MIME 262, Lecture #20,
April 2nd, 2012

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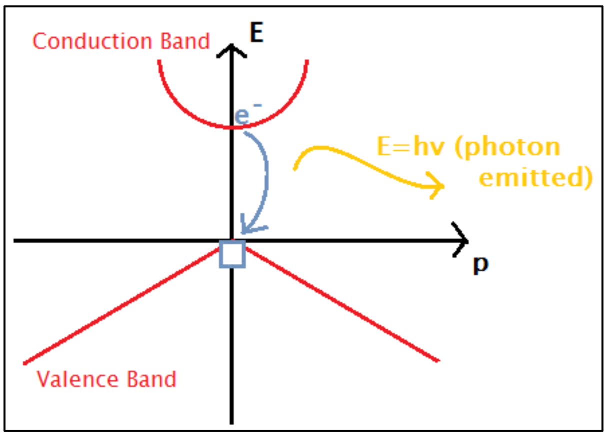
Direct Band Gap Materials

(Ex: GaAs, InN, GaN, GaP, InP)



Electrons (**conduction band minimum**) and holes (**valence band maximum**):

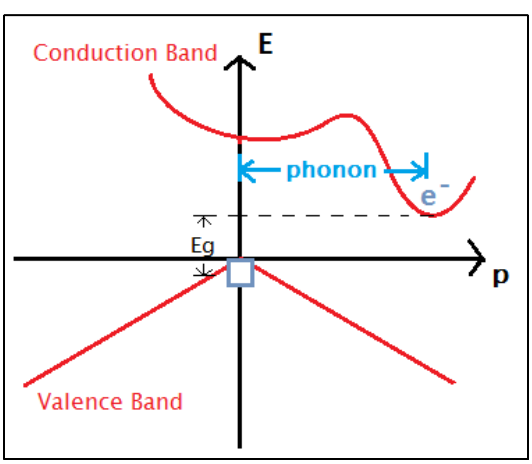
Momentum: SAME for both (p = 0)
Recombination: EASY

-When an electron recombines with a hole it directly emits a photon with energy *hv*.

h: Planck's constant
v: Light frequency.

Applications: LED's, lasers, detectors and high speed power amps.

Indirect Band Gap Materials



Momentum: DIFFERENT
(Electron → p is shifted,
Holes → p = 0)
Recombination: Difficult & inefficient

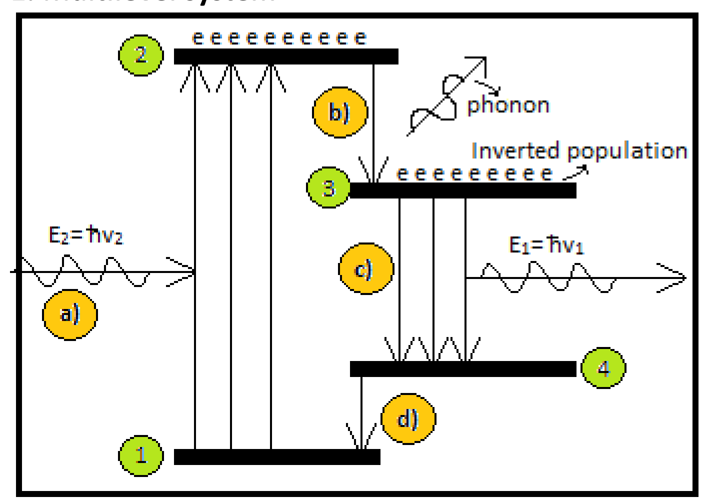
To recombine electrons and holes, phonon with large "p" is required for momentum conservation.

Phonons: requires more "p" and less "E"
e^- h^+ recombination: requires less "p" and more "E"

Application: logic devices (low cost).

Lasers

1. Multilevel system



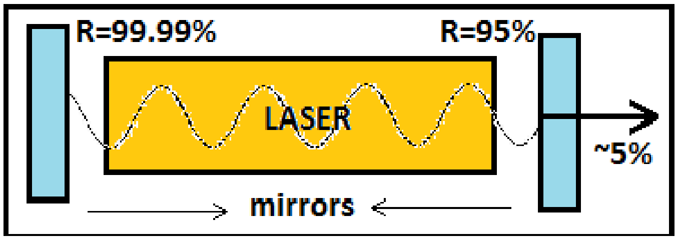
a) High intensity light with enough energy to excite electrons from the ground state (1).

b) Ions decay almost immediately to an intermediate state (3). This relaxation does not emit radiation. Energy is conserved by emitting lattice phonons.

c) Photon emission from level (3) to an intermediate state (4). The simulating radiation cannot excite transitions from the ground state

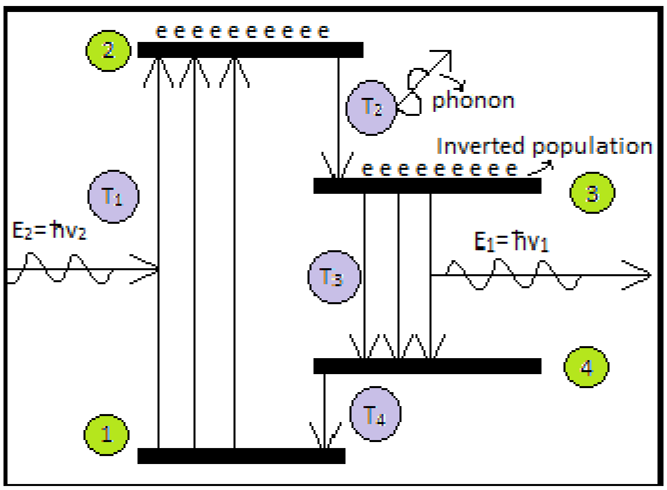
d) Electrons leave state (4) almost as soon as they are transferred to it.

2. Resonant cavity



To ensure that light is coherent, the laser crystal is placed in a mirrored cavity. Phonons are reflected multiple times before exiting the laser and they are in phase with one another.

3. Time in states



- The ion decays almost immediately to <u>state 3</u>.

T1 > T2

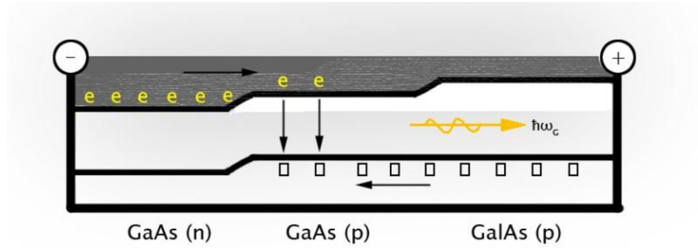
- <u>State 3</u> must have the characteristic that an electron that fills it cannot easily return to the ground state. **T_3** is large so that the state is relatively long lived.
- **T_4** is short lived so that electrons leave <u>state 3</u> almost as soon as they are transferred to it.

4. Inverted Population

- Population inversion occurs when a system exists in a state with more electrons in an excited state than in lower energy states.

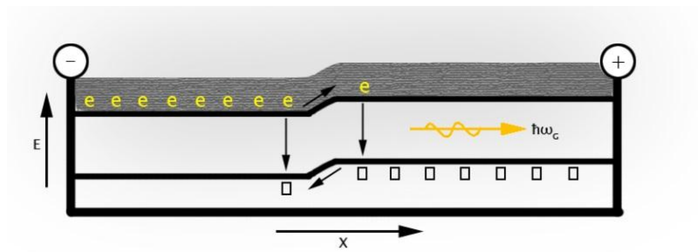
- The simulating radiation of frequency v1 cannot excite electrons from the ground state and transition from (3) to (4) is very short which allows for population inversion at state 3.

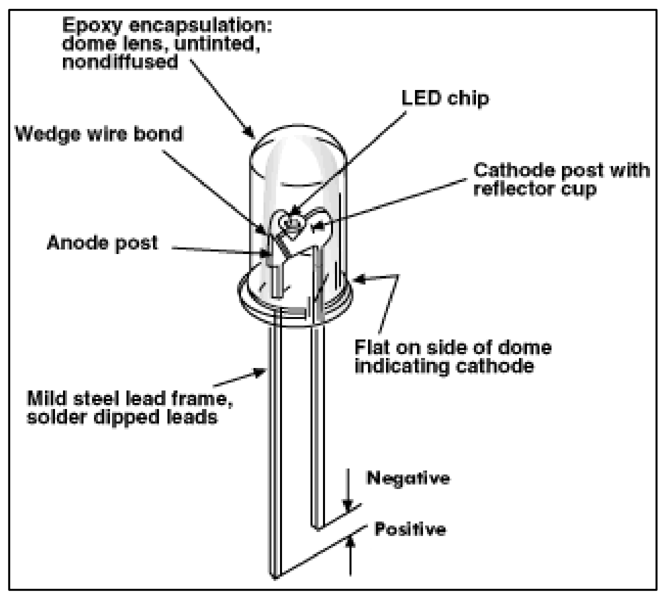
<u>Simple Semi-Conductor Laser</u>



→ Converts electric current into laser light. The simplest model is a LED with increased dopant concentration and voltage. In order to produce an intense laser beam, we must confine the carriers to a particular region until they recombine.

<u>LED (Light Emitting Diode)</u>





When **FORWARD BIASED**: switch is **ON**

What happens?

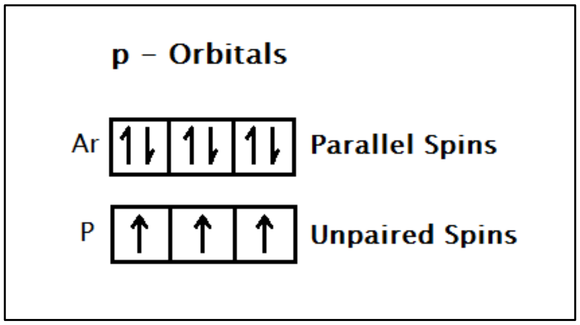
- The <u>electrons</u> move into <u>p-type</u> material
- The <u>holes</u> move into <u>n-type</u> material.

p-type: electrons are outnumbered by holes (electrons get eliminated, they **DIE**)

n-type: holes are outnumbered by electrons (holes get eliminated, they **DIE**)

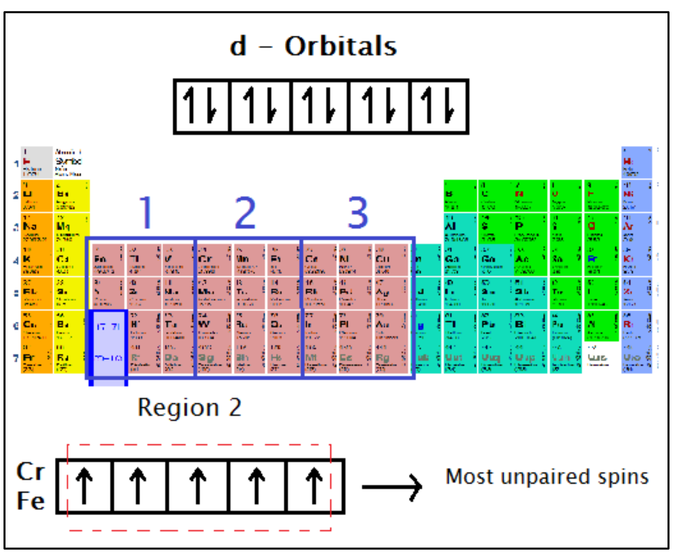
In both cases, an electron recombines with a hole which releases energy in the form of a photon (LIGHT!!)

Magnetic Properties



- Atoms or ions with parallel spins → No net electron spin
- Atoms that have magnetic moments are:
    - Transition Metals
    - Rare Earth Elements
    - They all have unfilled electron states in the ion core
- The core magnetic moment (μ) = # unpaired spins of an element. Units in Bohr Magneton (μ_B).

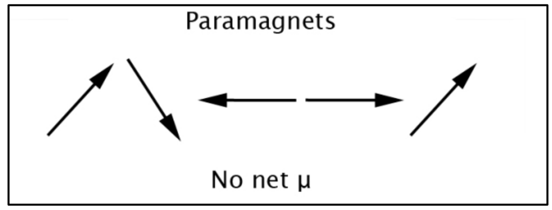
Transition Metals



- Best metals are in the second region because they have the most unpaired spins.

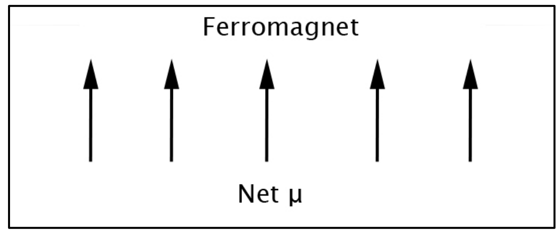
Types of magnetic order:

Paramagnets



- When the core moment is random
- No net magnetic moment

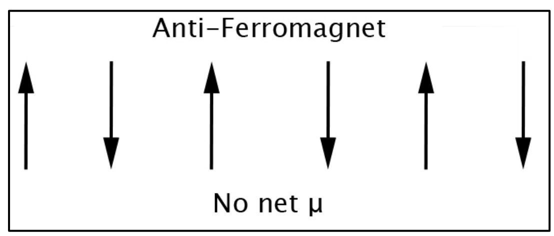
Ferromagnets



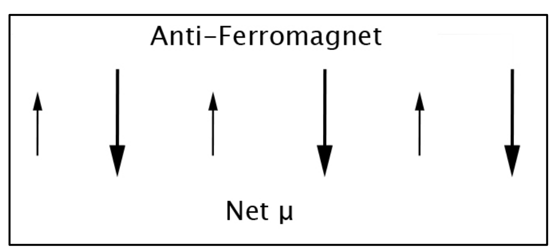
- When the core moment align in parallel
- Net magnetic moment

Anti-Ferromagnetics

2 Types of anti-ferromagnetics:



- Core moment alternates in direction
- Magnitude is equal
- Then they cancel out, which means no net moments.



- Core moment alternates in direction
- Magnitude is NOT equal
- Possess net magnetic moment
- Also known as *FERRIMAGNETIC*