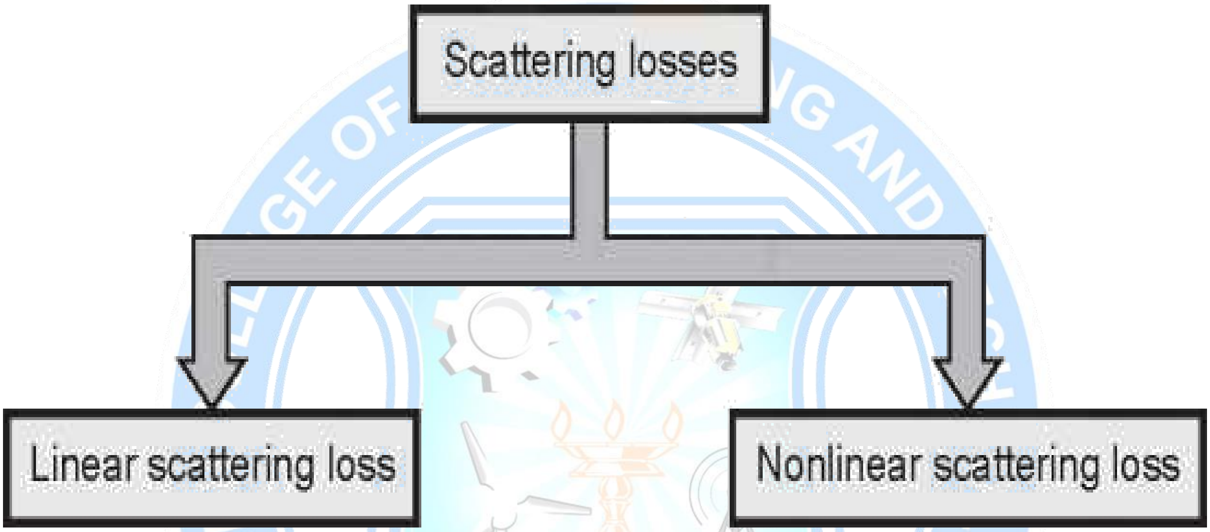
2.3 Scattering Losses

- **Scattering losses in fiber exists due to various factors :**
  Microscopic variations in density of fiber material
  Compositional fluctuations
  Structural in homogenities
  Structural defects in fiber



1. Rayleigh scattering
2. Mie scattering

1. Stimulated Brillouin scattering
2. Stimulated Raman scattering

Rayleigh Scattering Losses

- Scattering losses exists in optical fibers because of microscopic variations in the material density and composition.
- As glass is composed by randomly connected network of molecules and several oxides (e.g. SiO_2, GeO2 and P2O5), these are the major cause of compositional structure fluctuation. These two effects results to variation in refractive index and Rayleigh type scattering of light.
- **Rayleigh scattering** of light is due to small localized changes in the refractive index of the core and cladding material.
- There are two causes during the manufacturing of fiber.
- 1. The first is due to slight fluctuation in mixing of ingredients. The random changes because of this are impossible to eliminate completely.
- 2. The other cause is slight change in density as the silica cools and solidifies. When light ray strikes such zones it gets scattered in all directions.

- The amount of scatter depends on the size of the discontinuity compared with the wavelength of the light so the shortest wavelength (highest frequency) suffers most scattering.
- Scattering loss for single component glass is given by

$$\alpha_{scat} = \frac{8\pi^2}{3\lambda^4}(n^2\text{-}1)2\ KB\ T_f\ \beta_T \text{ nepers}$$

n=refractive index

KB =Boltzmann's constant

β_T =Isothermal compressibility of material

Tf =Temperature at which density fluctuations are frozen into the glass as it solidifies (fictive temperature)

Another form of equation is

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

Scattering loss for multicomponent glasses is given by

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}(\delta_n^2)^2 \delta v$$

- Multimode fibers have higher dopant concentrations and greater compositional fluctuations. The overall losses in this fibers are more as compared to single mode fibers.

Mie Scattering

- Linear scattering also occurs at inhomogenities and these arise from imperfections in the fiber's geometry, irregularities in the refractive index and the presence of bubbles etc. caused during manufacture.
- Careful control of manufacturing process can reduce mie scattering to significant levels.

Nonlinear Scattering Losses

- Because of non-linear scattering, optical power from one mode to other modes is transferred in forward or backward direction at different frequency.
- The non-linear scattering losses are dependent on optical power density in the fiber.
- The non-linear scattering losses are more significant above threshold power levels.

- The non-linear scattering effects are used in obtaining optical gain in optical amplifiers.

Types of non-linear scattering losses

1. Stimulated Brillonin Scattering (SBS)
2. Stimulated Raman Scattering (SRS)

Stimulated Brillonin Scattering (SBS)

- The SBS exists when light is modulated through the thermal molecular vibrations within fiber.

• The scattered light is observed as both upper and lower sidebands separated from incident light by modulation frequency.

• The optical power threshold for SBS is given by

Stimulated Raman Scattering (SRS)

- SRS is stimulated with a high frequency optical photon generated in scattering phenomena.
- SRS may exist both in forward and backward directions in optical fibers.
- The optical power threshold is three times higher than SBS threshold.
- The threshold optical power for SRS is given by -