Technical note on lamp types

Not surprisingly light sources have a variety of uses in spectroradiometry. This document gives an overview of typical light sources, the uses thereof and the issues to consider in choosing a light source.

There is a wide range of light sources available, here we shall consider the two most common in these applications: incandescent and discharge lamps.

Incandescent Sources

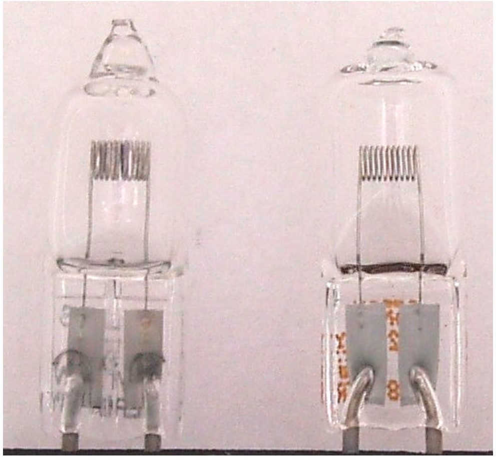
The process of emission of light from a heated solid is called incandescence. The spectral emission from such lamps is smooth, broad band, the peak of which moves to the shorter wavelengths as the temperature of the solid is increased. It behaves very closely to a black body.

There are two lamp types commonly employed, the quartz halogen lamp and the Nernst element. Bentham recommends that both are operated in a constant current regime to ensure stable output.

Quartz Halogen lamps

Tungsten is a very common example of filament material, such as in those bulbs that are traditionally used in domestic situations. However these are on the whole very unreliable and have a relatively short lifetime- for spectroradiometric applications, a source of stable amplitude and spectral content is required. This instability is due to discolouration of the bulb envelope during lifetime and filament failure.

During lamp use, an incandescent lamp filament reaches very high temperatures at which some of the tungsten evaporates and moves around inside the bulb by convection currents. If the envelope is cold, it is likely that the tungsten is deposited thereupon, hence the discolouration of the glass. Furthermore, since the tungsten is evaporated, gradually the structure is of the filament is thinned in places. This leads to a runaway failure. The resistivity of the thinned section increases, leading to increase in temperature at that point, and consequently higher rate of evaporation conspiring to thin the filament further.



These problems are mitigated by using the quartz halogen lamp.

A quartz halogen lamp has two main differences with respect to “standard” incandescent lamps, which together promote the halogen cycle.

The bulb is filled with a halogen gas which combines with the evaporated tungsten from the filament. Provided that the envelope of the bulb is over 250°C, the tungsten-halogen compound does not condense thereupon, and eventually returns via convection to the filament, at which point the tungsten is re-incorporated, releasing the halogen to continue the process. This constitutes the halogen cycle.

In order to maintain the envelope at high temperature the envelope is made as close to the filament as possible without melting. Quartz, which can withstand higher temperatures than conventional glass, is therefore used as the envelope material.

The re-deposition of the tungsten is of course a random phenomenon, eventually parts of the filament structure become thinner and failure ensues.

Bulb temperature being therefore important, for the halogen cycle to work, the lamp must be run for long enough to heat up the lamp. The lamp should not be under-run either, under-running the lamp less than 80% of rated voltage will result in failure of the halogen cycle due to the lower bulb temperature.

In some instances the orientation of the lamp becomes important, for example in some instances the envelope is not equidistant above/below the filament. Running such a lamp in the 'pins down' orientation is satisfactory since the upper part remains hot, but in the 'pins down' orientation, it is possible that it becomes sufficiently cool to condense tungsten.

Should a lamp be over-run, it is possible to re-evaporate that material condensed on the envelope by letting the lamp run to the temperature required to re-initiate the halogen cycle.

It was evoked previously that tungsten filament emission is close to that of a black body. However all tungsten filament lamps are housed in an envelope to prevent oxidation of the filament. The transmission of the envelope can modify the output of the filament.

Quartz for example transmits 250-2500nm and is used in most cases, however where for example UV blocking is required, a hardened glass may be used which transmits from 350nm.

The quartz halogen lamp is typically used in the spectral range 250-2500nm.

Nernst lamps

Like quartz halogen lamps, nernst lamps are a form of incandescent lamp, using rather than a tungsten filament, a ceramic rod which is heated to incandescence. Since this rod does not oxidise in air, there is no need to enclose it in a vaccum or noble gas environment. The Nernst ceramic rod not being conductive at room temperature has a heater filament through it to take it to such a temperaure that the rod can conduct on its own.

This lamps runs much cooler than a tungsten lamp, the output is therefore more towards the red and is used in most infra-red applications.

The Nernst lamp is typically used in the spectral range 1-50μm.

Discharge Sources

Discharge lamps operate by passing an electric current through a rare gas or metal vapour to produce light. The electrons collide with the gas atoms, exciting them to higher energy levels, or to an ionised state (plasma) in which electrons are completely removed from the atoms. From these states, the electrons decay to lower energy levels by the emission of light.

In common to all discharge sources is the configuration of electrodes in close proximity in an atmosphere of a gas chosen for its emission.

In low-pressure lamps, sharp emission lines are seen, characteristic of the energy levels of the atoms in the gas.

In high-pressure lamps, collision between electrons and atoms lead to broadening of these discrete lines. Furthermore, due to the higher temperature in the lamp, electrons have a much higher kinetic energy, these electrons lose energy by emission of light which results in a continuum generation, upon which is superimposed the discrete emission lines.

Common discharge lamps are Xenon, Deuterium and Mercury. Whilst the former two are used as light sources, the mercury lamp is mainly used for wavelength calibration purposes, the presence of emission lines at defined wavelengths being of use.

Xenon short arc lamp

The xenon short arc lamp comprises two electrodes sealed in a quartz envelope, in which is present xenon gas. The cathode is narrow, and is doped with another material to ensure that it reaches a high temperature to emit as much electrons as possible. The anode is much larger to withstand being inundated with electrons. The distance between the cathode and may be up to several mm.

A starter is employed to initially drop a high voltage across the electrodes to "start" the arc.

In general the Xenon lamp provides a higher UV output and less IR than the quartz halogen, however the continuous spectrum is superimposed by unstable line emission which may not be desirable in some uses.

The xenon lamp is typically used in the spectral range 250-1100nm.

Deuterium lamp

The deuterium lamp, with a high UV output and little VIS/ NIR, is the preferred source for UV measurements, in terms of signal level and of scattered light.

These lamps use a heated cathode which is made of a tungsten filament, typically coated with a highly emissive material. The starting sequence of these lamps consists of typically around one minute application of heater current prior to establishing the arc.

The useful output of these lamps is from around 180nm to 900nm, however the actual output obtained is largely related to the envelope used. The output is line free up to around 360nm.

The envelope of these lamps, is cylindrical in shape, although there are a number of variants having a "snout" in the output direction to reduce discoloration of the output window by condensation of arc vapours.

There are four main window materials used, selected for their transmission properties. Whilst UV glass and fused silica are often used for the entire envelope, magnesium fluoride and synthetic silica are used as windows at the lamp output, particularly in the case of those lamps having a "snout".

The lamp is filled with low pressure, very high purity deuterium gas. Deuterium is the selected gas rather than hydrogen due its more intense UV continuum.

Mercury discharge lamp

The mercury discharge tends to consist of a mercury discharge tube within an outer envelope. The discharge tube has electrodes at either end, and contains a quantity of mercury vapour.

The mercury spectrum contains a large number of emission lines in the UV- visible domain and is used widely as a standard for wavelength calibration. In effect the mercury spectrum is virtually omnipresent to a certain extent in the laboratory environment, overhead fluorescent tubes containing some of this vapour.

This lamp also finds a variety of uses in industry as a UV source of intense emission,

The mercury lamp is typically used in the spectral range 250-800nm.