18PYB101J MODULE-5 LECTURE 7

- Nd: YAG laser
- Semiconductor Lasers

Nd: YAG Laser (Doped insulator laser)

Lasing medium

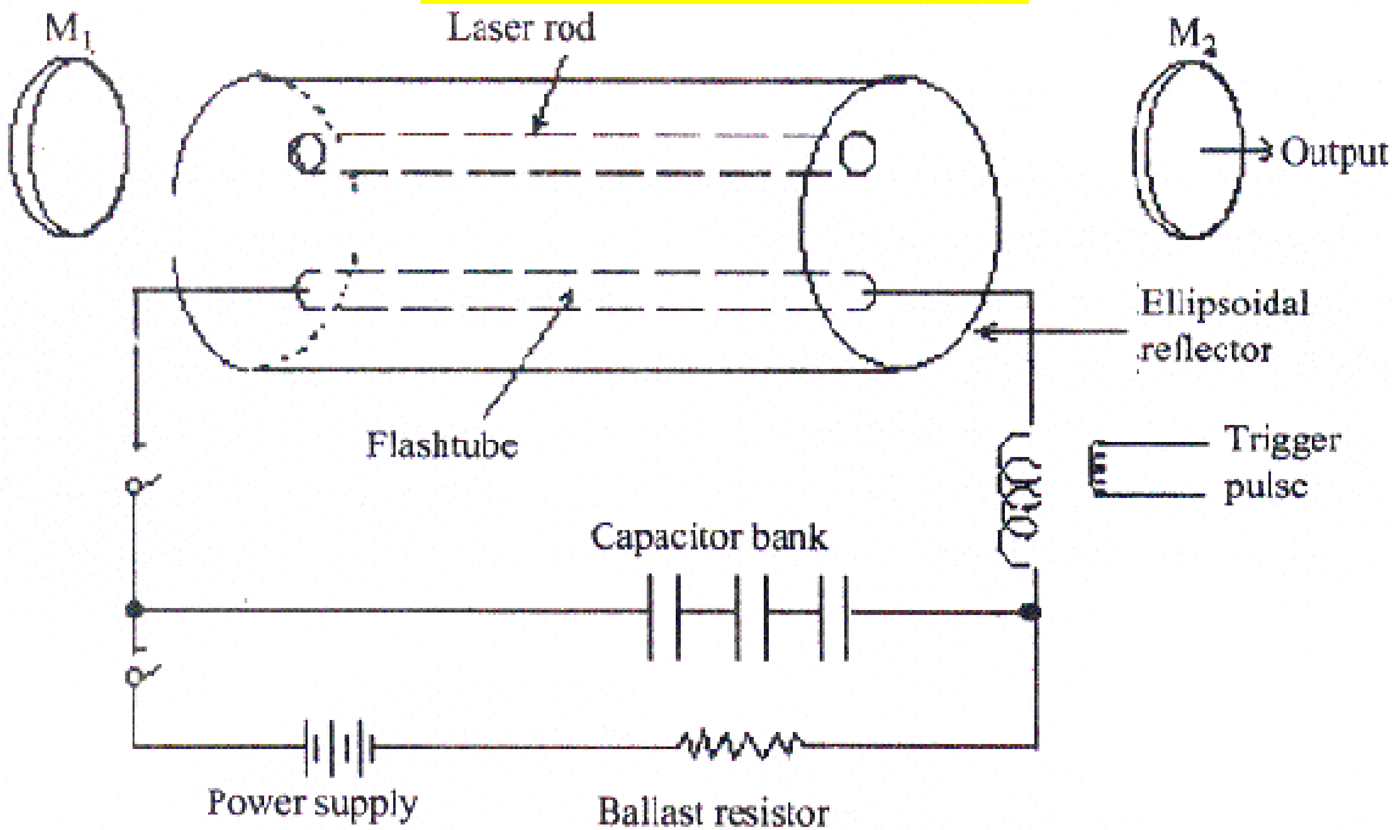
- The host medium for this laser is Yttrium Aluminium Garnet (YAG = $Y_3\ Al_5\ O_{12}$) with 1.5% trivalent neodymium ions (Nd^{3+}) present as impurities.

- The (Nd^{3+}) ions occupy the lattice sites of yttrium ions as substitutional impurities and provide the energy levels for both pumping and lasing transitions.

- When an (Nd^{3+}) ion is placed in a host crystal lattice it is subjected to the electrostatic field of the surrounding ions, the so called crystal field.

- The crystal field modifies the transition probabilities between the various energy levels of the Nd^{3+} ion so that some transitions, which are forbidden in the free ion, become allowed.

Nd: YAG laser



M_1
Laser rod
M_2
Output
Ellipsoidal reflector
Flashtube
Trigger pulse
Capacitor bank
Power supply
Ballast resistor

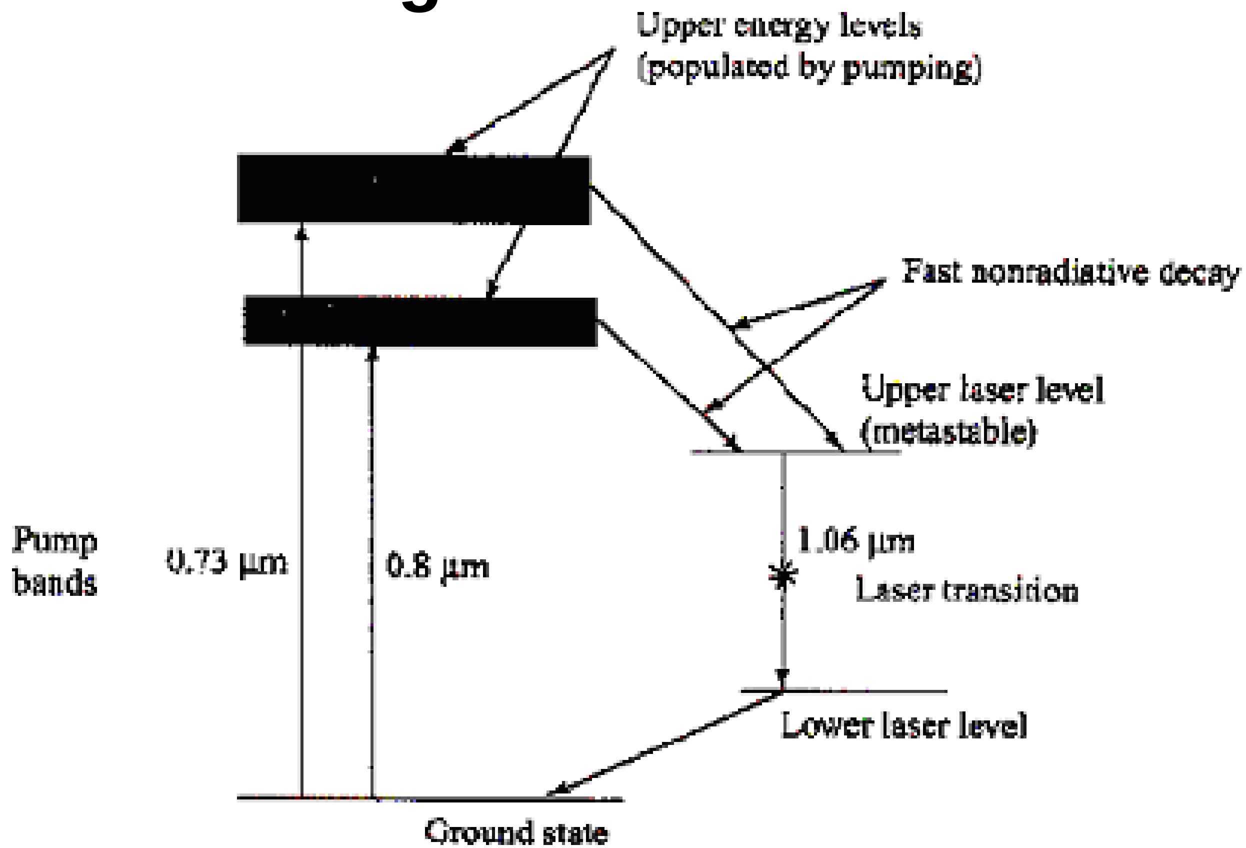
- The length of the Nd: YAG laser rod varies from 5cm to 10cm depending on the power of the laser and its diameter is generally 6 to 9mm.
- The laser rod and a linear flash lamp are housed in a elliptical reflector cavity
- Since the rod and the lamp are located at the foci of the ellipse, the light emitted by the lamp is effectively coupled to the rod.
- The ends of the rod are polished and made optically flat and parallel.

•The optical cavity is formed either by silvering the two ends of the rod or by using two external reflecting mirrors.

• One mirror is made hundred percent reflecting while the other mirror is left slightly transmitting to draw the output

• The system is cooled by either air or water circulation.

Energy level diagram



Simplified energy level diagram for the neodymium ion in YAG showing the principal laser transitions

- This laser system has two absorption bands (0.73 μm and 0.8 μm)
- Optical pumping mechanism is employed.
- Laser transition takes place between two laser levels at 1.06μm

Output characteristics

- The laser output is in the form of pulses with higher repetition rate
- Xenon flash lamps are used for pulsed output
- Nd: YAG laser can be operated in CW mode also using tungsten-halide incandescent lamp for optical pumping.
- Continuous output powers of over 1KW are obtained.

- YAG beams penetrate the lens of the eye to perform intracular procedures.
- YAG lasers are used in military as range finders and target designators.

Semiconductor(Ga-As) lasers

Introduction

The semiconductor laser is today one of the most important types of lasers with its very important application in fiber optic communication.

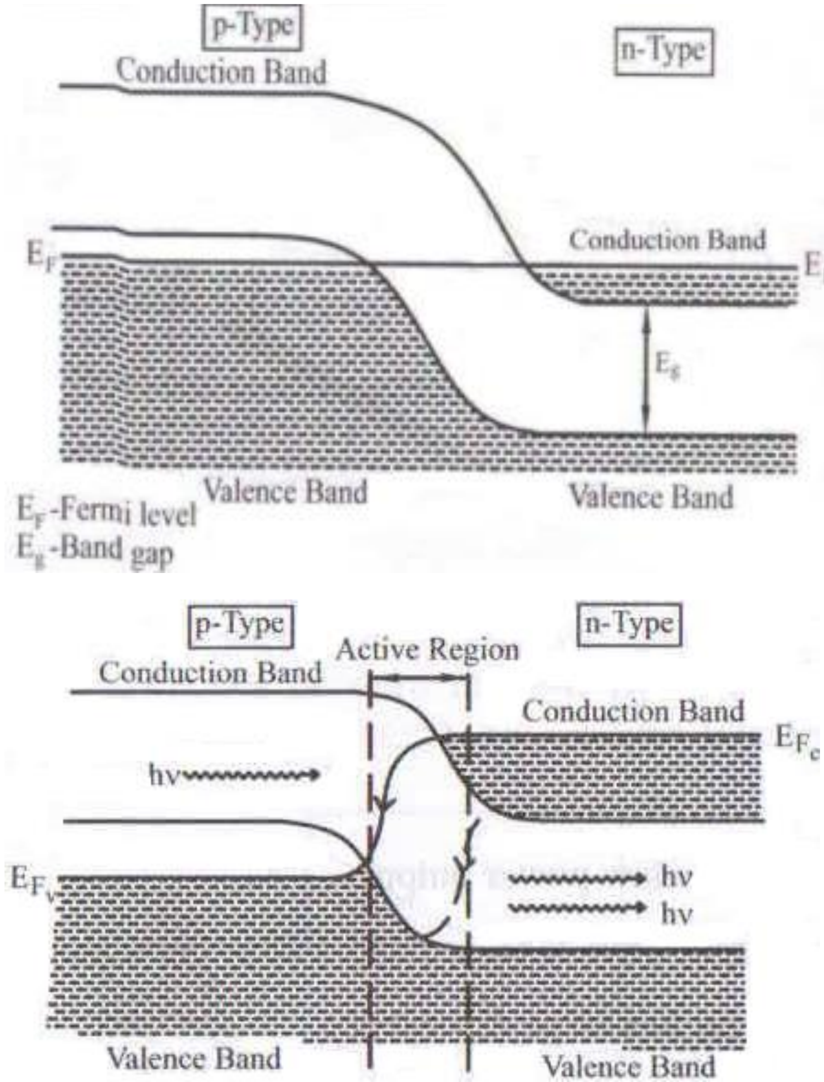
These lasers use semiconductors as the lasing medium and are characterized by specific advantages such as the capability of direct modulation in the gigahertz region, small size and low cost.

Basic Mechanism

The basic mechanism responsible for light emission from a semiconductor is the recombination of electrons and holes at a *p*-*n* junction when a current is passed through a diode.

There can be three interaction processes

1) An electron in the valence band can absorb the incident radiation and be excited to the conduction band leading to the generation of eletron-hole pair.


p-Type
Conduction Band
n-Type
Conduction Band
E_F
E_F
E_g
Valence Band
Valence Band
E_F-Fermi level
E_g-Band gap
p-Type
Active Region
n-Type
Conduction Band
Conduction Band
E_{F_c}
hv
E_{F_v}
hv
hv
Valence Band
Valence Band

2) An electron can make a spontaneous transition in which it combines with a hole and in the process it emits radiation

3) A stimulated emission may occur in which the incident radiation stimulates an electron in the conduction band to make a transition to the valence band and in the process emit radiation.

To convert the amplifying medium into a laser

- ✓ Optical feedback should be provided
- ✓ Done by cleaving or polishing the ends of the *p-n* junction diode at right angles to the junction.

- When a current is passed through a *p-n* junction under forward bias, the injected electrons and holes will increase the density of electrons in the conduction band.

- The stimulated emission rate will exceed the absorption rate and amplification will occur at some value of current due to holes in valence band.

- As the current is further increased, at threshold value of the current, the amplification will overcome the losses in the cavity and the laser will begin to emit coherent radiation.

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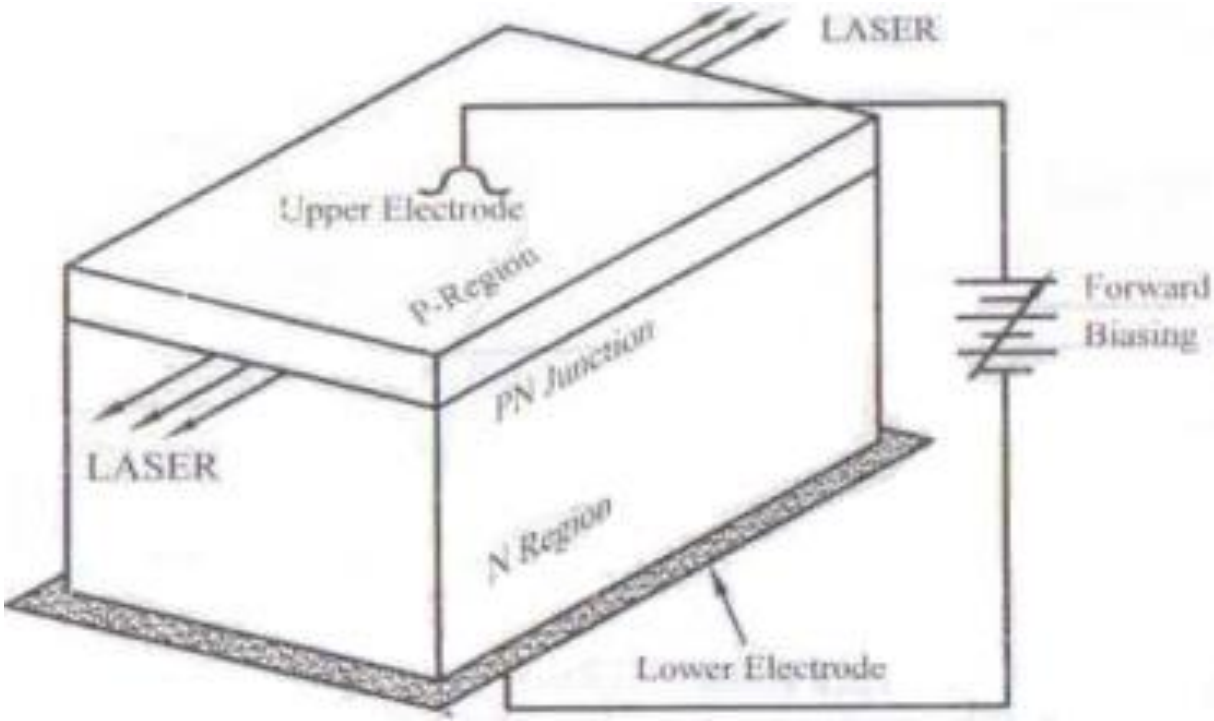
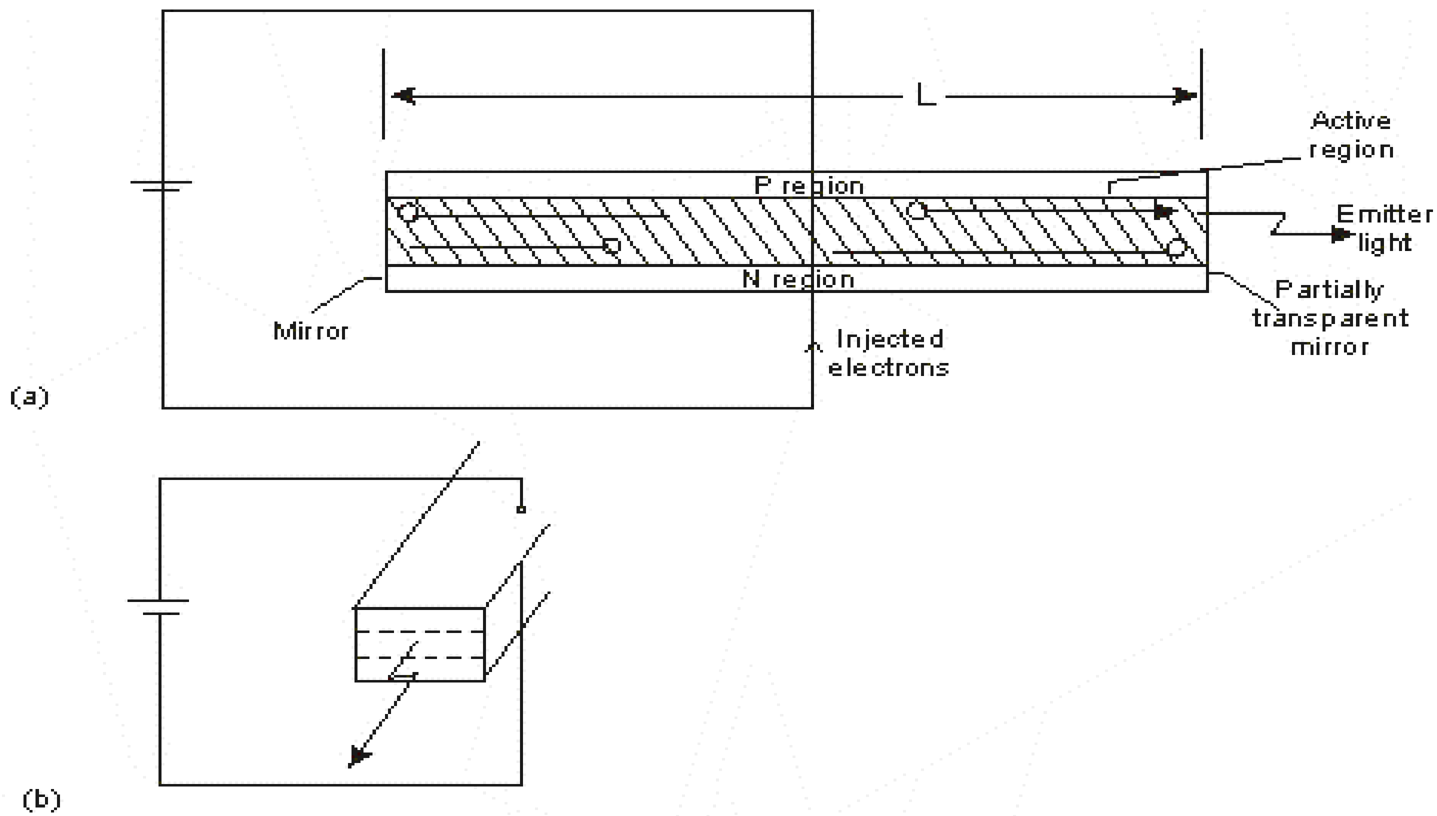
Simple structure (Homojunction)

- The basic semiconductor laser structure in which the photons generated by the injection current travel to the edge mirrors and are reflected back into the active area.
- Photoelectron collisions take place and produce more photons, which continue to bounce back and forth between the two edge mirrors.
- This process eventually increases the number of generated photons until lasing takes place. The lasing will take place at particular wavelengths that are related to the length of the cavity.


LASER
Upper Electrode
P-Region
PN Junction
Forward
Biasing
LASER
N Region
Lower Electrode



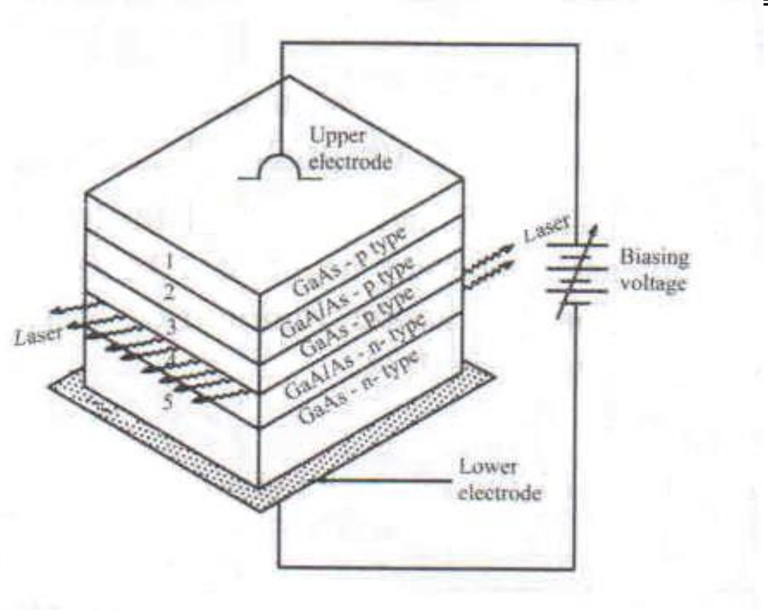
Basic semiconductor laser structure
a)Side view b)Projection Heterostructures

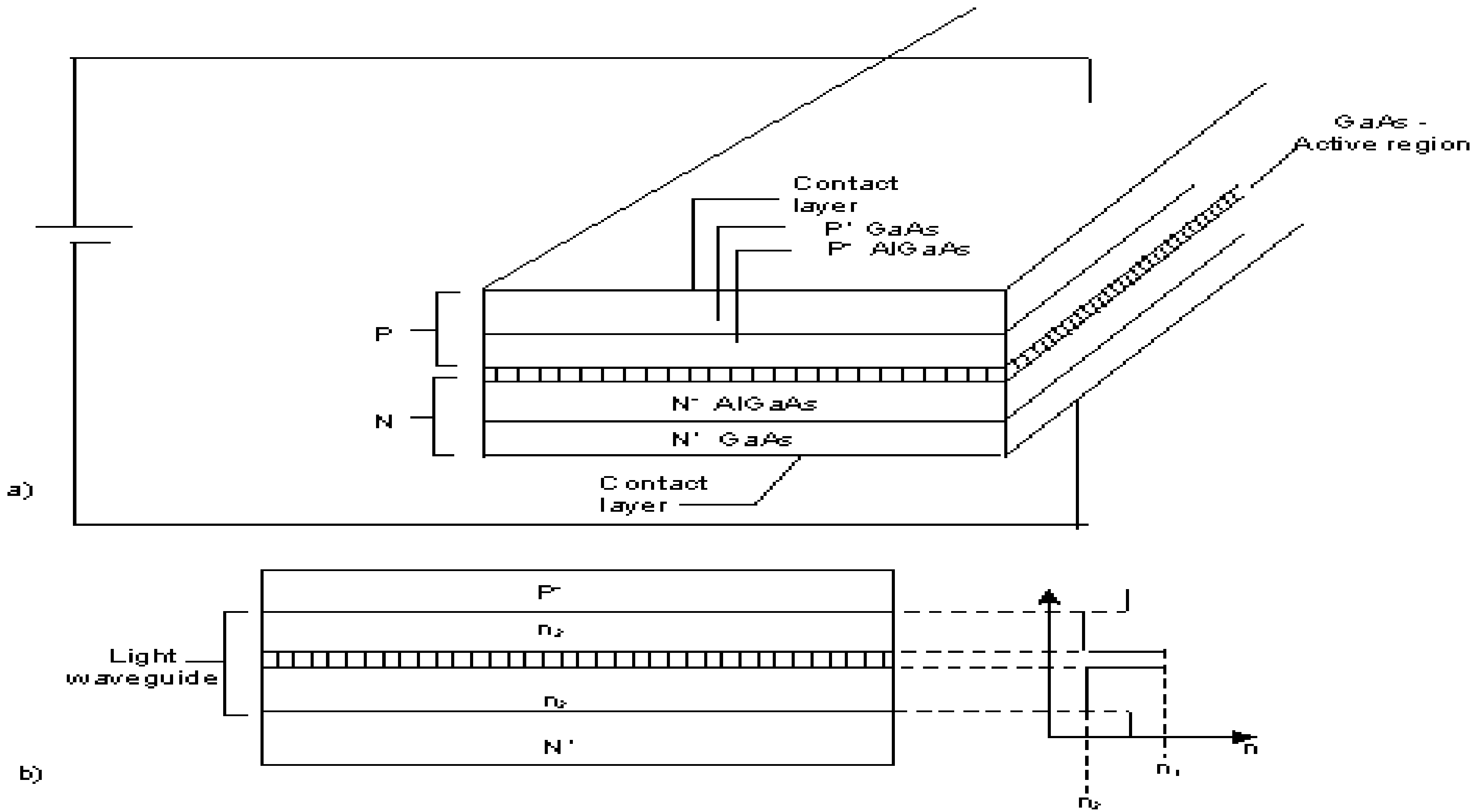
Heterostructures

The heterostructure laser is a laser diode with more than single P and N layers. GaAs/AlGaAs is a heterojunction laser. The notations P^+ and N^+ and P^- and N^- indicate heavy doping and light doping respectively. The P-N structure consists of the two double layers, P^+ - P^- and N^+ - N^- .

A thin layer of GaAs is placed at the junction, the active region. The substance is selected because the electron-hole recombinations are highly radiative. This increases the radiation efficiency.

The P and N regions are lightly doped regions that have an index of refraction n_2 less than n_1 of the active region. These three layers, n_2-n_1-n_2, form a light waveguide much like the optical fiber, so that the light generated is confined to the active region.





Laser heterostructure (a) Schematic projection (b) Refractive index profile