# How Fluorescent Lights Work



*This document is located at* http://lasttechage.wordpress.com/pdf-references/

One of the best accessible description of how the lamps work is in wikipedia. The process of generating visible light is diagrammed here.

- **Electric** current (yellow arrow) passes through a column of **mercury vapor** (*blue region*).
- The beam excites the Hg atoms, which spontaneously emit 2 pure spectral lines (184.45 nm, 253.65 nm) in the **ultraviolet** (*dark blue wavy lines*) .

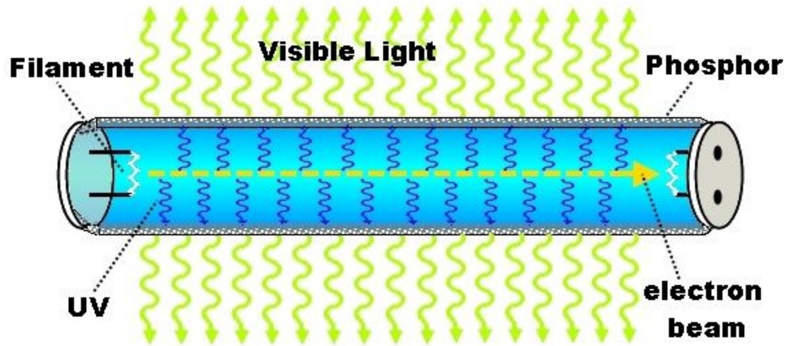


Fig. 1 The Fluorescent Light process

- The UV is emitted in all directions, until it hits the the **phosphor coating** on the inner wall (*dotted edges*).
- The coating re-emits lower energy long wavelength **visible light** (*light green wavy lines*).

This identifies many shortcuts that could degrade the operation of a fluorescent light.

**Filament:** When the tungsten (W) filament is heated, its special coating will boil off electrons, not light. If the coating is too thin, it will fail early because of the sudden heating at turn-on can cause expansion, cracking or flaking. (Image from the Wikipedia Open Commons.) Care must be taken to keep the tungsten from evaporating onto the tube inner wall; it can lead to a thick opaque layer, blocking light.

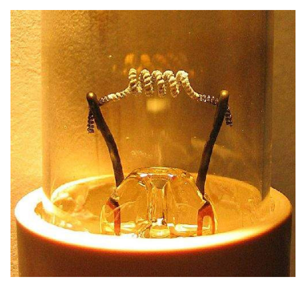

Fig. 2 Fluorescent light filament

**Electron beam:** This flows between the filaments and is needed to bounce against the Hg atoms, causing UV emission. A key point not often mentioned is the startup process needed to generate the beam and Hg vapor at an acceptable range of temperatures. The starting process is the most electrically violent in the tubes operating cycle, but must be capable of happening at most temperatures. During operation, the beam reverses direction with a steady frequency. In older tubes, off and reverse happens twice every power line cycle (120 flickers per sec by North American standards, 100 by European standards). Modern tubes avoid flicker-headache problems because they cycle at about 40 kHz. There are no natural resonance with biological vision rates.

**Tube:** The FL tube must be cleaned of all contaminants which could interfere with the electron-Hg atom interactions or interfer with the attachement of the phosphor layer to the glass wall. This means cleaning the inside walls at high vacuum, then careful backfilling with an inert gas such as argon (Ar). The residual oil and water in the final gas to be less than parts per million.

**Phosphor:** This is a coating applied to the inside surface of the tube to change UV light into visible. If you accidentally break a tube, this is the (usually) white powder that dusts the area. Coatings can be a difficult process, especially for long thin tubes. Due to the environment in which it must function, it probably needs a conductive layer to remove excess charge that could cause light uniformity issues.

Fig. 3 Phosphors under UV illumination, made by TianYuan (China)

Phosphors generate the stated color of the tube and new forms are continually being invented. A phosphor is a compound of many rare-earth elements such as lead (Pb), germanium (Ge), strontium (Sr), yttrium (Y), europium (Eu), terbium (Tb), and sometimes it actually includes phosphorus (P). Some of the easiest to get (least costly) generate light at unpleasant wavelengths. Finding a reasonable mix of UV-to-visible light converting compounds is a separate science, one that has been studied for at least 5 decades. *Image from* Tian Yuan *sales website*.

**Mercury vapor:** For public health reasons, the goal is to make a fluorescent light with as little Hg as possible. Due to a great deal of research and careful manufacturing care, the current generation of fluorescents contain less than 4 mg Hg, down from about 12 mg just 10 years ago. Research efforts to find a replacement have been without success, to date. An easy way to correct for manufacturing short cuts is to increase the Hg, perhaps by a great deal.

Note that mercury is inserted into most current generation of tubes as a solid amalgam but must operate as a conductive vapor of metallic Hg atoms. This requires start up steps to form the vapor. Again short cuts can be done to make startup at room temperature easier.

It is interesting to note that, although law in most countries set standards for fluorescent tubes and compact fluorescent lights, there are no testing labs to be found that continuously check that the bulbs actually sold match the lab testing results that enabled sale of the product.