Photonics in Semiconductors, Spring 2017

Exercise 4, 16.2.2017

1. Optical fiber dimensions

A typical single mode fiber has a core diameter of 8 µm and a refractive index of 1.46. Normalized index difference is 0.3%. Cladding diameter is 125 µm. Calculate: a) numerical aperture, b) acceptance angle and c) cut-off wavelength.

2. Group index

The wavelength dependent refractive index can be modeled using the Sellmeier equation:

$$n^2 = 1 + \frac{A_1\lambda^2}{\lambda^2 - \lambda_1^2} + \frac{A_2\lambda^2}{\lambda^2 - \lambda_2^2} + \frac{A_3\lambda^2}{\lambda^2 - \lambda_3^2} + ...$$

For pure silica, the first three coefficients are (wavelengths in µm):

$$A_1 = 0.696749, \quad A_2 = 0.408218, \quad A_3 = 0.890815$$
$$\lambda_1 = 0.0690660, \quad \lambda_2 = 0.115662, \quad \lambda_3 = 9.900559$$

Calculate the group index (numerically) from 500 nm to 1.8 µm.

3. Material dispersion

Calculate the broadening of an optical pulse in 1km long pure silica fiber due to material dispersion for an LED operating at 850 nm (linewidth 20 nm).

4. Attenuation & scattering

a) 1 mW of optical power is sent along a single mode fiber. The photodetector at the end of the fiber has a detection limit of 10 nW. Assuming, that the signal is barely detected after 130 km of fiber, compute the attenuation coefficient (decibels / length).
b) Attenuation is glass fiber due to Rayleigh scattering is approximately given by:

$$\alpha_R \approx \frac{8\pi^3}{3\lambda^4}\left(n^2 - 1\right)\beta_T k_B T_f.$$

i) Explain briefly how Rayleigh scattering attenuates the signal. ii) Calculate α_R for silica at $\lambda = 1.55$ µm (Check literature for coefficient values).