
		23	23	167	0.62	2.4	71.4	
	Stick	11	10.5	75	0.61	2.4	69.8	Elman

CONCLUSIONS

- Referring to power values after check the result of the experiment we can say that only the halogen lamps and CFL longlife mach exactly with the theoretical value, the rest of types of bulbs have some kind of variation being the biggest of almost 18.2% of different between the real value and the theoretical.

- The power factor in the incandescent bulbs and in the halogen bulbs is 1 this mean that the real power and the apparent power are the same. This do not happened in the other type of bulb where the power factor is near of 0.60, its means than the CFL had some reactive power.

- If we focus in the THDv we saw that in all the types of lamps the value of it is near 2.3 its mean that the fundamental frequency power is the really more big that the other ones.

- Looking in the column of the THDi we appreciate that there are different values depending of the type of bulbs, for the incandescent and halogen the value is very low near 3 but for the CFL it is quite high 70, this mean that the decomposition of the current is made of a lot different harmonic and this had a important influence.

9. TABLES

Table 7. Average values

Type	*Lum/W*	*Lifetime(h)*
LED	150 (40)	50000
CFT	60/72	15000
Fluorescent Lamp	50/90	18000
Halogen Lamp	10/30	2000
Incandescent Lamp	8/17	1000

Table 8. Equivalences between incandescent bulbs and CFL

Incandesces Watts	*CFL Watt Range*	*Lumen Range*
40	8 - 10	450
60	13 - 18	890
75	18 - 22	1210
100	23 - 28	1750
150	34 - 42	2780

Table 9. Example cost

Type	*Cost (€)*	*W*	*Lum*	*Lifetime (h)*
LED	60	15	550	50000
CFT	13.90	18	1050	20000
Fluorescent Lamp	10.30	14	1200	18000
Halogen Lamp	5.95	28	350	2000
Incandescent Lamp	1.90	25	210	1000

Table 10. Energy and economic savings

Type	*Power (W)*	*Life (hours)*	*Cost (€)*	*Save energy (kWh)*	*Save money (€)*	*Amortization (years)*
LED	7	50000	60	1260	300.4	5
CFL	20	15000	18	800	106	1
Halogen (light)	20	5000	10	75	24.5	1
Fluorescent	28	20000	10	240	53.6	1

Table 11. Summary of application of the different bulbs

Type	*Applications*
LED	• Visual signals • Illumination (LED lamp) • Generate light with processes that do not involve the visual system
CFL	• Lighting • Households
Fluorescent Lamp	• Residential uses (kitchen, basement, garages) • Schools • Office buildings
Halogen Lamp	• Automotive • Architectural • Home use • Stage lighting
Incandescent Lamp	• Household • Headlamps • Advertisement lighting • Commercial lighting • Heat generators

Table 12. Summary of the advantages and disadvantages of the different bulbs

Type	*Advantage*	*Disadvantages*
LED	• Efficiency • Color • Size • On/Off time • Cycling • Dimming • Cool light • Slow failure • Lifetime • Shock resistance • Focus • Toxicity: LEDs do not contain mercury.	• High initial price • Temperature dependence • Voltage sensitivity • Light quality • Area light source • Blue hazard • Blue pollution
LED Lamp	• No break • Dimmable • No minimal current • No mercury	• Manufacturing process of white LED • Phosphor are needed • Low colour rendering index (CRI) • Variation colour correlated temperature (CCT) • Variation temperature => low efficiency • Bulb maker do not

		earn enough money
CFL	• Efficiency • Low cost • Save money in the electric bill	• Ultraviolet & blue light emitted • Mercury • Size • End of life • Dimming • Heat • Power quality • Time to archive full brightness • Audible noise • Iridescence • Fire hazard • Out door use • Life time brightness
Fluorescent Lamp	• Luminous efficacy • Life • Lower luminosity • Lower heat	• Frequent switching • Health and safety issues • Ballast • Power quality and radio interference • Operating temperature • Lamp shape • Flicker problems • Dimming
Halogen Lamps	• Excellent colour rendering. • Light is whiter than incandescent.	• Heat • Emit ultraviolet radiation

	• Continuous spectrum with particular emphasis on warm colours. • Unmatched in precise light control from small, lightweight luminaries. • Small luminaries because of small lamp size and no ballast required. (Low volt versions do require a transformer.) • Luminaries are easy to install. • Halogen lamps deliver full light output at the flick of a switch. • No warm-up required. • Simple dimming control is possible.	• Can not be touch not to alter his Chemicals composition
Incandescent Lamp	• Cost	• Inefficient • Heat • Life time • Consumption

Table 13. Comparison of efficacy by power of standard incandescent light bulbs

Power (W)	*Output (lm)*	*Efficacy (lm/W)*
5	25	5
15	110	7.3
25	200	8.0
35	350	10.0
40	500	12.5
50	700	14.0
55	800	14.5
60	850	14.2
65	1,000	15.4
70	1,100	15.7
75	1,200	16.0
90	1,450	16.1
95	1,600	16.8
100	1,700	17.0
135	2,350	17.4
150	2,850	19.0
200	3,900	19.5
300	6,200	20.7

Table 14. Table of colour of the fluorescent tubes

Halophosphate tubes			
Numeric colour code	Colour	Approximate CRI	Colour temperature (K)
27	Warm white	50–79	2700
33	Cool white	50–79	4100
83	Medium warm white	80	3000
84	Cool white (high CRI)	80	4100
Tri-phosphor tubes			
Numeric colour code	Colour	Approximate CRI	Colour temperature (K)
827	Warm white	~85	2700
835	White	~85	3500
841	Cool white	~85	4100
850	Sunlight	~85	5000
865	Cool daylight	~85	6500
880	Skywhite	~85	8000
Multi-phosphor tubes			
Numeric colour code	Colour	Approximate CRI	Colour temperature (K)
927	Warm white	~95	2700
941	Cool white	~95	4100
950	Sunlight	~98	5000
965	Cool daylight	~95	6500

Table 15. Table of colour temperature of the CFL

Colour temperature	Kelvin
'Warm white' or 'Soft white'	≤ 3,000 K
'White' or 'Bright White'	3,500 K
'Cool white'	4,000 K
'Daylight'	≥ 5,000 K

Table 16. Table of colour of the LED bulbs

Colour	*Wavelength (nm)*	*Voltage (V)*	*Semiconductor Material*
Infrared	$\lambda > 760$	$\Delta V < 1.9$	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
Red	$610 < \lambda < 760$	$1.63 < \Delta V < 2.03$	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Orange	$590 < \lambda < 610$	$2.03 < \Delta V < 2.10$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Yellow	$570 < \lambda < 590$	$2.10 < \Delta V < 2.18$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Green	$500 < \lambda < 570$	1.9[32] < $\Delta V < 4.0$	Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN)

			Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
Blue	450 < λ < 500	2.48 < ΔV < 3.7	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate — (under development)
Violet	400 < λ < 450	2.76 < ΔV < 4.0	Indium gallium nitride (InGaN)
Purple	multiple types	2.48 < ΔV < 3.7	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic
Ultraviolet	λ < 400	3.1 < ΔV < 4.4	diamond (235 nm)[33] Boron nitride (215 nm)[34][35] Aluminium nitride (AlN) (210 nm)[36] Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN) — (down to 210 nm)[37]
White	Broad spectrum	ΔV = 3.5	Blue/UV diode with yellow phosphor

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