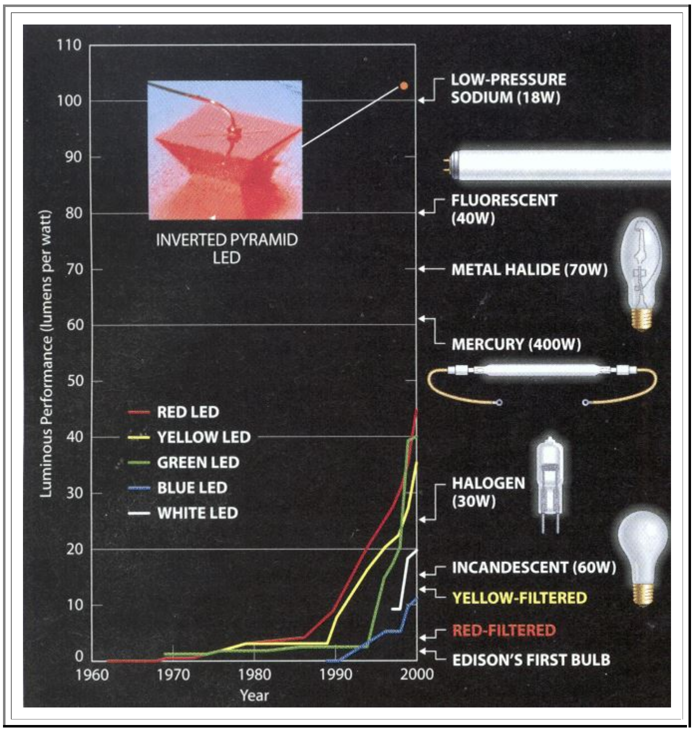
7. Light Emitting Devices

7.1 Basic Requirements and Design Principles

7.1.1 Products, Market, Materials, and Technologies

General Considerations

- All light emitting devices – **LEDs** or laser diodes – have some device principles and requirements in common:
  - There is a defined volume in the device – the *recombination zone* (or active volume) – where the generation of light takes place.
  - The increase in the minority carrier density necessary for radiative recombination is obtained by injecting electron and hole currents across suitable junctions.
  - The device is made so that most of the injected carriers recombine radiatively in the active volume – i.e. the quantum efficiency and the current efficiency should be as large as possible. This is exactly the opposite of the regular **Si p–n** junction, where we try to keep recombination in the **SCR** (and thus leakage currents) as low as possible.
  - For lasers, an optical feedback mechanism is added (e.g. a Fabry–Perot resonator). In addition, the geometric shape is important: Should the laser emit along a line, or just from a "point"?
  - The optical efficiency must be optimized, too
  - And, not to forget, an important consideration neglected so far: For many applications the modulation **frequency range** should be large. In other words, we want to modulate the light intensity by modulating the injection currents at high frequencies – **GHz**, if possible.
- This is a demanding list of specifications; it cannot be met with just a few basic device architectures.
  - Considering the wide range of available semiconductors and the extremely diversified product spectrum, there is a bewildering multitude of devices from many materials involving often ternary and quaternary semiconductors from the **III-V** zinc-blende lattice set.
  - While the most complicated devices concern laser diodes (always with spectacular physics involving all kinds of quantum well structures and tricky resonators), the humble **LED** is not to be sneered at either. It is always the base of laser: If you cannot make an **LED** for a certain wavelength, you sure like hell will also not be able to make a laser.
  - The field was revolutionized some years ago when Shuji **Nakamura** , almost single-handedly, made working **blue LEDs** based on **GaN**; a feat that seemed to be impossible since all the big players in the field could not do it.
  - At present, a race for a **$12 \cdot 10^9$ \$/year** market is gaining in speed (and expenditures for research): *Cheap* **LEDs** suitable to **replace light bulbs**, emitting *white* light at high intensity may be around the corner! But maybe they are not. Only time (after considerable research and development) will tell.
- For light emitting diodes (and of, course, for laser diodes even more so), efficiency is of supreme importance: How much light can you get for **1 W** of electrical power that goes in the device?
  - Much progress has been made, and more will have to be made for light bulb replacement. The figure below illustrates that.



- The record holder, the inverted pyramid LED, is described in some detail in the link.

How large is the market for III-V devices?

- Here is a link to some information.