EE2003 – SEMICONDUCTOR FUNDAMENTALS (Part III)

Tutorial 12
Lasers & LEDS

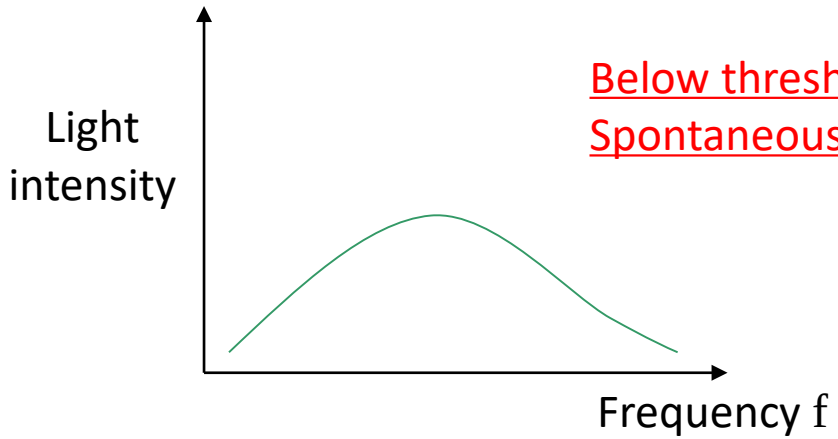
Q1

For a laser diode, plot the emission spectra below and above the lasing threshold. Briefly explain the main features of each spectrum.

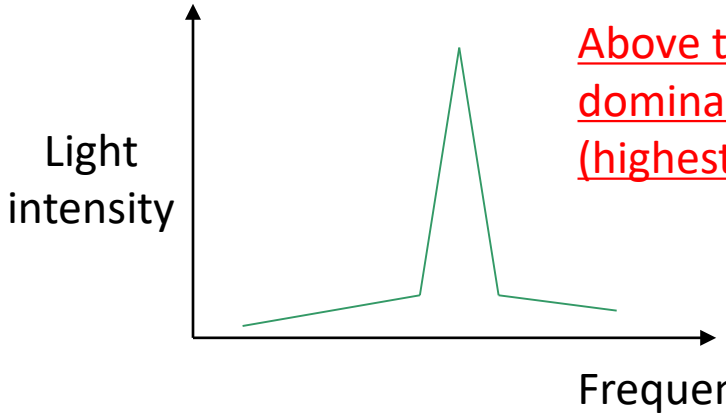
- Below the threshold: broad spectrum, related to spontaneous emission.

- Above the threshold: Narrow spectrum, stimulated emission dominates. Single dominant mode (frequency) appears as this frequency has the highest gain.

Q1



Below threshold: Spontaneous emission

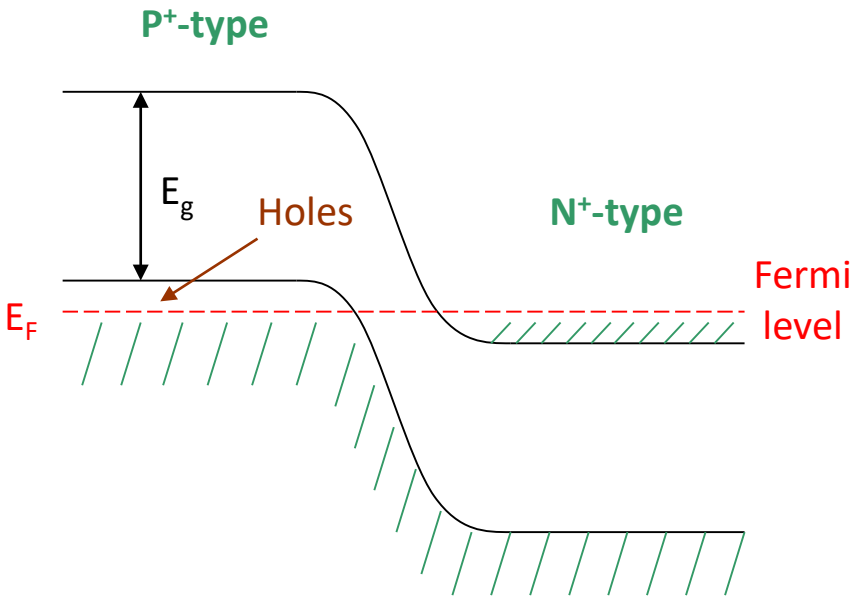


Above threshold: single dominant mode appears (highest gain).

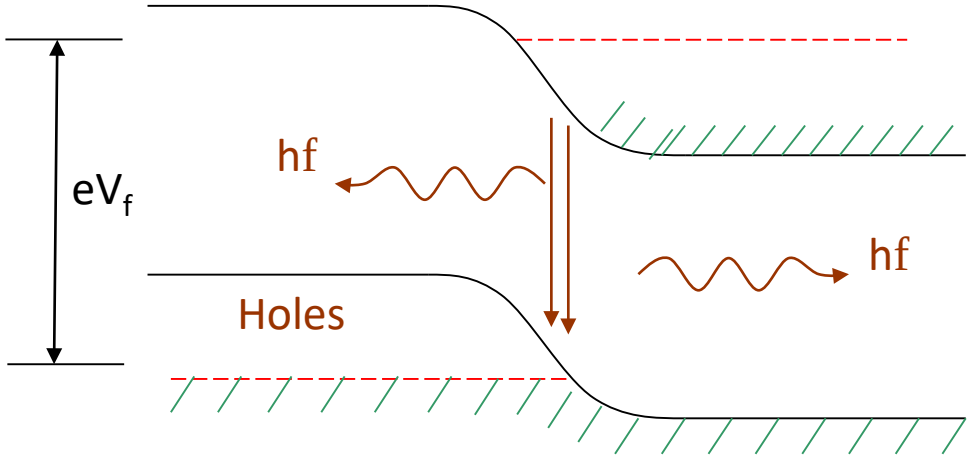
Q2

A semiconductor laser diode is typically comprised of a highly doped junction such that the Fermi level on the n-side lies in the conduction band and that on the p-side in the valence band. Sketch the energy band diagrams of this laser diode under the equilibrium condition (zero bias) and then under the forward bias. Mark the conduction band, the valence band, and the Fermi levels. Explain it.

Q2



Semiconductor laser diode in equilibrium



Semiconductor laser diode under forward bias

Q2

To achieve a semiconductor laser, the pn junction needs to be heavily doped on both sides and also under strong forward-biased so as to achieve strong population inversion.

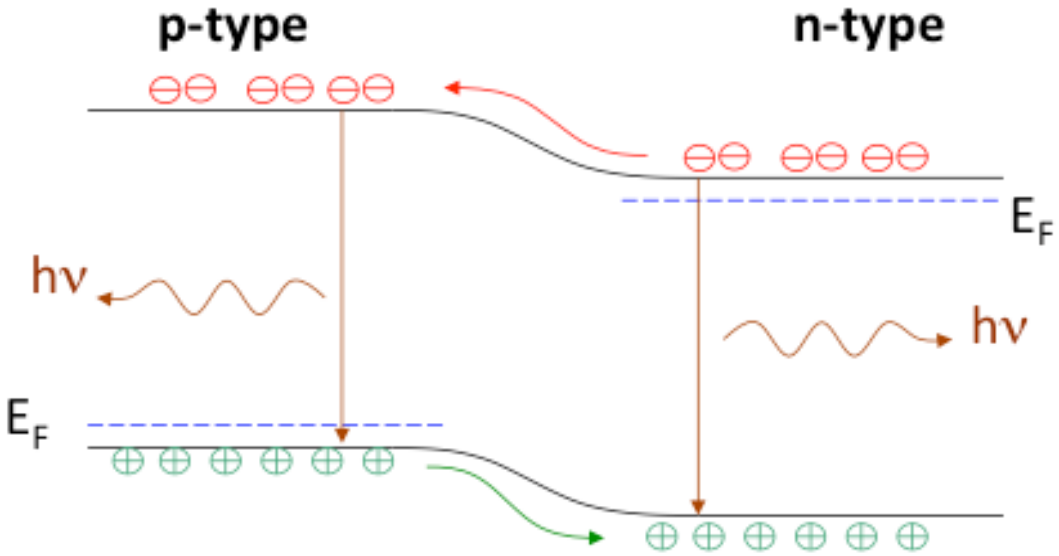
For such a junction, there will be a large number of minority electrons injected into the p–side which has many holes. Similarly, a large number of minority holes are injected into the n–side which has many electrons.

Thus there will be a lot of recombination occurring.

With direct gap semiconductors used, the recombination will result in photons being emitted.

Q3

Sketch the energy band diagram of a typical light-emitting diode (LED) under forward bias. Explain how LED works.



Q3

LED is a pn junction under forward biased condition.

When a forward-biased voltage is applied, electrons and holes are injected across the space charge region, becoming excess minority carriers;

These minority carriers diffuse into the neutral semiconductor materials, where they recombine with majority carriers.

If this recombination process is a direct process, photons are emitted.

Q4 What are the differences between a laser diode (LD) and a light emitting-diode (LED)?

The main difference between an LD and an LED is the way the optical signal is generated and manipulated. LD generates stimulated emission, while LED generates spontaneous emission. Because of this, a LD compared to a LED has the following features:

It generates coherent light output.

- It has a narrow emission linewidth as it is highly monochromatic (all photons have the same frequency).
- The output is polarized (electric field of the EM waves all vibrating on the same plane).
- The light output is directional.
- The light output is higher due to the amplification process.

LEDs are cheaper than LDs.