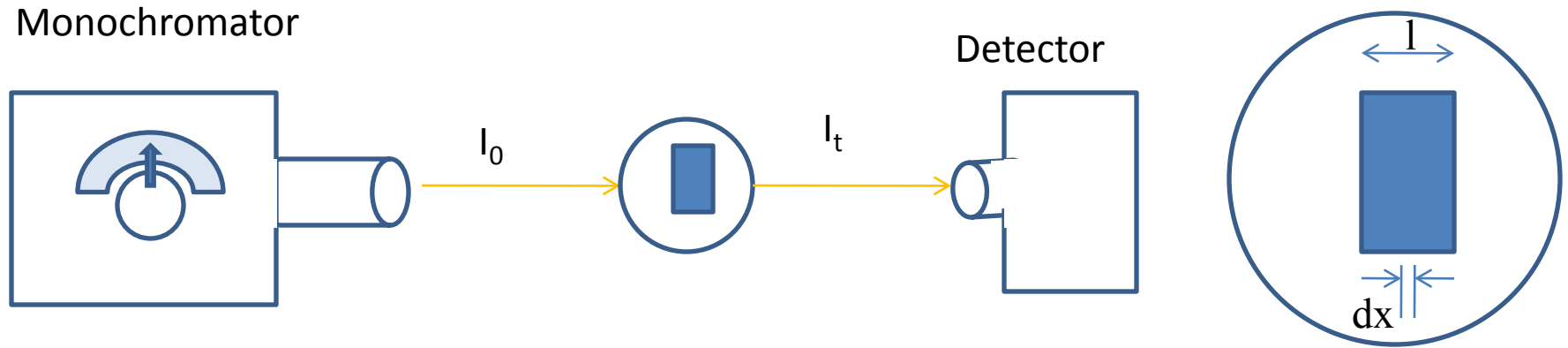


Optical absorption

A photon with energy less than E_g is unable to excite an electron from the valence band to the conduction band. Thus in a pure semiconductor, there is negligible absorption of photons with $h\nu < E_g$. This explains why some are transparent in certain wavelength ranges. We are able to see through certain insulators such as good NaCl crystal because a large energy gap containing no electron states exists in the material. If the band gap is about 2 eV wide, only wavelengths (infrared) and red part of the visible spectra are transmitted. On the other hand, a band of about 3 eV allows infrared and the entire visible spectrum to be transmitted.

If the beam of photons with $h\nu > E_g$ falls on a semiconductor there will be some predictable amount of absorption determined by the properties of the material. We would expect the ratio of transmitted to incident light intensity to depend on photon wavelength and thickness of the sample.

Optical absorption



Let us assume that a photon beam of intensity I_0 (photons/cm²-s) is directed at a sample thickness l . The beam contains only photons of wavelength λ , selected by a monochromator. As the beam passes through the sample, its intensity at a distance x from the surface can be calculated by considering the probability of absorption within any increment dx ,

Optical absorption

Consider a layer($x, x+dx$) through which light passes the amount of energy absorbed in the layer dx and be proportional to the layer width and the energy reaching the layer $x, x+dx$, $I(x)$. Denoting the proportionality factor between the absorbed energy and the incident energy, we may write

$$-dI(x) = \alpha I(x) dx$$

Hence α is the amount of energy absorbed a beam of unit intensity in a layer of unit width.

$$-dI(x) = \alpha I(x) dx$$

$$-\frac{dI(x)}{I(x)} = \alpha dx$$

$$-\int \frac{dI(x)}{I(x)} = \alpha \int dx$$

$$-\log I(x) = \alpha x + \text{const}$$

At $x=0, I(x)=I_0$

$$-\log I_0(x) = \text{const}$$

$$\log I(x) - \log I_0 = -\alpha x$$

$$\log \frac{I}{I_0} = -\alpha x$$

$$I = I_0 e^{-\alpha x}$$

Hence intensity at a length l

$$I = I_0 e^{-\alpha l}$$

Equation of continuity gives

$$\begin{aligned}\frac{d\rho}{dt} &= \frac{\delta\rho}{\delta t} + \text{div}J \\ &= e \frac{dn}{dt} + \text{div}J\end{aligned}$$

It should be

$$0 = \frac{dn}{dt} + \frac{\text{div}J}{e}$$

This equation means that volume charge density may change only as a result of the current divergence.

Now electron or hole concentration $n(v,t)$ not equal to the their equilibrium values $n_0(v)$ are termed non equilibrium concentration.

The quantity

$$\Delta n(v,t) = n(v,t) - n_0(v)$$

Now we have to take account the concentration variation due to generation and recombination. Hence we have to write equation of continuity taking account generation and recombination.

Optical absorption

$$\frac{\delta n}{\delta t} = -\text{div} \frac{J}{e} + G - R$$

If we assume
current is small

$$\frac{\delta n}{\delta t} = G - R$$

$$\frac{\delta(n_0 + \Delta n)}{\delta t} = G - R$$

Now amount of light falling per unit area per second is the Intensity

Let the intensity of light falling on the material is I_0

$$\text{Then } I = I_0 e^{-\alpha x}$$

Amount of light absorbed $\Delta I = I_0 - I = (I_0 - I_0 e^{-\alpha x})$

$$\Delta I = (I_0 - I_0 e^{-\alpha x}) = I_0 \alpha x \text{ [if } \alpha x \ll 1 \text{]}$$

$$\Delta I = I_0 \alpha x$$

Again, $\Delta I = \Delta N h \nu$

$$\Delta N h \nu = I_0 \alpha x$$

$$\Delta N h \nu / x = I_0 \alpha$$

Now quantum efficiency β is defined by

Optical absorption

$$\beta = \frac{\text{No of pairs produced / vol / time}}{\text{No of photons absorbed / vol / time}}$$

No of pairs produced/vol/time = β x No of photon absorbed /vol/time

$$= \beta \times \frac{\Delta N}{x}$$

$$= \beta \times \frac{I_0 \alpha}{h\nu}$$

$$= I_0 k \beta$$

$$k = \frac{\alpha}{h\nu}$$

Now the rate of production ΔN

$$\frac{d(\Delta N)}{dt} = \underbrace{k I_0 \beta}_{\mathbf{G}} - r_n \underbrace{(np - n_0 p_0)}_{\mathbf{R}}$$