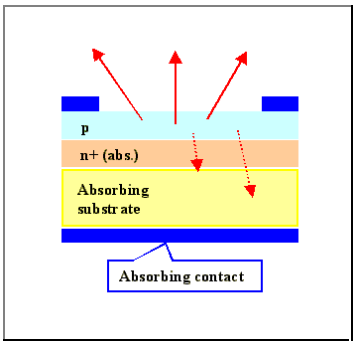
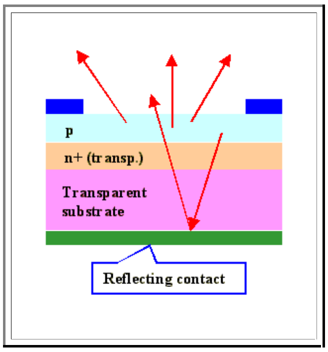
7.1.2 Some LED Concepts

- **LEDs** come in many variants, satisfying needs form being cheap to being "super". The figures show some common devices

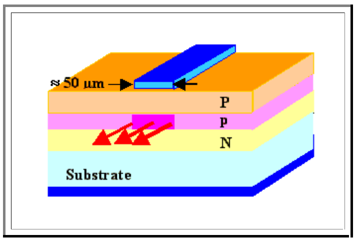


- This is possibly the most simple **LED** device. Electrons are injected into the top **p**-layer, and only the photons that manage to escape will be seen. Of course, you will try to keep the top layer as thin as possible.
  - Not very good, but then there are many applications were you do not want particularly bright light, but cheap products, e.g. for indicator lights in stereo systems, dashboards, etc.
  - You may use the same kind of material – which will be automatically absorbing the light flowing into the depth of the device. For red light, you use **GaAlAs**, for green **GaP**, or anything that comes in handy from the table of possible mixtures.
  - The necessary layers you make with some kind of epitaxy, which allows you to work with relatively cheap substrates.



- A somewhat better device uses the light emitted to the back side by reflecting it back to the front side.
  - If the light has sub-bandgap energies because it stems from excitons, you do not have large absorption effects in the basic material. So for **GaP LEDs**, it pays to make the back contact reflective and keep the layers thin.
  - Generally, however, this approach requires heterojunctions where the $\mathbf{n^+}$ layer and the substrate material must have a larger bandgap than the active layer, so they are transparent to the light.
  - The $\mathbf{N^+p}$ heterojunction may have the added benefit that the injection of electrons becomes more efficient, but it also has the added problem that now you must watch out for lattice constant compatibility, otherwise you may encounter misfit dislocations

- These kinds of **LEDs** emit over the whole area of the active layer; they are called **surface-emitting LEDs**. They are good enough for most general light source applications.
  - With quite some additional effort, such an **LED** can be further developed into a laser, then known as a **VCSEL** (= vertical-cavity surface-emitting laser). Meanwhile, despite the additional effort (mainly for making the mirrors), **VCSELs** are already widely used. (For more information, crawl the web yourself.)
- If you want really high **intensities** , i.e., not just a lot of photons but a lot of *photons per area*, you must confine the light emission to a small area where you realize high injections ratios. This is particularly important if the emitted light is to be coupled to a fiber or wave guide for optical communication purposes. This can be done with an **edge-emitting LED**:



  - The active **p-**layer is confined in its lateral extension and holes and electrons are injected through a "**double heterojunction**". One will be of the diode type, the other one necessarily of the isotype.
  - As already outlined in the chapter about heterojunctions, it is possible to achieve very large injection ratios – essentially only the wide band gap semiconductor injects its majority carriers and the injected carriers can not easily escape.
  - We will look into this situation in more detail for laser "diodes".
  - All things considered, we have a considerably larger efficiency with this design and **LEDs** of this kind are sometimes called **"superradiant" LEDs**.

- Much more could be said about the design of **LEDs**, some special or recent developments are discussed in advanced modules.
  - Standard LED structures
  - Recent developments