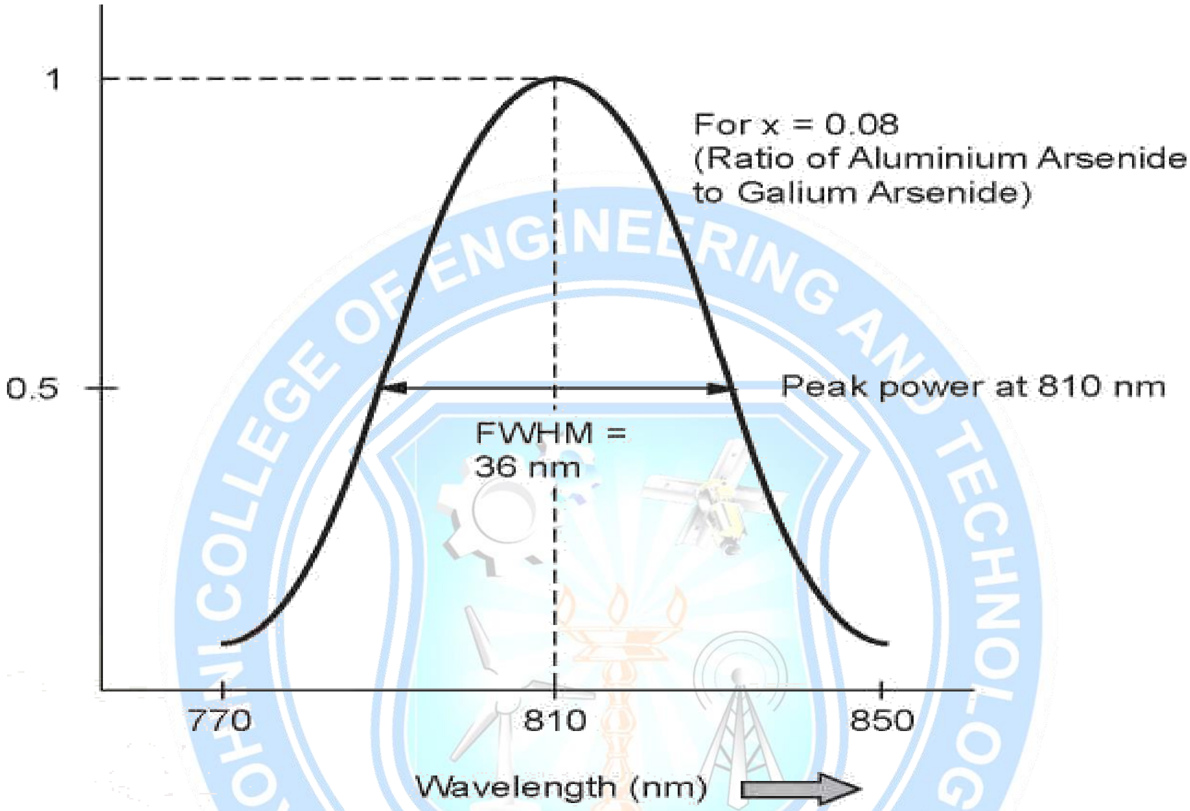
3.4 Light Source Materials

- The spontaneous emission due to carrier recombination is called electro luminescence. To encourage electroluminescence it is necessary to select an appropriate semiconductor material. The semiconductors depending on energy bandgap can be categorized into,
  1. Direct bandgap semiconductors - GaAs, GaSb,InAs, In,Sb
  2. Indirect bandgap semiconductors - Si, Ge, Gap.
- Some commonly used bandgap semiconductors are shown in Table

Semiconductor	**Energy bandgap (eV)**	**Recombination** **B_r (cm^3 / sec)**
GaAs	Direct : 1.43	7.21 x"0 $^{"0}$
GaSb	Direct : 0.73	2.39 x10 ^{10}
InAs	Direct : 0.35	8.5 x"'0 ""
InSb	Direct : 0.18	4.58 X10^{-11}
Si	Indirect : 1.12	1.79 x"0 $^{"5}$
Ge	Indirect : 0.67	5.25 X10^{-14}
GaP	Indirect : 2.26	5.37 x10$^{“14}$

- Direct bandgap semiconductors are most useful for this purpose. In direct bandgap semiconductors the electrons and holes on either side of bandgap have same value of crystal momentum. Hence direct recombination is possible. The recombination occurs within 10$^{“8}$ to 10–^{10} sec.
- In indirect bandgap semiconductors, the maximum and minimum energies occur at different values of crystal momentum. The recombination in these semiconductors is quite slow i.e. 10$^{“2}$ to "10–^{3} sec.
- The active layer semiconductor material must have a **direct bandgap.** In direct bandgap semiconductor, electrons and holes can recombine directly without need of third particle to conserve momentum. In these materials the optical radiation is sufficiently high. These materials are compounds of group III element (Al, Ga, In) and group V element (P, As, Sb). Some tertiary alloys Ga$_{1-x}$ Al$_x$ As are also used.
- Emission spectrum of G $_{al\_x}$ Al$_x$As LED is shown in Figure

- The peak output power is obtained at 810 nm. The width of emission spectrum at half power (0.5) is referred as **Full Width Half Maximum** (FWHM) spectral width. For the given LED FWHM is 36 nm



- The fundamental quantum mechanical relationship between gap energy E and frequency v is given as -

$$E = hv \qquad E = h\frac{c}{\lambda} \qquad \lambda = \frac{hc}{E}$$

where, energy (E) is in joules and wavelength (λ) is in meters. Expressing the gap energy (E_g) in electron volts and wavelength (λ) in micrometers for this application.

$$\lambda(\mu m) = \frac{1.24}{E_g\,(eV)}$$

Different materials and alloys have different bandgap energies.

- The bandgap energy (E_g) can be controlled by two compositional parameters x and y, within direct bandgap region. The quarternary alloy $In_{1-x}\,Ga_x\,As_y\,P_{1-y}$ is the principal material used in such LEDs. Two expressions relating E_g and x, y are -

$$E_g = 1.424 + 1.266\,x + 0.266\,x^2$$

$$E_g = 1.35 - 0.72\,y + 0.12\,y^2$$