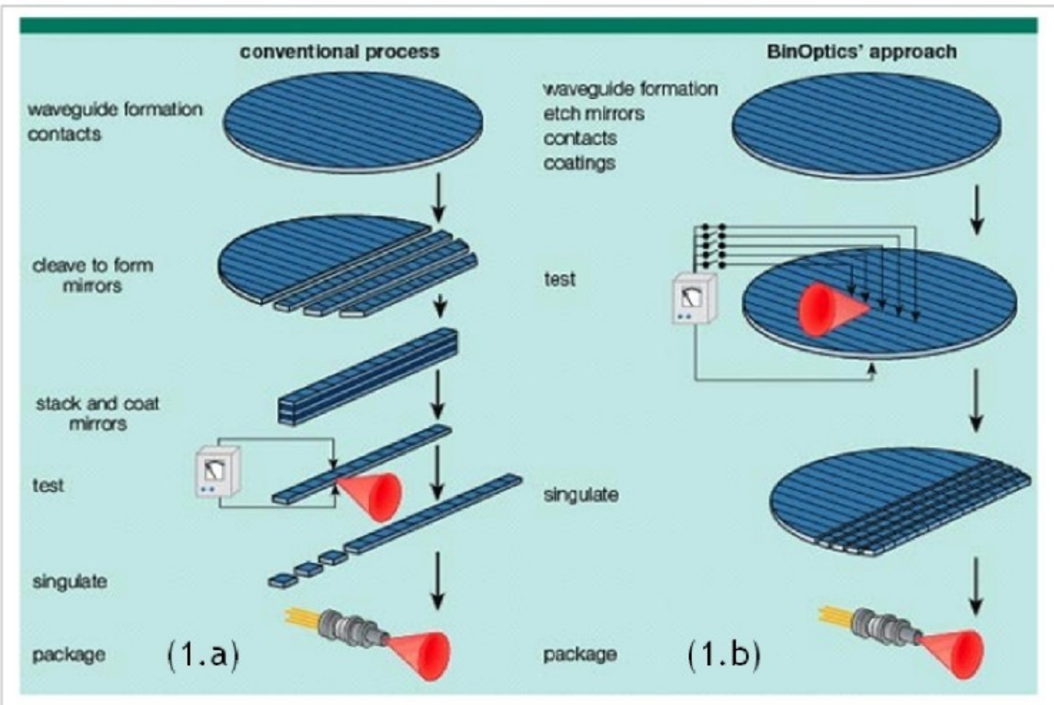
Semiconductor Lasers

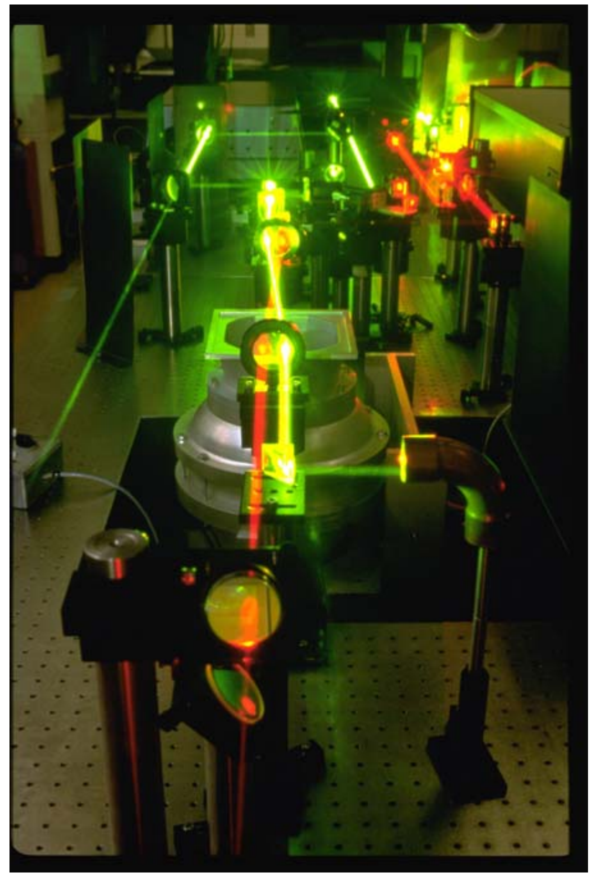
Malik Little
ECE 3080

Facts

<u>Semiconductor lasers:</u>

- Cheap and smallest Lasers available
- Easy fabrication
- Mass produced
- Gain medium is a p-n junction diode
- Used for fiber optic communication





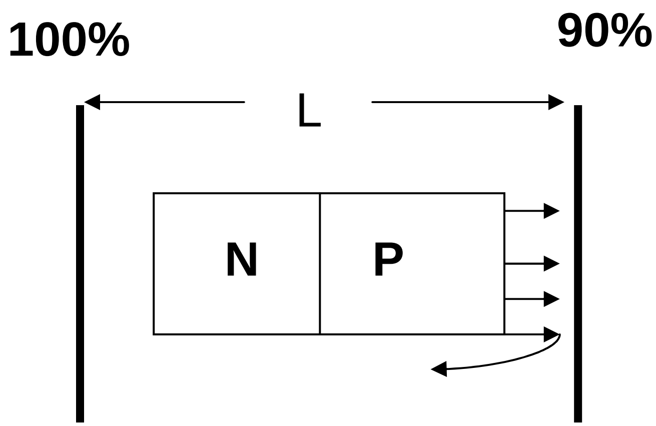
Purdue universities Diode LASER

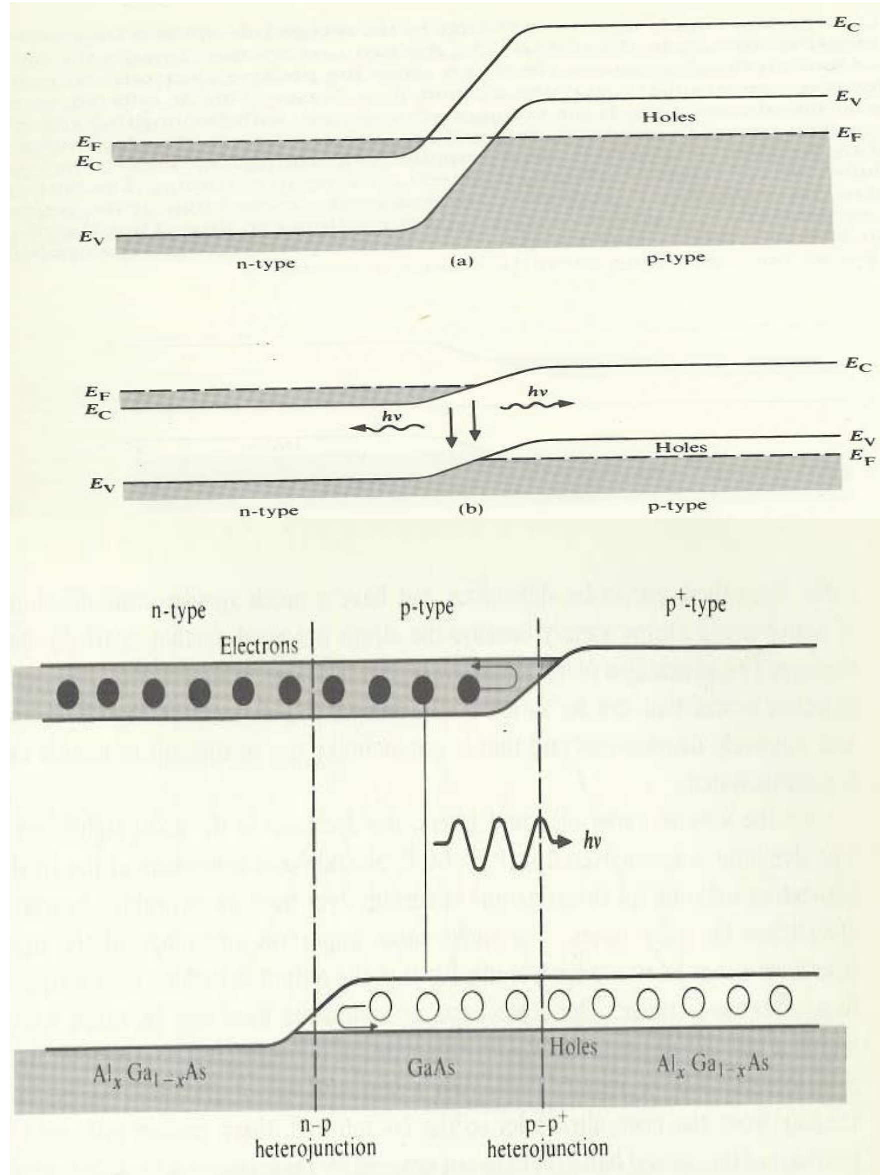
Theory: Concept

Requirements for lasing:

- Diode must be forward biased.
- Population inversion must occur
- Electrons and holes both have to be in the junction

Resonating Cavity





Theory: Math

When calculating the population inversion and threshold values these are the key parameters:

$$\Gamma a := \frac{\text{power\_in\_active\_region}}{\text{Total\_Power}} \qquad \Gamma n := \frac{\text{Power\_in\_n\_region}}{\text{Total\_Power}} \qquad \Gamma p := \frac{\text{power\_in\_p\_region}}{\text{Total\_Power}} \qquad \lambda := \frac{c}{\nu}$$

$$\alpha\text{eff} := \alpha s + \Gamma a \cdot \alpha a + \Gamma n \cdot \alpha n + \Gamma p \cdot \alpha p$$

$$R := \left[\frac{(n-1)}{(n+1)}\right]^2$$

$$\beta_{th} := \alpha\text{eff} + \frac{1}{2 \cdot L} \cdot \ln\left(\frac{1}{R1 \cdot R2}\right)$$

$$J_{th} := \frac{\left(N_{th} \cdot e \cdot d\right)}{\tau}$$

$$I_{th} := \frac{\left(N_{th} \cdot e \cdot A \cdot d\right)}{\tau}$$

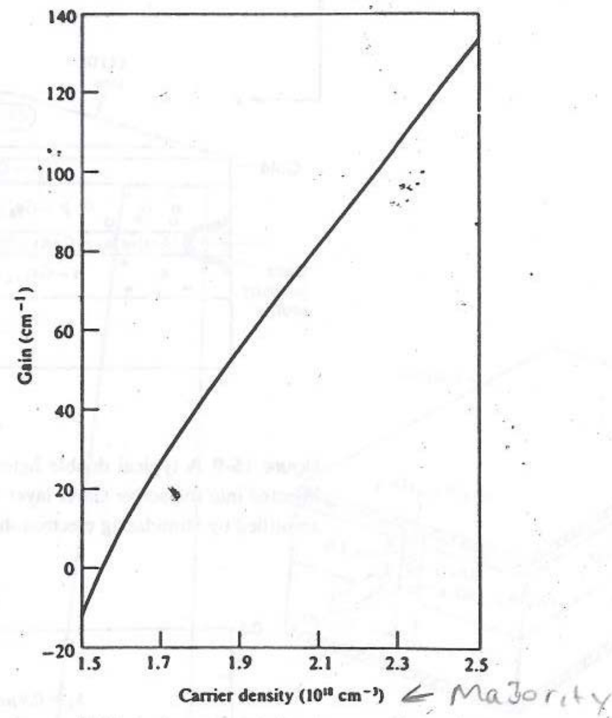
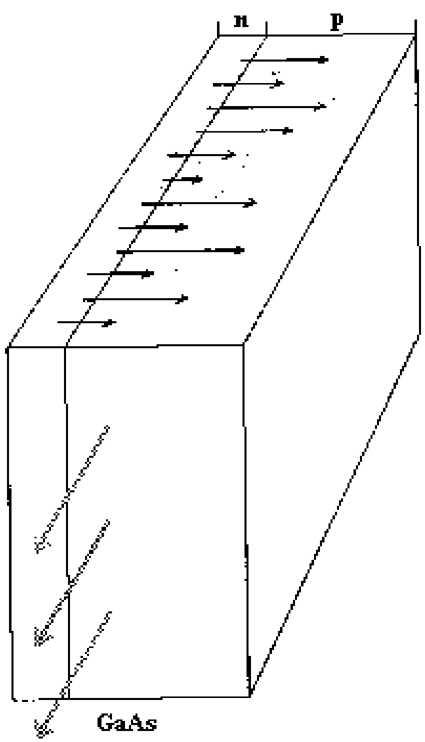
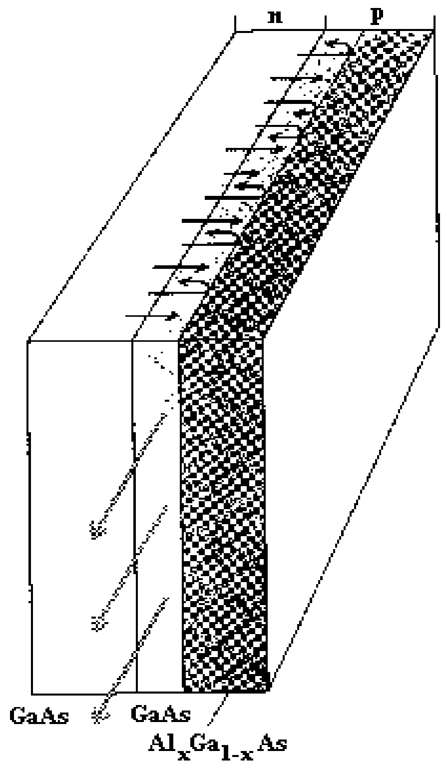


Figure 15-8 A plot of the peak gain γ_{max} of Figure 15-7 as a function of the inversio at $T = 300$ K.

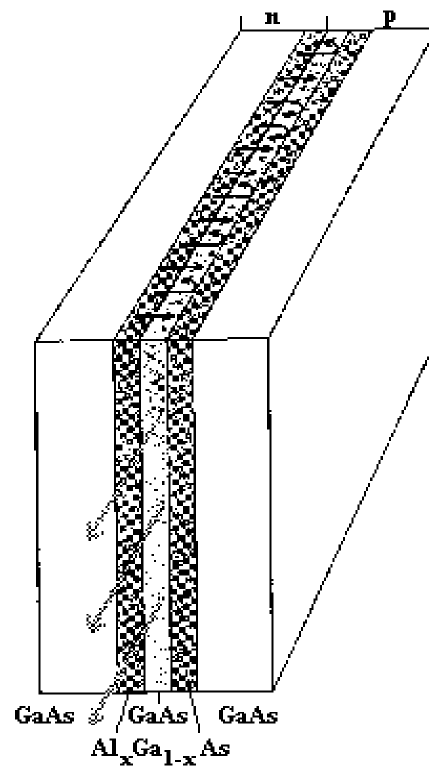
Types of Stuctures



Homojunction



Heterostructure



Double Heterostructure

Double Heterostructure

Calculating output Power and efficiency:

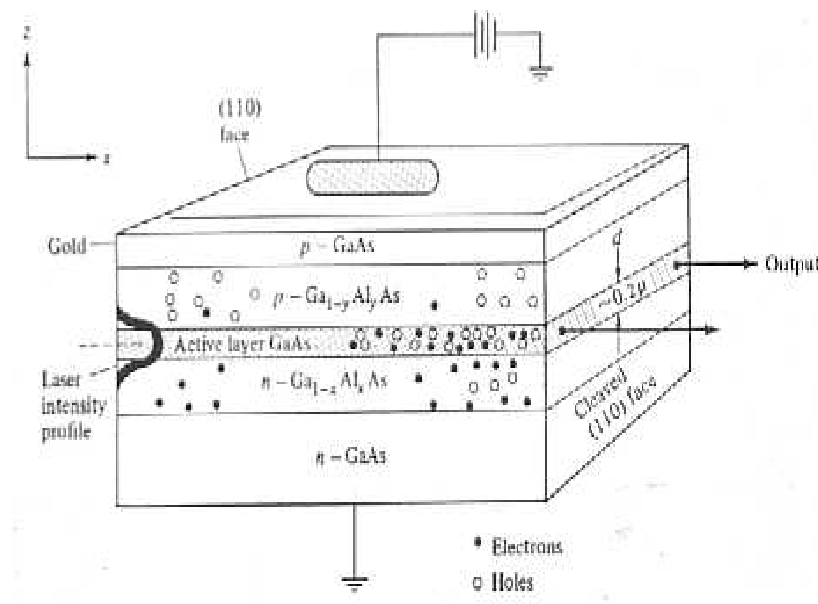
$$P_{pump} := \boxed{\frac{1}{4}\cdot\frac{Eg}{e}}\cdot I$$

Voltage

$$P_e := \frac{\left[\eta_i\cdot\left(I - I_{th}\right)\right]}{e}\cdot h\cdot\nu$$ =>emitted Power

$$P_o := \left(P_e\right)\cdot\frac{\left(\frac{1}{2\cdot L}\cdot\ln\left(\frac{1}{R1\cdot R2}\right)\right)}{\left(\alpha eff + \frac{1}{2\cdot L}\cdot\ln\left(\frac{1}{R1\cdot R2}\right)\right)}$$

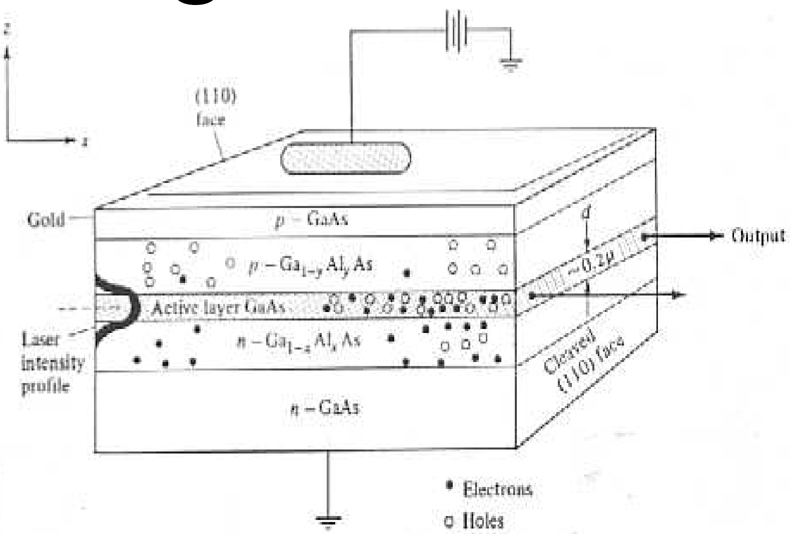
$$\eta := \frac{P_o}{P_{pump}}$$



Note:
•Where Eta equals the quantum Efficiency. Meaning EHP recombination Efficiency.

• I equals the current needed for pumping

Lasing Orientation



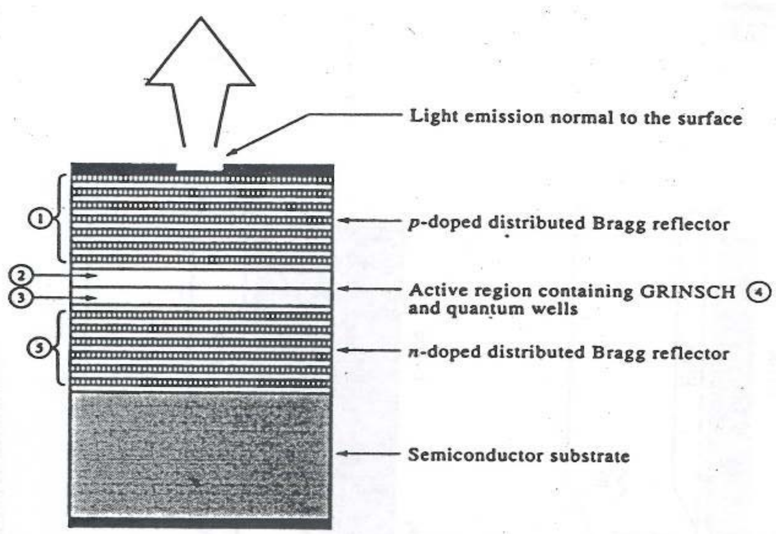


Figure 16-13 A schematic cross section of a vertical cavity surface emitting semiconductor laser based on the GaInAlAs alloy system.

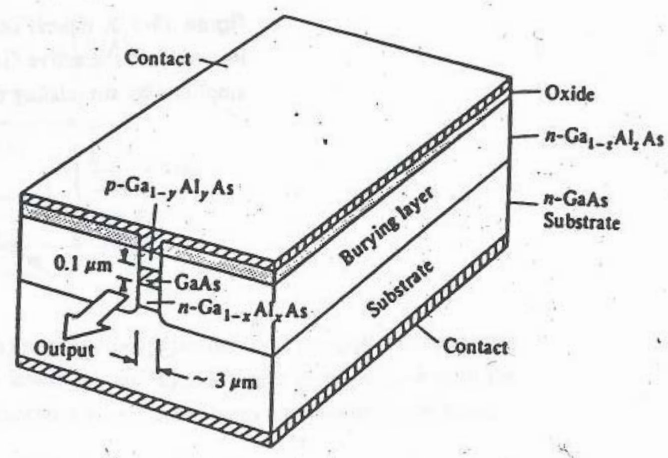
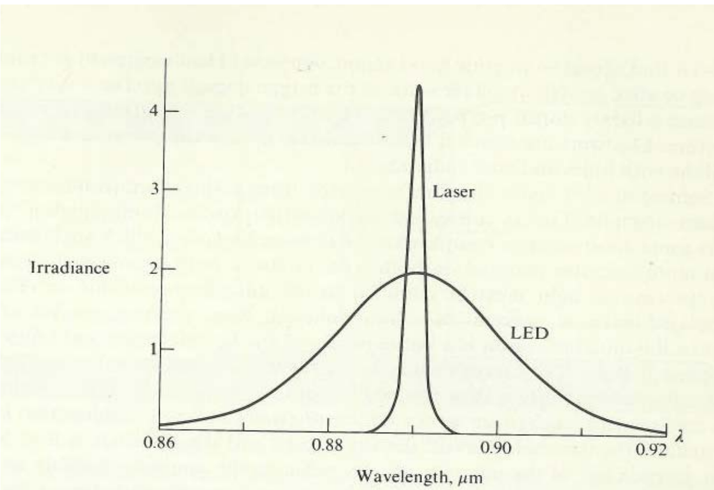


Figure 15-15 A buried heterostructure laser [20].

Questions

Additional Notes



$$\hbar\omega(\mathbf{k}) = E_g + \frac{\hbar^2 k^2}{2m_c} + \frac{\hbar^2 k^2}{2m_v} \qquad (15.2\text{-}1)$$

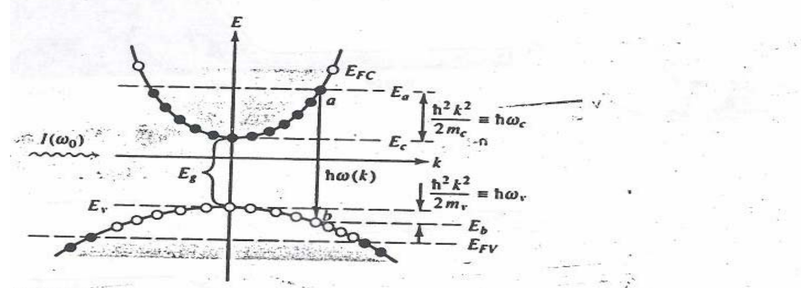


Figure 15-5 An optical beam at ω_0 with intensity $I(\omega_0)$ is incident on a pumped semiconductor medium characterized by quasi-Fermi levels E_{F_c} and E_{F_v}. A single level pair a-b with the same k value is shown. The induced transition $a \rightarrow b$ contributes one photon to the beam.

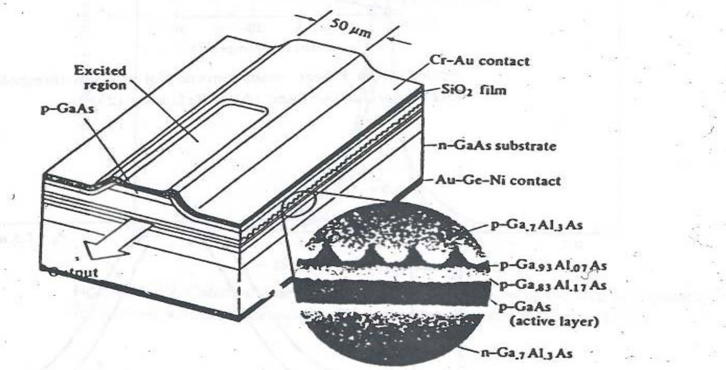
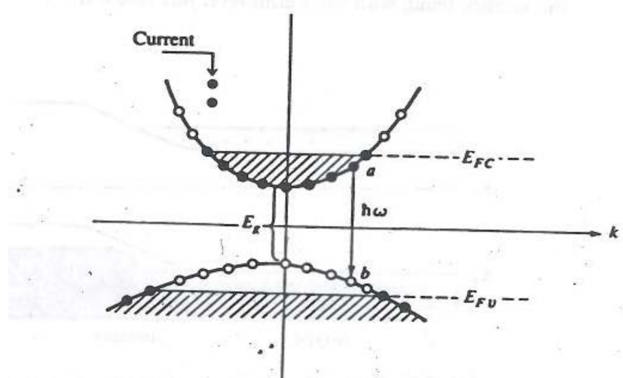


Figure 16-9 A GaAs–GaAlAs *cw* injection laser with a corrugated inferface. The insert shows a scanning electron microscope photograph of the layered structure. The feedback is in third order ($\ell = 3$) and is provided by a corrugation with a period $\Lambda = 3\lambda_g/2 = 0.345$ μm. The thin (0.2 μm) p-$Ga_{.83}A_{.17}As$ layer provides a potential barrier which confines the injected electrons to the active (p-GaAs) layer, thus increasing the gain. (After Reference [11].)



$$E = \frac{(\hbar k)^2}{2m}$$

Figure 15-4 Electrons are injected at a rate of I/eV per unit volume (I = total current) into the conduction band of a semiconductor.