Example: LED Output Wavelength Variation

- Consider a GaAs LED
- GaAs bandgap at 300K is 1.42 eV
- Derivative of the bandgap is

$$\frac{dE_g}{dT} = -4.5\times10^{-4}\,\frac{eV}{K}$$

- What is the change in emitted wavelength if the temperature is 10°C?

$$E_g = \frac{hc}{e\lambda} - \frac{k_B T}{e}$$

$$\lambda = \frac{c}{\nu} = \frac{hc}{E_g} = \frac{\left(6.626\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(1.42\times1.6\times10^{-19}\right)} = \frac{1.24\times10^{-6}\,eV*m}{1.42eV} = 875nm$$

$$\frac{d\lambda}{dT} = -\frac{hc}{E_g^2}\left(\frac{dE_g}{dT}\right) = -\frac{\left(6.626\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(1.42\times1.6\times10^{-19}\right)^2}\left(-4.5\times10^{-4}\right)\left(1.6\times10^{-19}\right)\frac{m}{K}$$

$$\frac{d\lambda}{dT} \approx 2.77\times10^{-10}\,\frac{m}{K} = 0.277\,\frac{nm}{K}$$

$$\Delta\lambda = \frac{d\lambda}{dT}\Delta T \approx 0.277\,\frac{nm}{K}\times10K \approx 2.8nm$$

- Since E_g decreases with temperature, the wavelength increases with temperature. This calculated change is within 10% of typical values for GaAs LEDs quoted in the literature

Example: InGaAsP on InP Substrate

- Ternary alloy $In_{1-x}Ga_xAs_yP_{1-y}$ is grown on an InP crystal substrate for LED applications
- The device requires sufficiently small lattice strain due to mismatch between the two crystals at the interface to allow for electroluminescence.
- Strain reduction in tern requires a value for y =2.2x
- The bandgap energy for the alloy in eV is given by the empirical relationship

$$E_g \approx 1.35 - 0.72y + 1.12y^2$$

$$0 \le x \le 0.47$$

- Calculate the composition of InGaAsP ternary alloys for peak emission at a wavelength of 1.3 um

$$E_g = \frac{hc}{e\lambda} - \frac{k_B T}{e} \qquad \text{For} \quad \lambda = 1300nm; T = 300K$$

$$E_g = \frac{hc}{e\lambda} - \frac{k_B T}{e} = \frac{\left(6.626\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(1.6\times10^{-19}\right)\left(1.3\times10^{-6}\right)} - 0.0259eV = 0.928eV$$

$$E_g = 0.928 = 1.35 - 0.72y + 1.12y^2$$

$$y = 0.66$$

$$x = 0.66 / 2.2 = 0.3$$

- Requires $In_{0.7}Ga_{0.3}As_{0.66}P_{0.34}$