Intensity vs λ

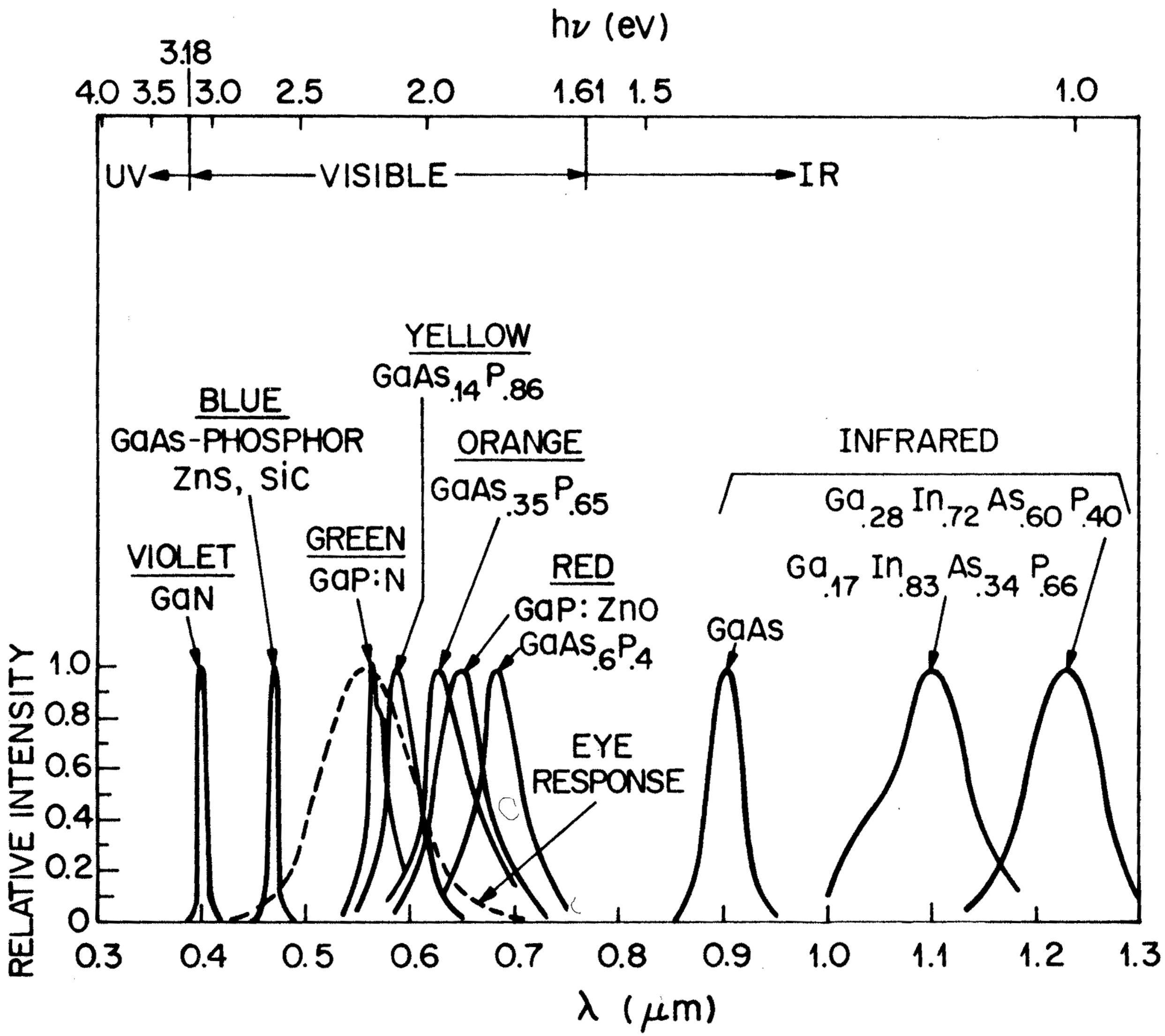


Fig. 13 Relative intensity versus wavelength for various visible and infrared LEDs.

Luminous Equivalent of Radiation

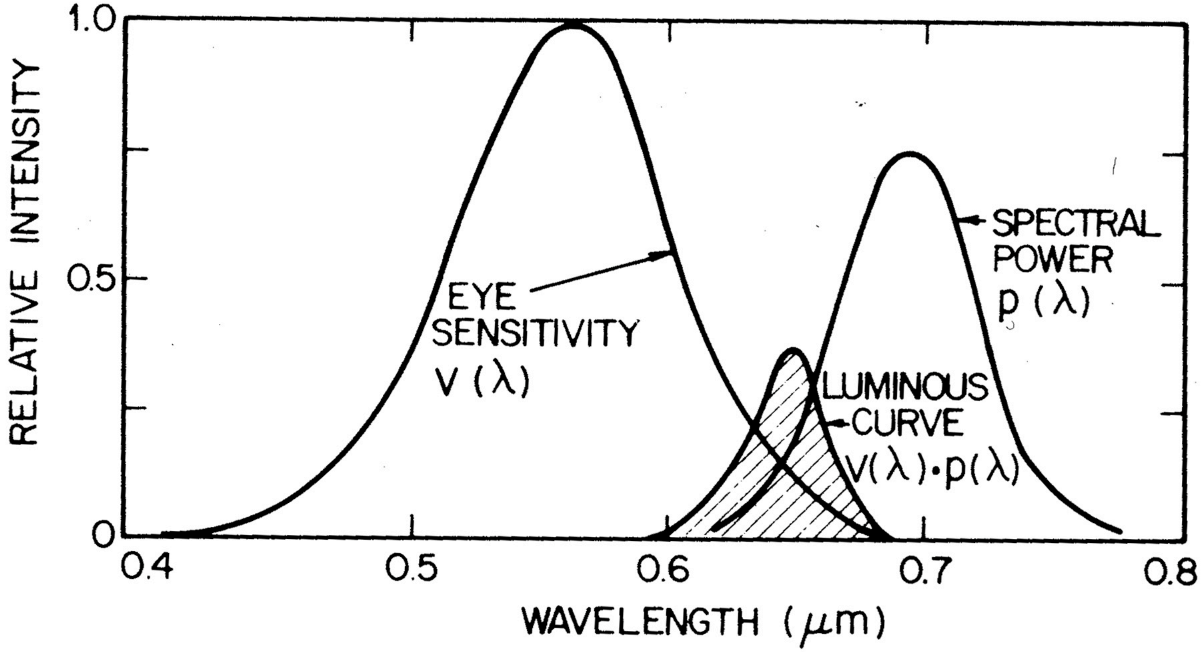


Fig. 15 Evaluation of luminous equivalent of radiation. (After Gooch, Ref. 29.)

When the spectral power (p(λ) for GaP-ZnO diode has a peak at 0.69μm) is combined with the eye-sensitivity curve a peak response at 0.65μm is obtained with a luminous equivalent of 11lm/W.

Heterojunction LED

If the LED is made from a single semiconductor it is very difficult to have the photon emission volume very close to the surface so that the emitted photons are not readsorbed and furthermore the electrons injected from the n-side to the p-side can diffuse over long distance before recombining with holes.

The heterojunction LED resolves these problems by injecting carriers from a larger bandgap material in a narrow gap active region. The injected electons can not enter into the wide gap p-region. The photons emitted are also not adsorbed in the top or bottom region since the photon energy is smaller than the bandgap of the barrier.

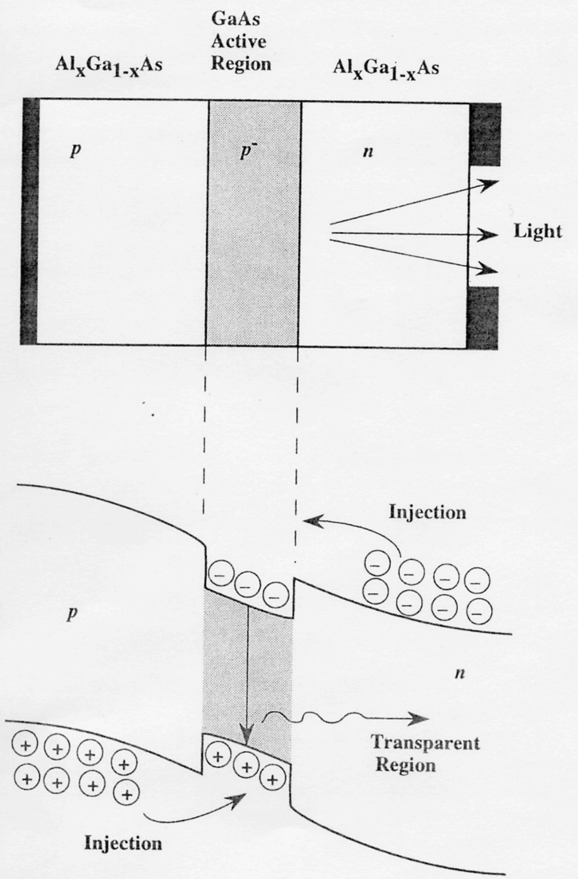
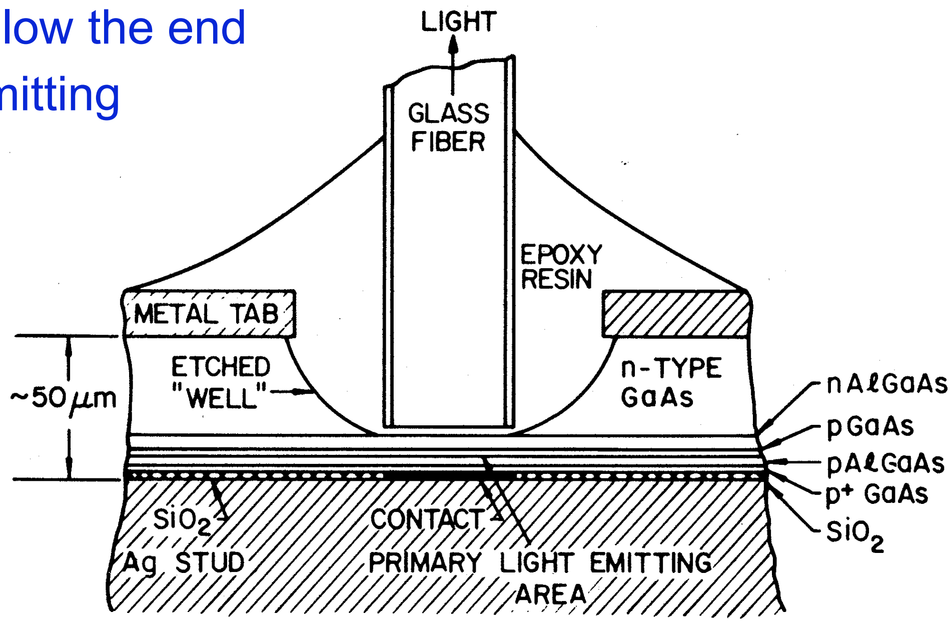


Figure 11.11: A heterojunction LED uses a narrow gap semiconductor for the active region. The photons that are emitted are not reabsorbed in the top or bottom layers, which are transparent

Infrared LED

Infrared LED are potential source for optical-fiber communications (low losses).
The surface emitter and the edge emitter are the two basic device configurations to couple the LED light output into a small fiber.

For the surface emitter, the emitting area at the junction is confined by oxide isolation, and the contact area is usually 15 to 100μm in diameter.
The semiconductor throught which the emission must be collected is made be very thin, 10 to 15μm, to minimize absorption and allow the end of the fiber to be very close to the emitting surface.
The use of heterojunctions ($GaAs$-$Al_xGa_{1-x}As$) can increase the efficiency.



(a)

Edge emitting LED

In order to increase the the coupling efficiency one needs a very collimated beam. In the Edge emitting LED wide gap caldding layers confine electrons and holes to the active region and allow the emitted photons to travel along the LED axis and emerge from the edge of the device.
These LED have, therefore, superior collimation properties.

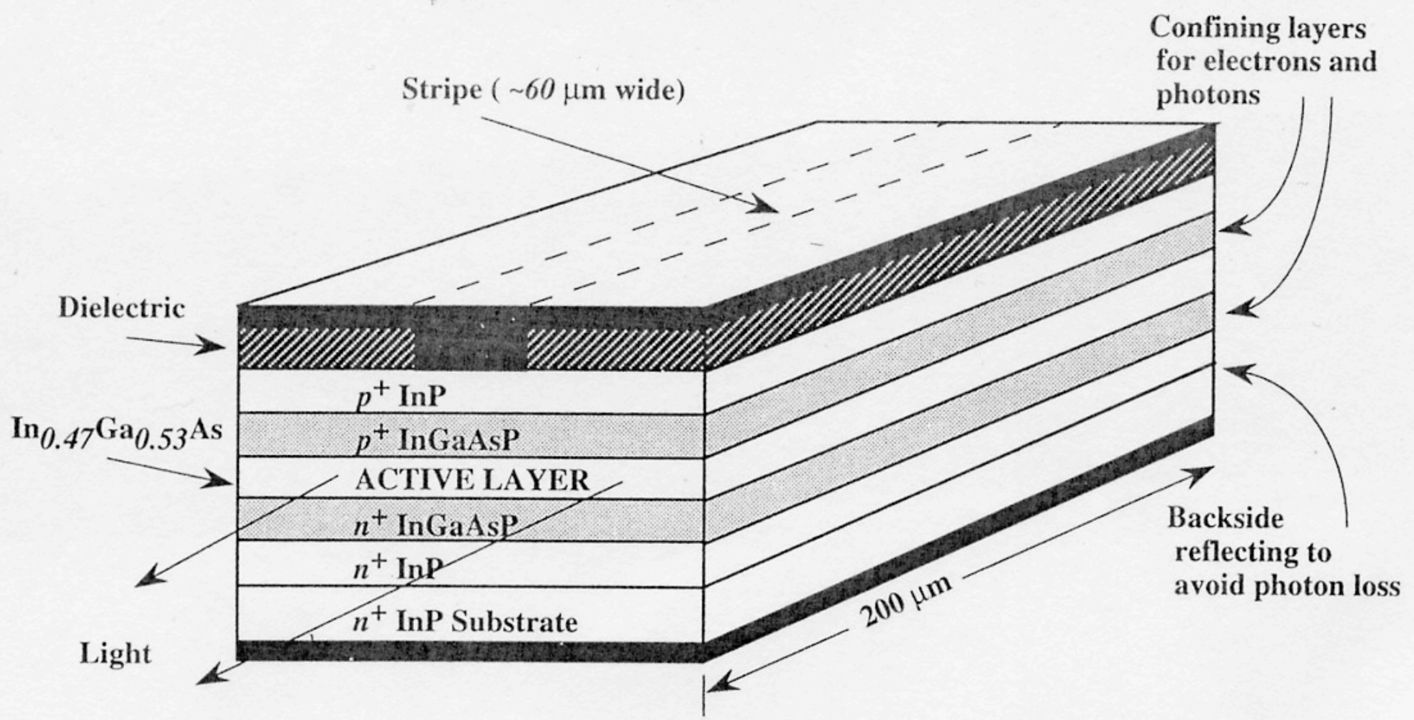


Figure 11.12: A schematic of an edge emitting LED. The active region is $In_{0.47}Ga_{0.53}As$ (E_g = 0.8 eV) surrounded by confining layers fabricated from InGaAsP (E_g ~1.0 eV). The confining layers cause the light to be coupled out through the edge of the device.

LED vs LASER

The LED is an important optical source which finds use in many applications, including those in display systems and optical communication.

The main advantages of LED are the simplicity of fabrication process and the easy incorporation of the device (p-n junction) in most circuitry.

The key drawbacks of the LED are the broad spectrum of the emitted light .

The laser diode is able to overcome this problem providing an extremely sharp emission line with linewidth up to orders of magnitude narrower than that of an LED.

Laser Processes

The operation of any light-emitting devices involves the absorption and emission of electromagnetic radiation.
The absorption of a photon with the energy $h\nu=E_2-E_1$ causes a transition from the ground state to the excited state.

The transitions from the excited state to the ground state lead to the emission of photons with energy $h\nu=E_2-E_1$ (spontaneous emission in the low injection regime).

However, the laser structure is so designed that at higher injections the emission process occurs by stimulated emission. An important and interesting event occurs when a photon of energy $h\nu$ impinges on an atom while is still in the excited state. In this case, the atom is immediately stimulated to make its transition to the ground state and gives off a photon of energy $h\nu$, which is in phase with the incident radiation (stimulated emission).

The stimulated emission process provides spectral purity to the photon output, coherent photons (in phase), and offers high speed performance.

Laser Processes

Absorption

Spontaneous Emission

Stimulated Emission

Excited states more populated (inversion population)

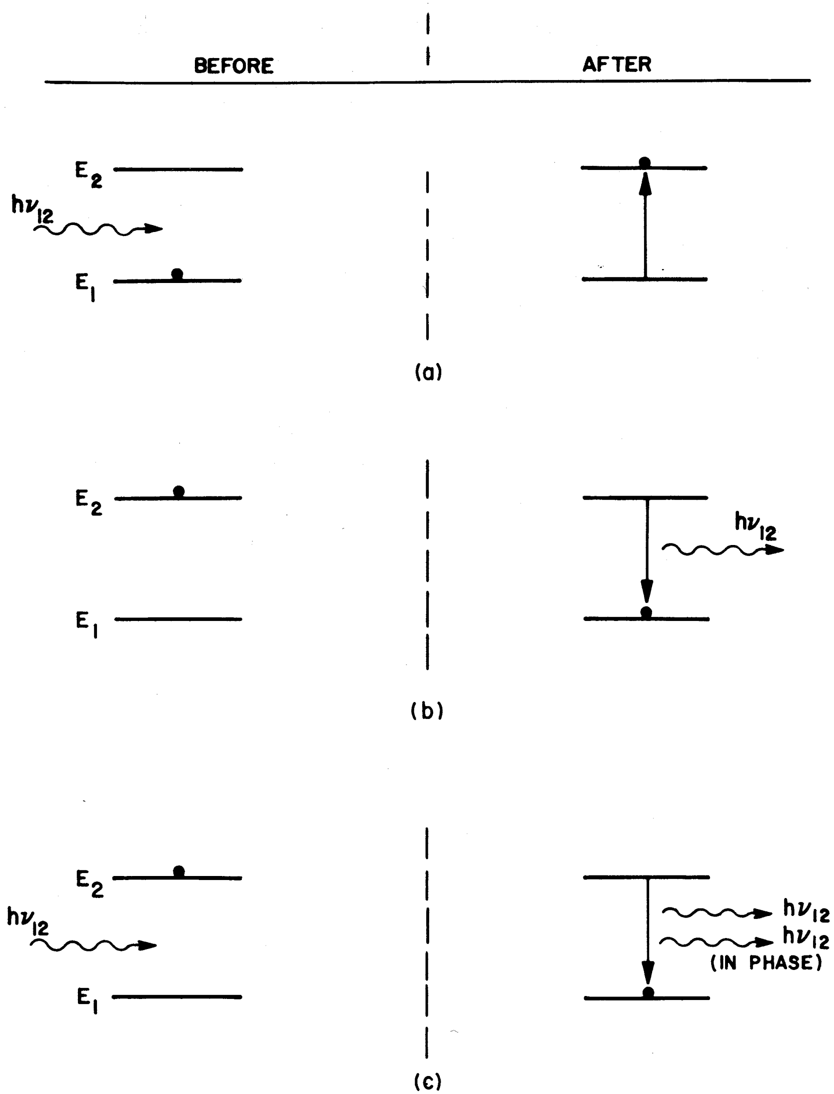


Fig. 25 The three basic transition processes between two energy levels E_1 and E_2. The black dots indicate the state of the atom. The initial state is at the left; the final state, after the process has occurred, is at the right. (*a*) Absorption. (*b*) Spontaneous emission. (*c*) Stimulated emission. (After Levine, Ref. 47.)

Semiconductor Lasers Properties

Semiconductor lasers differs from conventional lasers (solid-state ruby lasers and He-Ne gas lasers) in several important aspects:

1. In conventional lasers, the quantum transitions occur between discrete energy levels, whereas in semiconductor lasers the transitions are associated with the band properties of materials.
2. A semiconductor laser is very compact in size (of the order of 0.1 mm long). In addition, because the active region is very narrow (1μm or less).
3. The spatial and spectral characteristics of a semiconductor laser are strongly influenced by the properties of the junction medium (such as bandgap, and refractive index variations)
4. For the p-n junction laser, the laser action is produced by simply passing a forward current through the diode itself. The result is a very efficient overall system that can be modulated easily by modulating current. Since semiconductor laser have very short photon lifetimes, modulation at high frequencies can be achieved.

Semiconductor Lasers Properties

Because of its compact size and capability for high-frequency modulation, the semiconductor laser is one of the most important light sources for optical-fiber communications.

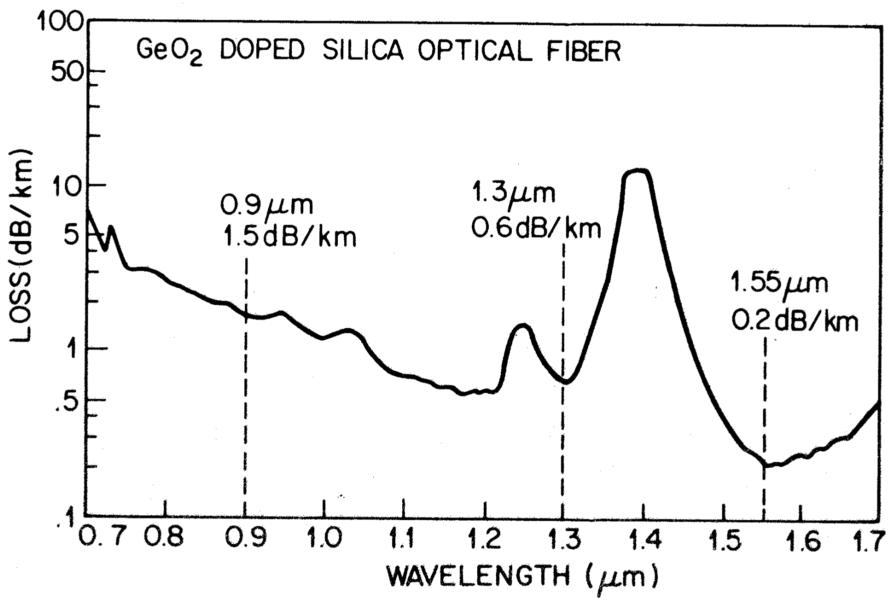


Fig. 22 Loss characteristics of a silica optical fiber. The three wavelengths of intere[s]
are also shown. (After Miya et al., Ref. 43.)

Three wavelengths are of particular interest: 0.9-μm wavelength (GaAs-AlGaAs HS laser), for the two wavelengths (1.3 μm and 1.55 μm), III-V quaternary compound lasers, such as GaInAsP-InP lasers are candidates for optical sources.

Semiconductor Materials

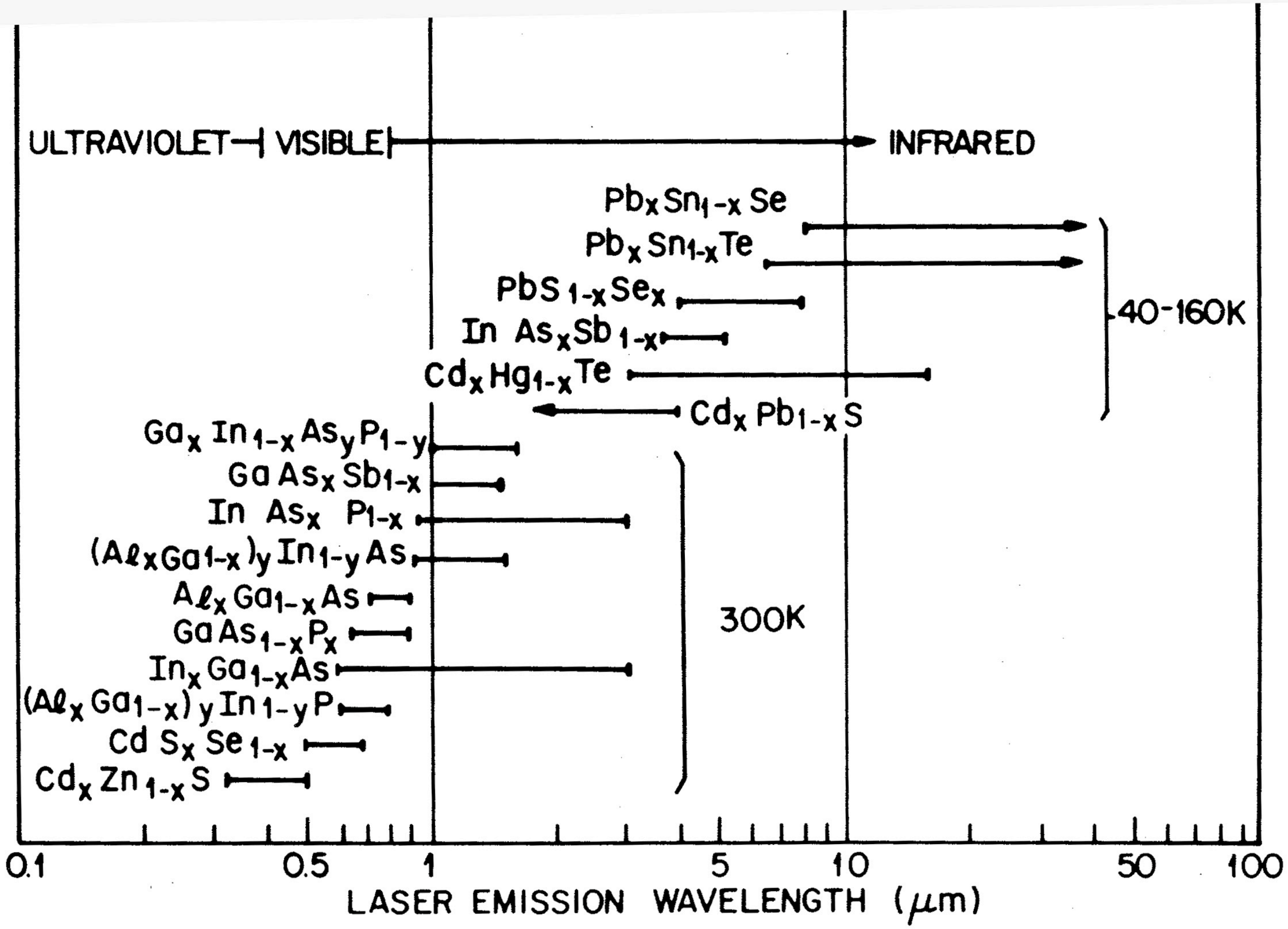


Fig. 23 Emission wavelengths either presently or potentially available with III–V and IV–VI heterostructure lasers. (After Casey and Panish, Ref. 20.)

At present all the lasing semiconductors have direct bandgaps. This is expected since the radiative transition in a direct bandgap semiconductor is a first-order process, the transition probability is high.

Eg vs a

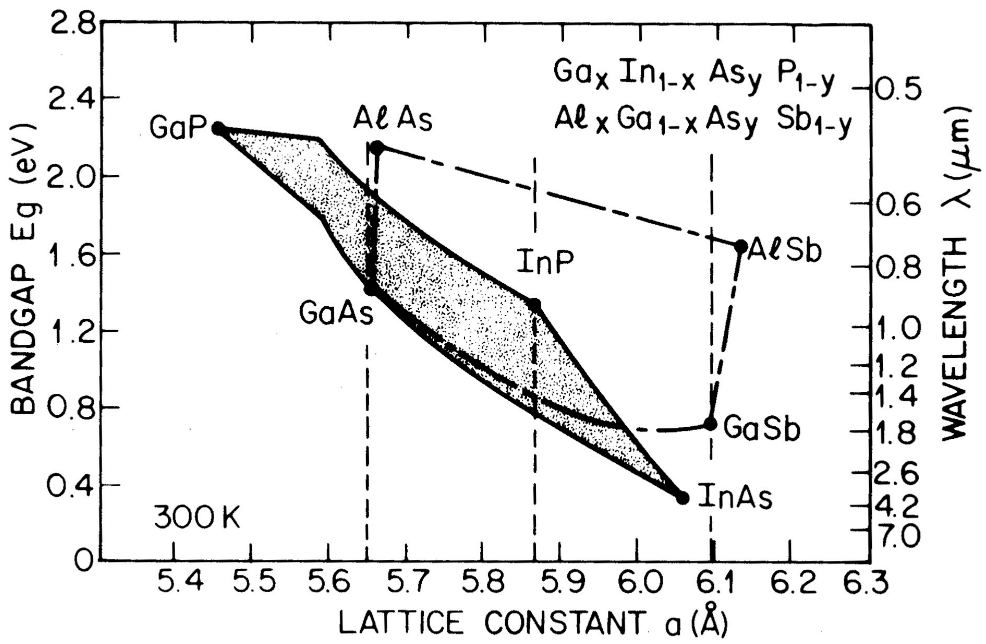


Fig. 24 Energy bandgap and lattice constant for two III–V solid solutions. (After Casey and Panish, Ref. 20.)

In heterostructure lasers, to achieve heterojunctions with negligible defects, the lattice between the two semiconductors must be closely matched.

GaAs-AlGaAs 0.1% (GaAs substrate)
InP-GaInAsP nearly perfect lattice matched