Unit-2

Lecture -2

Absorption, Intrinsic and Extrinsic Absorption, Scattering Loss

Absorption

Absorption in optical fiber is caused by these three mechanisms.

1. Absorption by atomic defects in the glass composition

2. Extrinsic absorption by impurity atoms in the glass material

3. Intrinsic absorption by the basic constituent atoms of the fiber material.

Atomic defects means that the atoms are not on their proper place in crystal lattice, they are displaced.

If the atoms are missing or there is high density of atoms in crystal lattice or there is oxygen in the glass, it is said to be atomic defects.

Material absorption can be divided into two categories.

Intrinsic absorption losses correspond to absorption by fused silica (material used to make fibers)

whereas **extrinsic absorption** is related to losses caused by impurities within silica.

Extrinsic absorption results from the presence of impurities.

Metal impurities such as Fe, Cu, Co, Ni, Mn, and Cr absorb strongly in the wavelength range 0.6–1.6 μm.

Their amount should be reduced to below 1 part per billion to obtain a loss level below 1dB/km.

The main source of extrinsic absorption is the presence of water vapors in the silica fibers.

So in order to reduce these kind of losses dry fiber is used.

The OH ion concentration is reduced in dry fibers.

Such fibers can be used to transmit WDM signals.

Scattering losses

Scattering means the transfer of some or all of the optical power contained within one propagating mode into a different mode.

The power may be transferred to a leaky mode which means that the propagation is not within the core but it is within the fiber.

Since the glass is made up of several oxides, SiO2, P2O5, so compositional fluctuations may occur.

These may vary refractive index of the glass because of the different material used for the fabrication.

This refractive index variation may cause Rayleigh scattering of the light.

This occurs mainly because of the variation in wavelength.

The scattering losses basically depend upon random molecular nature and various oxide constituent of the glass.

For a single component glass the scattering loss at a particular wavelength from density fluctuations is given by:

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4} n^8 p^2 k_B T_f \beta_T$$

β_T *is isothermal compressibility of the material*

p *is the photo elastic coefficient*

Scattering Loss

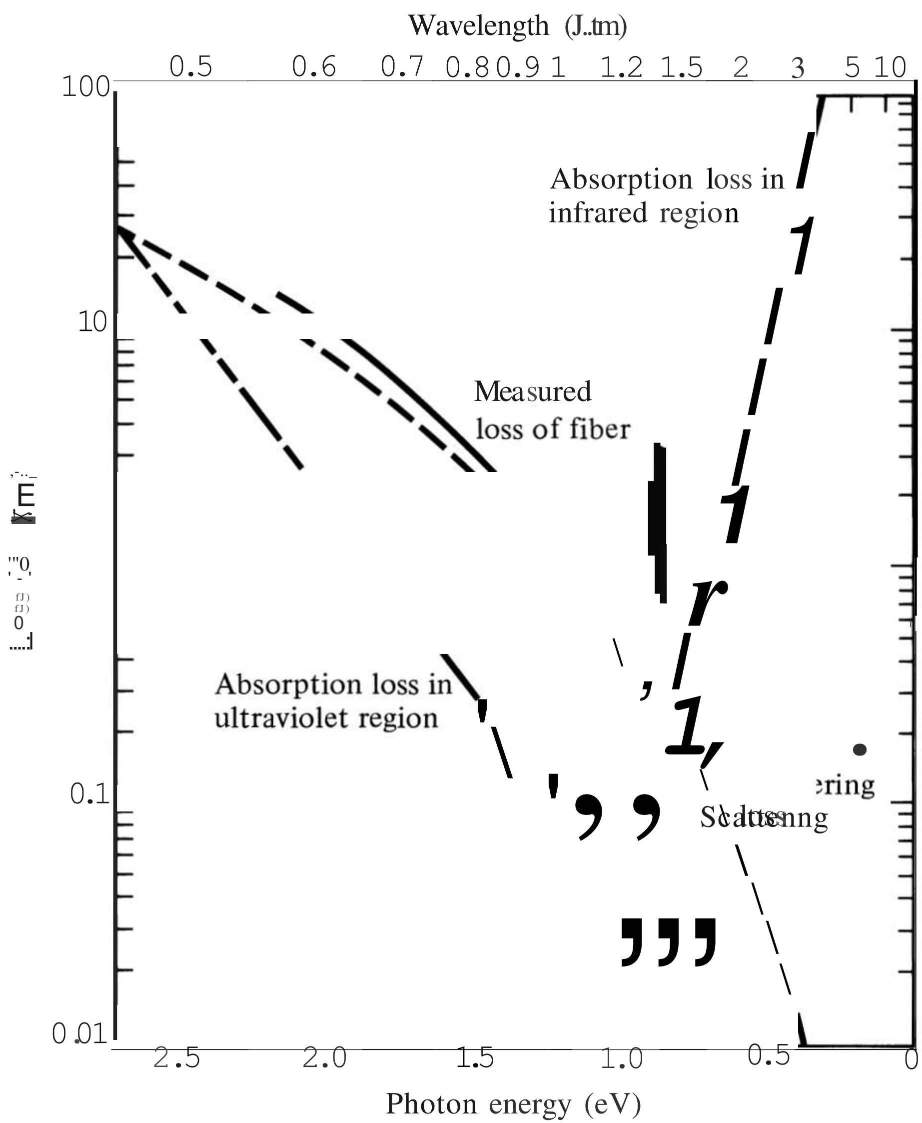
- Small (compared to wavelength) variation in material density, chemical composition, and structural inhomogeneity scatter light in other directions and absorb energy from guided optical wave.

- The essential mechanism is the Rayleigh scattering. Since the black body radiation classically is proportional to λ^{-4} (this is true for wavelength typically greater than 5 micrometer), the attenuation coefficient due to Rayleigh scattering is approximately proportional to λ^{-4}. This seems to me not precise, where the attenuation of fibers at 1.3 & 1.55 micrometer can be exactly predicted with Planck's formula & can not be described with Rayleigh-Jeans law. Therefore I believe that the more accurate formula for scattering loss is

$$\alpha_{scat} \propto \lambda^{-5}\left[\exp\left(\frac{hc}{\lambda k_B T}\right)\right]^{-1}$$

$$h = 6.626\times10^{-34}\ \text{Js},\quad k_B = 1.3806\times10^{-23}\ \text{JK}^{-1},\ T:\text{Temperature}$$

Absorption & scattering losses in fibers



Optical Fiber communications, 3 ed.,G. eiser,McGraw Hill, 2000

Typical spectral absorption & scattering attenuations for a single mode-fiber