Light sources

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Light sources

Our vision and thus our contact with the environment is inextricably connected to the light.

The sun as a source of light that accompanies us since our inception has one big drawback: it is not present at night.

In order to extend the day and thus have more opportunities for work, entertainment, development ... humans very early start to use artificial light sources.

Today's lighting with artificial light sources is an indispensable part of our lives

Light sources

Light sources can be divided according to different criteria:

Primary light sources

emit light by themselves and convert other forms of energy into light

Secondary light sources

do not emit light by themselves, but refract, reflect or otherwise alter the light from primary light sources.

The sun is so the primary light source but the moon is secondary.

Light sources

Light sources can be divided according to different criteria:

Temperature light sources

radiate light because of their (relatively) high temperatures. Each hot body emits energy and if it is sufficiently hot, the portion of the energy is emitted in the visible region of the spectrum.

Luminescent light sources

emit more light than it would have due to their temperature. There are different types of luminescence: bioluminescence, chemoluminescence, fluorescence, phosphorescence, triboluminescence, electroluminescence.

Light sources

Light sources can be divided according to different criteria:

Natural light sources

that are all the time or occasionally present in nature without human intervention.

Artificial light sources

that were introduced by humans because of certain advantages.

The most famous natural source is the sun, the most famous artificial source is ...

Natural light sources

The sun is the main primary and natural source of light.

Natural light sources

The moon is also natural light source.

However, the moon is secondary light source, because it only reflects light of the sun.

Natural light sources

Sky and clouds are also natural light source.

The atmosphere around the earth as well as clouds partly refract and partly reflect sun light. The light is also partly dispersed.

Natural light sources

Windows and skylights are natural light sources in the indoor environment.

They refract natural light of the sun (and partially disperse it) in the indoor environment.

Daylight - properties

Daily routine: low light level in the morning, level then increases until noon and then decreases again in the evening.

Light is coming from above and from the side.

The position of the light source changes with time as the sun "travels" from east to west.

Very rapid changes in brightness due to the weather (clouds).

Daylight

Daylight has its advantages (high levels, high illuminances of indoor environment, daily rhythm favorable technical parameters, energy savings ...)

as well as weaknesses (rapid changes, strong shadows, limited duration, the need for heating and air-conditioning, glare ...)

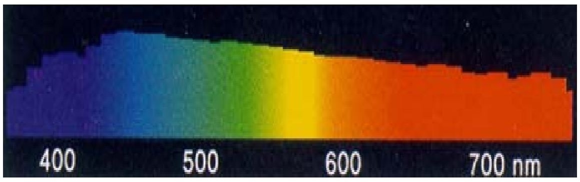
but the daylight is precisely what we are accustomed to during evolution so it is desirable that the artificial light mimics daylight.

Daylight - parameters

Daylight can be described with certain technical parameters:

The spectrum: full range

Spectrum is dominated by blue and purple hues, but the differences are not pronounced. The spectrum can vary with time of day (and year) and weather ...



Daylight - parameters

snow, water
blue sky

average daylight
(equator)

day- (sun-) light at noon

average daylight
(northern hemisphere)

sunlight
at sunrise or sunset

Daylight can be described with certain technical parameters:

Color temperature:
changes during the day.

The average is about 6500 K (at the equator) and slightly less in Europe (5000 K).

Daylight - parameters

Daylight can be described with certain technical parameters:

Color rendering index: 100.

Daylight is used as a reference source for calculation of color rendering index for white light with color temperature over 5000 K.

Artificial light sources

The history of artificial light sources is almost as long as the history of mankind:

Fire: 400,000 BC
Oil lamps: 13,000 BC
Candles: 400
Gas lamps: 1792
Electric arc lamps: 1809
Petroleum lamps: 1853
Incandescent lamps: 1879
Gas discharge lamps: 1901

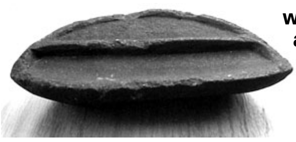
Artificial light sources

(Bon)Fire (40.000 BC)

Fire is the oldest artificial light source. Humans had used it since prehistoric times as evidenced for example by cave paintings of Altamira.

Artificial light sources

Primitive (oil) lamps (13.000 BC)



Made of stones, shells and similar materials. They were filled with the grease and for the wick a fibrous material (flax, dry reed, papyrus, ...) is used.

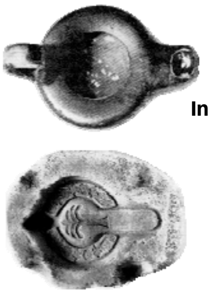
Artificial light sources

Ancient (oil) lamps (3.000 BC)

Instead of stones or shells pottery was used. They have already a “beak” for a wick. Fuel used for lamps was animal (fish oil) and vegetable oils (olive and palm oil).

Artificial light sources

Pottery oil lamps (500 BC)



In a further development the body of the lamp was closed, so it creates closed oil reservoir. Pottery lamps are produced manually or using molds. First decorated lamps appears.

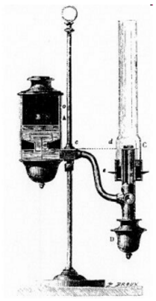
Artificial light sources

Candle (400 AD)

First candles were probably made by the ancient Egyptians, and were also widely used by the Romans. They were made from hardened tallow.

Artificial light sources

Oil lamp with cylindrical wick (1784 AD)



One of the major improvements in oil lamps was use of circular hollow wick and glass cylinder (F.P.A. Argand, Swiss). They used mainly whale oil. The amount of light is about the same as with 10 candles.

Artificial light sources

Betty oil lamp
(1790 AD)

Slightly improved oil lamp was primarily used in America during its colonization. Amount of light was like with 2 candles and they used animal or vegetable fats.

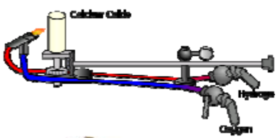
Artificial light sources

Gas lamp
(1814 AD)

1807 gas lamps were introduced for lighting the streets of London. The merit goes to the Scottish engineer Murdock, who lit his home and workshop with gas since 1792. Gas mantle was patented in 1885 (Thorium and cerium oxide).

Artificial light sources

Limelight
(1816 AD)



Magnesium lamp or lime lamp emits light without direct application of flame. Light is produced by the oxidation of lime or later magnesium (Limelight). To oxidized lime, it is necessary to heat it with oxygen and hydrogen flame.

The light is about 83 times stronger than with Argand lamp (about 800 candles).

Artificial light sources

Matches
(1827 AD)

Also English invention by chemist and pharmacist John Walker. The matches significantly facilitated lighting of lamps. Walker had never patented his invention.

Artificial light sources

Kerosene lamp
(1853 AD)

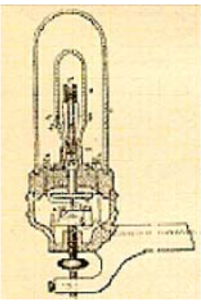
Improved Argand lamp fueled by kerosene. It was improved further with duplex burner (two parallel flat wick). They appear in Germany in 1853 for the first time.

Artificial light sources

Electric arc lamp
(1809)

The carbon arc light, which consists of an arc between carbon electrodes in air, invented by Humphry Davy in the early 1800s, was the first practical electric light. It was widely used starting in the 1870s for street and large building lighting until it was superseded by the incandescent light in the early 20th century.

Artificial light sources



First electric incandescent lamp (1820 AD)

The first electric incandescent lamp (light bulb) used platinum filament and evacuated glass tube. Created by Warren De la Rue who did not patented it.

Artificial light sources

Electric incandescent lamp (light bulb) (1820-1875)

1835 - James Bowman Lindsay demonstrates the operation of his prototype.

1850 - Shepard present a prototype of carbon filament.

(1854 - the first bulb produced by optician Goebel used carbonized bamboo fiber.)

1875 - Woodward and Evans patented the first light bulb in Canada. They used carbon filament and a glass balloon filled with nitrogen

Artificial light sources

Swan lamp (1879)

Swan first demonstrated the light bulb at a lecture in Newcastle upon Tyne on 18 December 1878, but he did not receive a patent until 27 November 1880 (patent No. 4933) after improvement to the original lamp. In 1881 he founded his own company, The Swan Electric Light Company, and started commercial production.

Artificial light sources

Edison lamp
(1879)

His first successful light bulb used carbonized cotton thread in vacuum and burns for 45 hours. Latter he used carbonized bamboo fibers. In 1880, Edison receives a patent for carbon filament light bulb but was declared invalid in 1883. He got it back in 1889.

Artificial light sources

Further improvements to electric light bulb
(1880-1960)

1907 - incandescent tungsten filament;

1913 - light bulb filled with gas and a helical filament;

1940 - PAR reflector lamps;

1955 - Dichroic lamps (coolbeam);

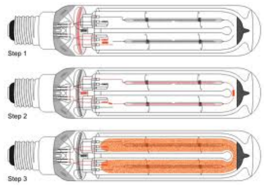
1960 – tungsten halogen lamps.

Artificial light sources

High pressure mercury lamp
(1901)

In year 1901 first high pressure lamp with mercury vapor was presented. Its light was blue-green in color. First high pressure mercury lamps similar to recent ones were presented in 1934.

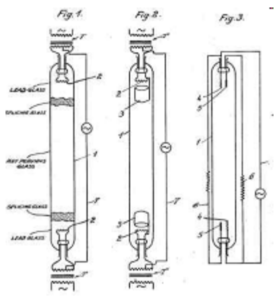
Artificial light sources



Low pressure sodium lamp (1932)

Research in the field of low pressure sodium lamps have started already in 1920. They were first time commercially used in 1932 for public street lighting in the Netherlands.

Artificial light sources



Fluorescent lamp (1937)

First fluorescent lamp was patented in 1927 in the USA and has been developed by German scientists. However, it was not useful until the version presented in 1937 in New York City (by GE)

Artificial light sources

Metal halide lamp (1960)

Represents an improvement of high pressure mercury lamp. It has a more continuous spectrum and better efficiency. The difference is in content of the burner. At metal halide lamp its contains not only mercury but also some metal salts (especially iodine).

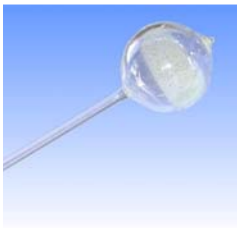
Artificial light sources

High pressure sodium lamp (1966)

High pressure sodium lamp was made from low pressure one by increasing pressure and adding of mercury in burner in 1966 This lamp has more continuous spectrum and thus better color reproduction factor as low pressure one.

Artificial light sources

Sulphur (plasma) lamp (1994)



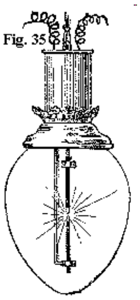
Most recent gas discharge lamp was developed in USA and is still not in full commercial use.

Artificial light sources

Light-emitting diode LED (1965)

Light-emitting diode (LED) is a semiconductor element which emits light while translating the flow of electrons through the barrier layer. First LEDs were red, but today also LED with other colors of light (including white) are available.

Electric light sources



Electric light sources used in history and today:

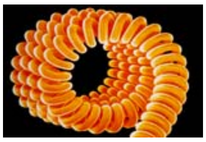
Carbon arc lamps: light produced by arc in the air between two carbon electrodes.

Incandescent lamps: light emitted from heated metal filament – temperature light source.

Gas discharge lamps: the source of light is discharge in gas and fluorescence.

LEDs: generates light by translation of electrons (electric current) through the semiconductor.

Incandescent lamp



Incandescent lamp operate on the principle of thermal radiators.

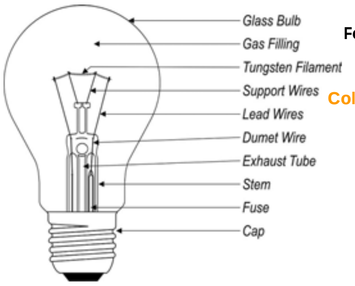
Most of the energy goes into heat, only 5-15% into the light.

Luminous efficiency throughout history: from 3 lm/W to 20 lm/W

Two main types of bulbs:

incandescent and tungsten halogen.

Incandescent lamp



Tungsten filament.

For the lower cooling the filament is bent in double or triple spiral.

Color temperature: 2700 K.

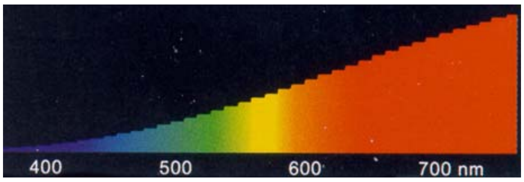
Electric current flowing through the filament heats it due to the resistance to approx. 2700 K.

Lifespan: 1000 hours

Incandescent lamp

Spectrum contains all wavelengths but blue ones are underrepresented. Spectrum has its peak in the IR part.

Luminous efficiency: 13 lm/W (100 W bulb)



Incandescent lamp

Color rendering index: excellent (95-100).

The light is compared to the sun slightly more yellowish, so yellow and red colors are more pronounced.

Incandescent lamp

Incandescent lamp can be directly connected to mains

If the nominal voltage of the lamp is the same as nominal voltage of the mains. If not, the transformer need to be used.

It works with AC as well as DC current (voltage).

Incandescent lamp

Tungsten halogen lamp

The glass bulb of the tungsten halogen lamp is filled not only with inert gas but also with halogen elements (iodine, bromine ...)

Tungsten halogen lamp

In the bulb a circular process is formed which extends the life span and enables the operation of the filament at a higher temperature.

Longer lifespan: 2000-4000 hours
Higher color temperature: 3000-3200 K.

Tungsten halogen lamp

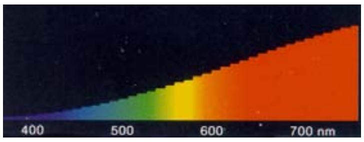
For the circular process the temperature of at least 180 ° C is required. Because ot that the bulb is smaller, and made of quartz glass.

Due to the porosity of the quarz glass bulbs should not be touched with your hands.

Tungsten halogen lamp

Spectrum contains all wavelengths. In comparison with the spectrum of incandescent lamp its top is moved to shorter wave lengths, but it is still in the IR part.

Color rendering index: excellent (95-100)



Luminous efficiency: 25 lm/W

Tungsten halogen lamp

Tungsten halogen lamp

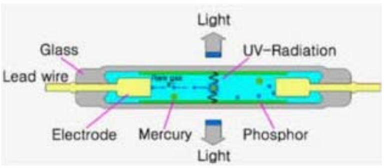

Tungsten halogene lamps can also be connected directly to the mains.

They are designed for a variety of voltages:
normal voltage (230 V, 110 V)
low voltage (6 V, 12 V, 24 V)

Tungsten halogen lamps for low voltage are usually connected to a mains via transformer (conventional, toroidal, electronic).
They work with AC and DC voltage.

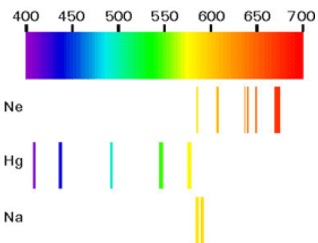
Gas discharge lamps

Gas discharge lamps produce light with electric discharge in gas.
The electrons passing through a gas collide with atoms of gas and eject atom electrons to higher orbit. When these electrons return back to its orbit, the excess energy is released in the form of photons - light.
Emitted light can be in visible or UV part of spectrum.



Gas discharge lamps

Different gases emitts different color of light at discharge:



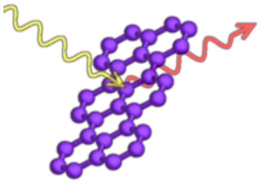
Neon - red
Mercury - bluish
Sodium - yellow
Xenon - white

The emitted light has typical line spectrum.

Gas discharge lamps

Since some gases (like Mercury) emit a major part of the light in the ultraviolet part of the spectrum, this UV light is converted into visible light with special fluorescent coating on the inside of the tubes.

The powders are made from rare earths, halophosphate or aluminate.



barium-magnesium-aluminate

zinc-silicate

calcium-borate

Gas discharge lamps

Gas is specific conductor

- it requires a high voltage to ignite discharge process;
- it has the inverse resistance curve so it is necessary to stabilize the electric current with the external device.
- gas discharge lamps so require ballasts, which help with ignition and/or stabilize current during the burning.

Following ballasts can be used:

- Electromagnetic (coil, starter, transformer, resistor)
- Electronic Ballasts

Used with electromagnetic ballasts lamps have a strobe effect.

Gas discharge lamps

Gas discharge lamps can be divided into:

Low pressure lamps

- pressure: 0,1 … 10 mbar
- glow and arc discharge in gas
- Light spectrum: typical line spectrum
- ignition: high voltage pulse with or without preheating of electrodes
- current limitation: resistor, transformer with stray field, ballast (coil), electronic ballast.

Gas discharge lamps

Gas discharge lamps can be divided into:

High pressure lamps

- pressure: 0,1 … 30 bar
- arc discharge in gas
- Light spectrum: line and continuous spectrum
- ignition: with auxiliary discharge, high voltage pulse
- current limitation: ballast with compensation capacitor, electronic ballast.

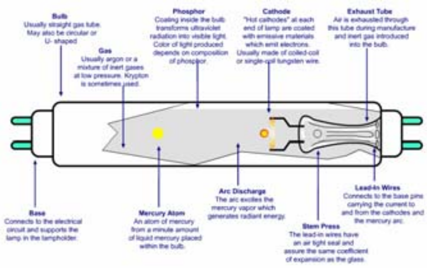
Gas discharge lamps

High pressure vs. low pressure discharge lamps

- Higher pressure of the gas in the burner and therefore higher gas temperature.
- Burner is made of special glass or ceramics.
- Better luminous efficiency.
- Smaller portion of UV light.
- Longer starting times.
- After the shutdown they can not be turn on again immediately.

Fluorescent lamp

Used gas: Mercury (Hg) vapor.



As Hg is a liquid at room temperature, the tube is additionally filled with an inert gas (krypton, argon) to provide initial heating of the interior which vaporize mercury.

Fluorescent lamp

Energy balance:

3% visible light, 63% UV light, 34% heat

63% UV light: 25% visible light, 38% heat

28% visible light, 34% IR light, 38% heat losses

Luminous efficiency: 96 do 104 lm/W

(depending on type of ballast: EM or electronic)

Lifespan: 10.000 do 24.000 hours.

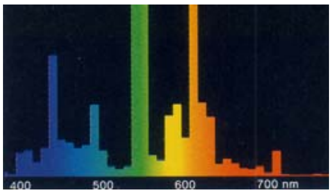
(depending on type of ballast: EM or electronic)

Fluorescent lamp

Typical line spectrum.

Color temperature: between 2700 K and 6500 K or even more, depending on phosphor coating on tube.

Color rendering index: between 60 and 95.



Fluorescent lamp

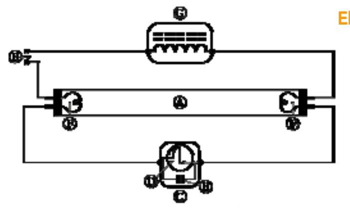
Ballast:

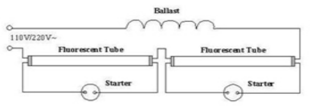
- electromagnetic: coil and starter
- electronic (high frequency)
- electronic with luminous flux control (made by frequency change)



Fluorescent lamp

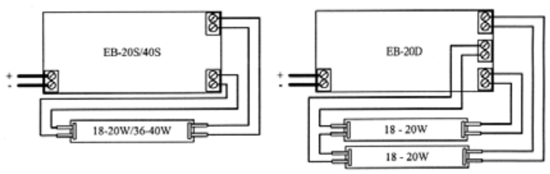
Electric connections
with EM ballast:





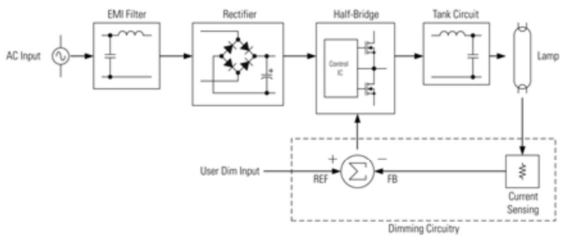
Fluorescent lamp

Electric connections
with electronic
ballast:



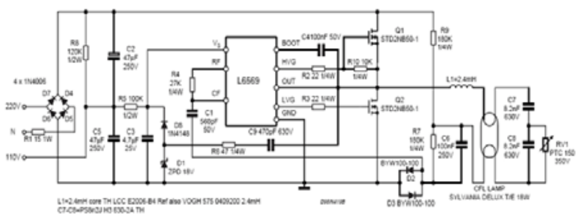
Fluorescent lamp

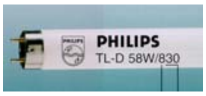
Inside of electronic ballast:



Fluorescent lamp

Inside of electronic ballast:





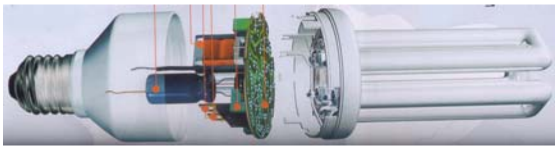
Fluorescent lamp

Compact fluorescent lamp

Has the same principle of operation as fluorescent lamp.

Lifespan: 8000 - 12000 hours, it can be drastically reduced by high number of on-off cycles.

Direct replacement for ordinary light bulb due to built-in ballast and E27 bulb holder.

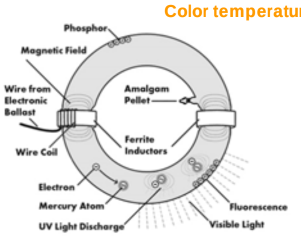


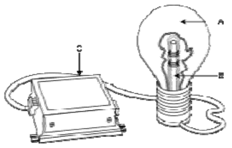
Compact fluorescent lamp

Induction lamp

Gas (Hg) starts to glow because of high frequency EM field and not because of electric current discharge.

Extremly long lifespan: 60.000 hours
Lumonous efficiency: 65 lm/W
Color temperature: between 2700 K and 4000 K (fluorescent coating)
Color rendering index: 80
Electrical power up to 165 W

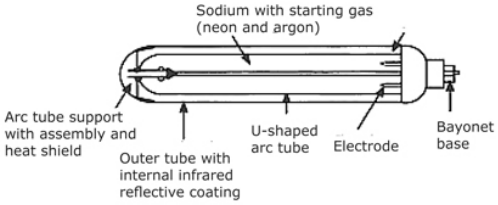




Induction lamp

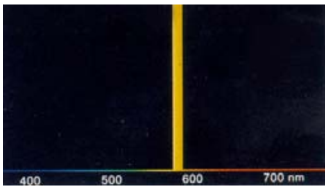
Low pressure sodium lamp

Gas: sodium (Na) at low pressure. Other gasses are added for the start.
Operating temperature: 290°C (outer tube is used as thermal insulation).
Lifespan: 16.000 hours.
El. power up to 180 W



Low pressure sodium lamp

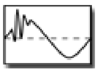
Monochromatic light: yellow 589 nm and 589,6 nm.
Best luminous efficiency: up to 200 lm/W.
Color temperature: 1750 K.
Very low color rendering index: <40.

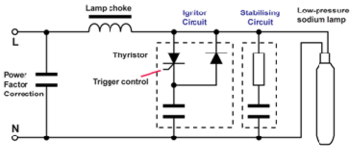


Low pressure sodium lamp

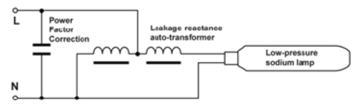
Electric connections with EM ballast:

Low power rating

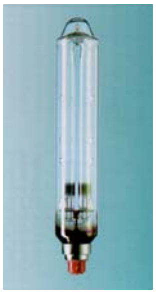




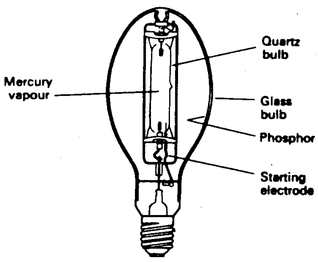
High power rating



Low pressure sodium lamp



High pressure mercury lamp



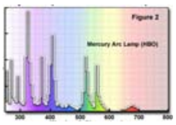
It works like fluorescent lamp but with a smaller proportion of UV light because of higher pressure. It still has a fluorescent coating.

Luminous efficiency: 60 lm/W.

Lifespan:> 15.000 hours.

El. power up to 400 W

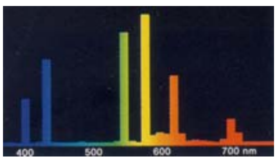
High pressure mercury lamp



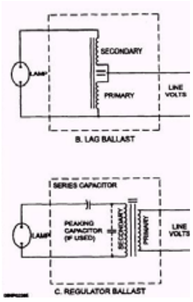
Line spectrum.

Color rendering index: 23 – 55.

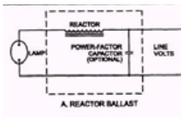
Color temperature: 2000 K - 4000 K.



High pressure mercury lamp



Electric connections
with EM ballast:



High pressure mercury lamp

Mixed light lamp

Hybrid between HP Mercury lamp and incandescent lamp:

Instead of ballast the tungsten coil is used for stabilization of the current through the burner. It can be used as a direct replacement of incandescent lamp.

Luminous efficiency: 30 lm/W.

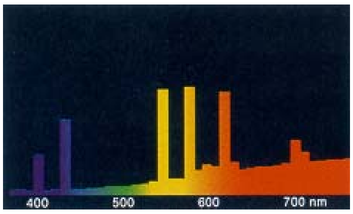
Lifespan 5000 hours.

El. power up to 160 W.

Mixed light lamp

Better color rendering index: up to 70

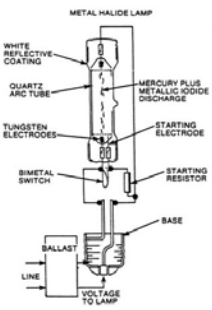
Color temperature: 3400 K.



Spectrum is a combination of HP Hg line spectrum and continuous spectrum of tungsteen incandescent lamp.

Mixed light lamp

Metal halide lamp



Based on HP Mercury lamp but with additives in burner: metal halide, rare earth elements ...

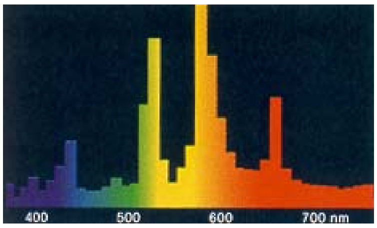
Less UV light and therefore no fluorescent coating. Light color is influenced by additives in burner.

Efficiency: 67 - 95 lm/W.

Lifespan: 15.000 hours.

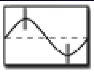
Metal halide lamp

Color temperature: 3000 K - 6000 K.
Color rendering index: up to 95.
Electric power up to 2000 W.



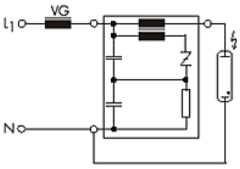
Due to additives in burner the spectrum is continuous one with still present Hg lines.

Metal halide lamp

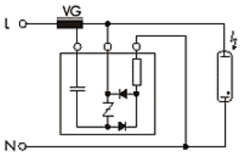


Electric connections with EM ballast:

Circuit principle of a superimposed ignitor



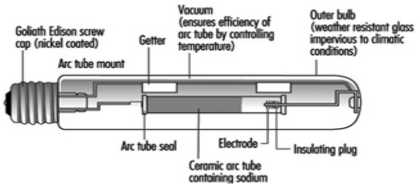
Circuit principle of a pulse ignitor



Metal halide lamp

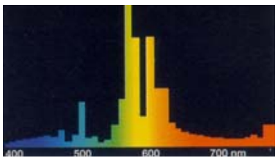
High pressure sodium lamp

Works at 0,25 bar and temperature of 1000 K.
Light is yellowish white and not monochromatic.
luminous efficiency: 95 - 150 lm/W.
Lifespan: up to 24.000 hours.
El. power up to 1000 W.



High pressure sodium lamp

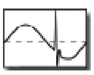
Color temperature: 2200 K.
Color rendering index: 20 – 65.

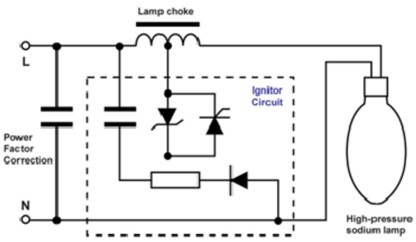


Due to higher pressure in burner the spectrum is not line one but continuous with some Hg and Na lines.

High pressure sodium lamp

Electric connections with EM ballast:



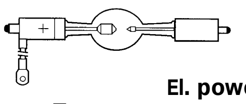


High pressure sodium lamp

High pressure xenon lamp

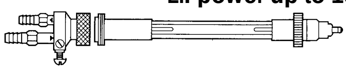
Works at pressure of 1 bar (long arc) or up to 30 bar (short arc) and at the temperature up to 500 °C

White light very similar to sun's light.

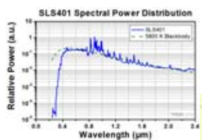


Efficiency: 25 - 40 lm/W.
Lifespan: do 3.000 hours.

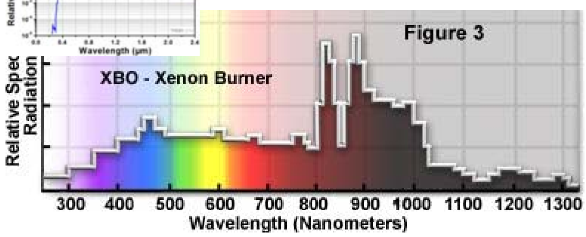
El. power up to 10.000 W (75.000W).



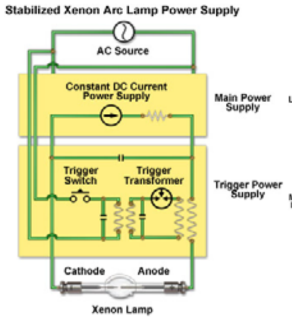
High pressure xenon lamp



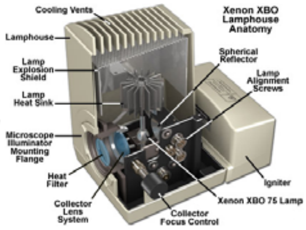
Color temperature: 6000 K - 6500 K.
Color rendering index: up to 100.



High pressure xenon lamp



Supply with electrical energy:



High pressure xenon lamp

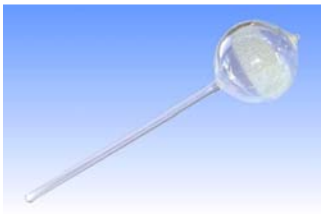
Automotive “xenon” lamp

Automotive xenon lamp (D2S) works on the same principle as metal-halide lamp.

It needs proper ballast with very high voltage ignition pulse for rapid start.

Sulphur plasma lamp

High efficient full-spectrum electrode less lamp where light is generated by sulfur plasma that has been excited by microwave radiation. Argon is added for starting.



Size: diameter 36 mm.

Permanent rotation and forced air circulation for cooling is necessary

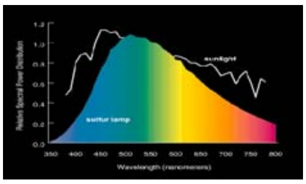
Sulphur plasma lamp

Developed between 1986 in 1990. Commercial failure but produced again since 2005.
El power: 1000W (1375W)

Efficiency: 130 (95) lm/W.

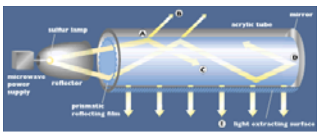
Lifespan: 60.000 hours, magnetron: 20.000 hours.

Sulphur plasma lamp

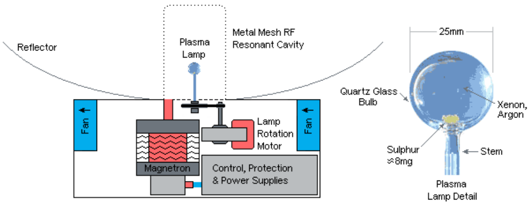


Color temperature: 6000 K.

Color rendering index: 79.

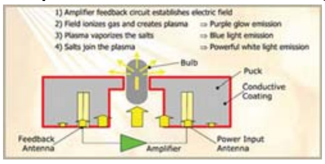


Sulphur plasma lamp



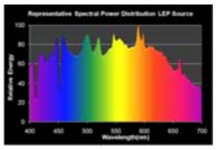
Light Emmitting Plasma lamp

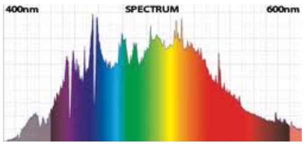
A radio-frequency signal is generated and amplified by the RF driver, which is guided into the ceramic resonator through a low loss coaxial cable. The structure of the resonator concentrates the RF field, delivering energy to the fully-sealed quartz lamp without electrodes or filaments. The highly concentrated electric field ionizes the gasses and vaporizes the halides in the lamp - creating a plasma state at its center - resulting in an intense source of white light.



Light Emmitting Plasma lamp

Lifespan:10.000 to 50.000 hours
Luminous efficiency: 50-90 lm/W
Color temperature: 5000 K to 7650 K
Color rendering index: 75 - 95
Electrical power: up to 500 W



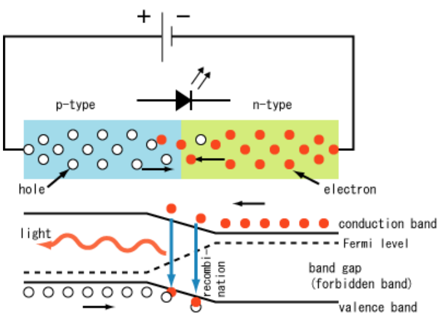


Light Emmitting Plasma lamp

Light-emitting diode - LED

Light is produced when electron meets a hole and so falls into a lower energy level. At some materials (Si) released energy is in form of heat and at other (GaAs, GaP) released energy is in form of a photon (light)

Light-emitting diode - LED



Light-emitting diode - LED

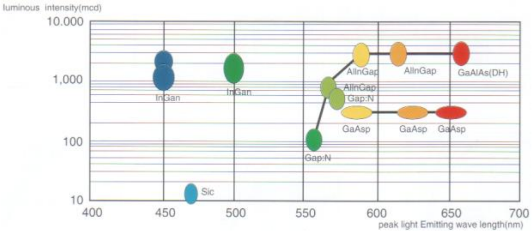
“Colour” of the photon depends on its energy.

$$E = hf = \frac{hc}{\lambda}$$

h … 6,63x10^{-34} … Planck constant

Light-emitting diode - LED

Energy of the photon depends on the used material.



Light-emitting diode - LED

Development of LEDs

1967: First LED dioda (red)

1973: Yellow-green LED

1975: yellow LED

1978: high brightness red LED

1993: Blue LED

1997: White LED (blue LED + phosphor)

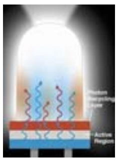
2001: White LED (UV LED + phosphor)

Light-emitting diode - LED

White LED (can be used in lighting)

White light is obtained as mixture of blue, green and red light from three LEDs

UV light from UV LED is converted to visible light with help of fluorescent phosphors.

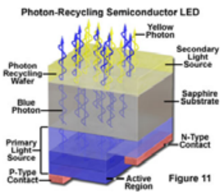


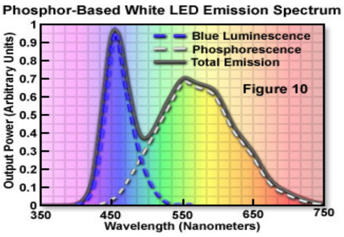
Special phosphor is used to convert part of the blue light (from LED) to yellow one.

Light-emitting diode - LED

Color temperature: 2700 K – 8000 K

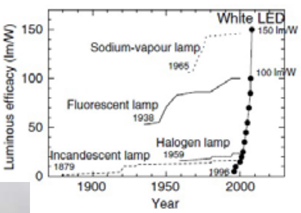
Color rendering index: up to 95





Light-emitting diode - LED

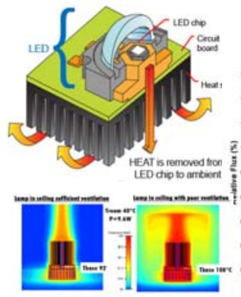
White LED

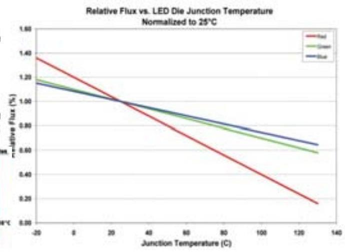


Efficiency: 100-200 lm/W.
Lifespan 50.000 hours.

Light-emitting diode - LED

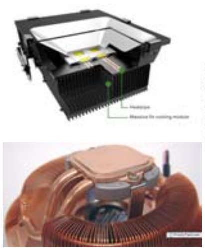
Problem: heat

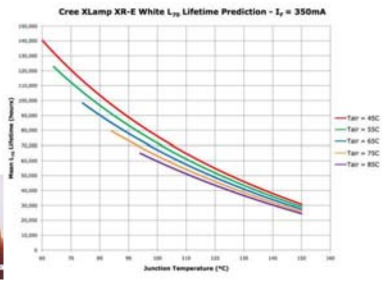




Light-emitting diode - LED

Problem: heat

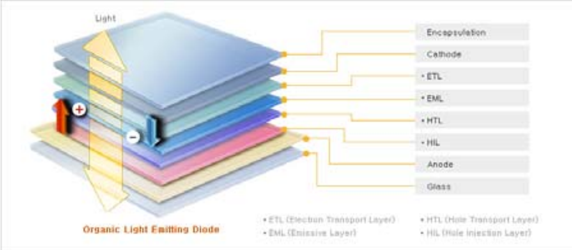




Light-emitting diode - LED

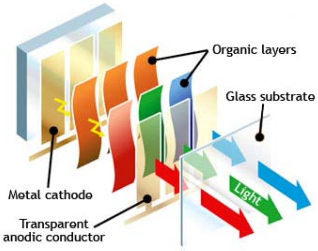
Organic LED - OLED

Similar to LED but organic materials are used in layers.



Organic LED - OLED

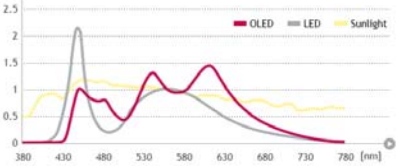
Different material produces different wavelengths. White light can be produced by mixing RGB…



Organic LED - OLED

Technical data (commercial products LG):

Efficiency: up to 60 lm/W
CCT: 3000 K / 4000 K
CRI: up to 90
lifespan: ??? (5.000 h)



Organic LED - OLED

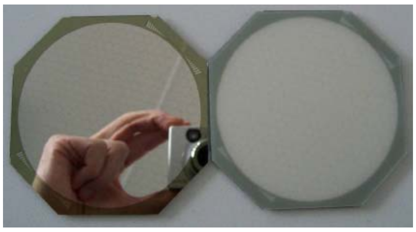
Expected results of EU FP7 project OLED100.eu (2008-2011)
efficiency: 100 lm/W;
lifespan: 100.000 h;
size up to 100 x 100 cm2;
price: less than 100 EUR/m2.

OLED 100.eu

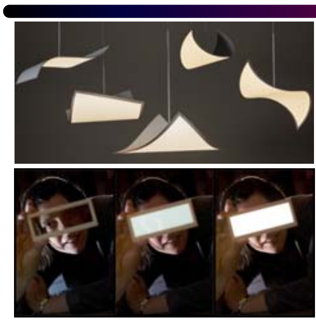
Parameters were achieved but not in one products.

Organic LED - OLED

Problems with OLED technology for lighting:
- demanding production technology;
- low efficiency;
- short lifespan;
- instantaneous breakdown;
- high price;



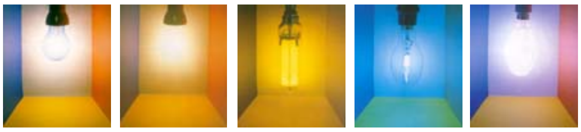
Organic LED - OLED



Organic LED - OLED

Possibilities for use:
- general lighting – large lighting areas with low luminance (ceiling, windows, ...);
- light decoration of architectural elements;
- human oriented lighting.

Color rendering index



Daylight	Incandescent lamp	LP Na lamp	HP Hg lamp	HP Na lamp

At the end ...

- Beside daylight there are many different artificial lighting sources available.
- Artificial lighting sources have different technical parameters: color temperature, color rendering index, luminous efficiency, lifespan, spectrum, electrical power ...
- The selection of artificial light source for indoor lighting should be based on human tasks and needs in the indoor environment.

... and now:

Questions?