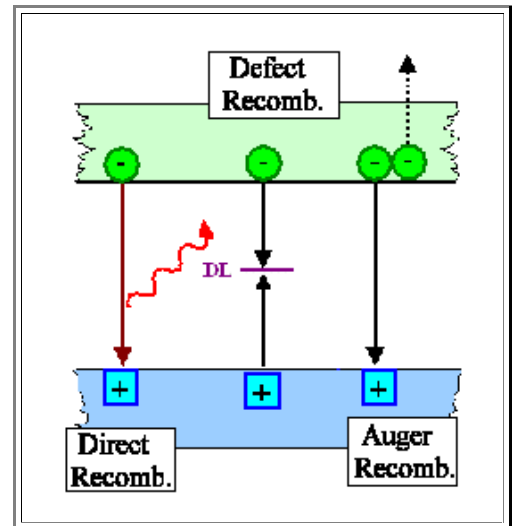


9.2.3 Summary to: 9.2 Optoelectronics - Important Principles and Technologies

There are always several recombination channels active in parallel

- Direct **band-band recombination**; *producing light*.
- **Defect recombination**; *not* producing light.
- **Auger recombination**; *not* producing light.
- "Exotic" mechanisms like **exciton recombination**; producing light in *indirect* semiconductors like **GaP**

- High efficiency **LED's** need optimized recombination.

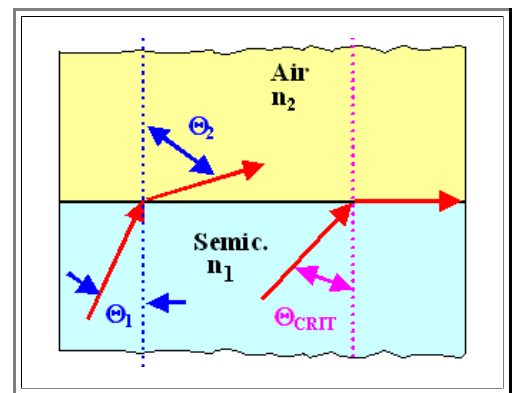


Without "tricks" only a fraction of the light produced gets out of the semiconductor

- Index grating is essential
- Avoiding re-absorption is essential
- Defined recombination volumes are important

Hetero junctions of the **NnP** or **NpP** type are the solution, but create problems of their own

- Hetero-interfaces must be defect free \Rightarrow Avoid misfit dislocations!



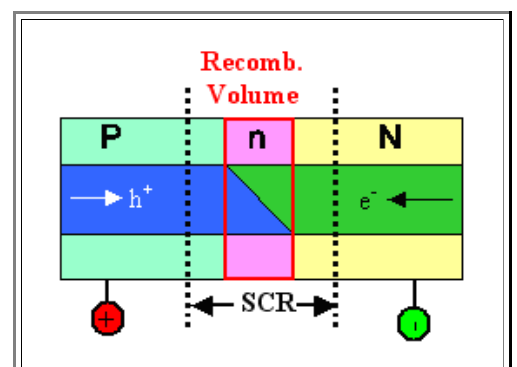
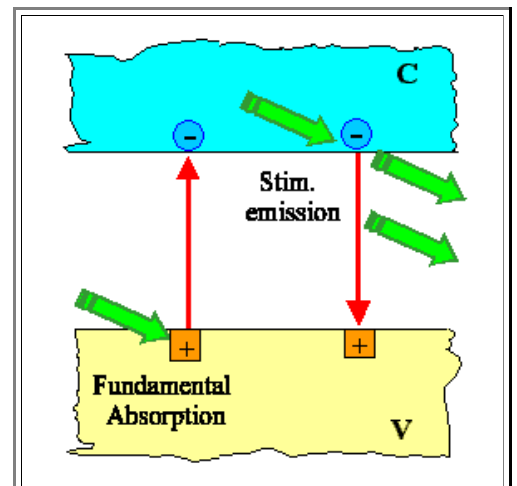
Laser diodes are similar to **LED's** but need to meet two additional conditions

1. The rate of **Stimulated emission**, a new process predicted by A. Einstein concerning the interaction of light and electrons in the conduction band, must be at least as large as the rate of **fundamental absorption**

- *Stimulated emission* results in *two fully coherent* photons for *one* incoming photon and thus allows optical *amplification*.
- Strong stimulated emission his requires large non-equilibrium electron concentrations in the conduction band. \Rightarrow strong "pumping" is necessary, moving electrons up to the conduction band just as fast as they disappear by recombination.
- In semiconductor junctions pumping can be "easily" achieved by very large injection currents across a forwardly biased (hetero) junction. \Rightarrow cooling problem!

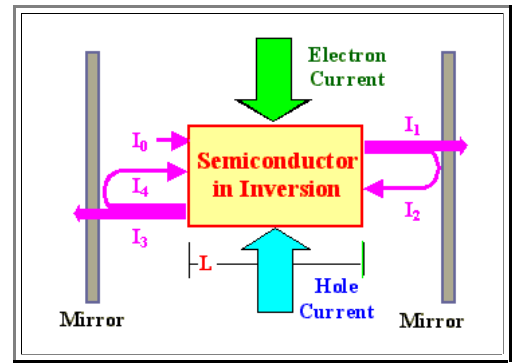
2. There must be some feed-back that turns an (optical) amplifier into an oscillator for one frequency

- *Feed-back* is achieved by partially transparent mirrors.



- Monochromatic output is achieved by the optical resonator formed by two exactly plan-parallel mirrors
- Only wavelengths $\lambda = 2L/i$ ($i = \text{integer}$) that "fit" into the cavity will be able to exist. Together with the condition $h\nu = hc/\lambda = E_g$ the Laser wavelength is given

▶ Semiconductor Lasers now span the range from **IR** to **UV**; essential materials are all **III-V's**, in particular the **GaN** family.



▶ **Molecular beam epitaxy** is the deposition method of choice for epitaxial multilayer structures

Exercise 9.2-1
All Quick Questions to 9.