1 Light propagation in step-index fibers

To understand the reasons for modal dispersion it is necessary to understand the characteristics of light propagation in waveguides. For that purpose we use the description of light as an electromagnetic wave.

a) What is meant by TE and TM modes? How are they different from Hybrid modes?

b) What is meant by the term "linearly polarized modes"? Under which conditions is this approximation applicable?

c) Assume the FG025LJA fiber by Thorlabs (https://www.thorlabs.com/thorproduct.cfm?partnumber=FG025LJA) with a core diameter of 25 µm, a cladding size of 125 µm and a numerical aperture of 0.1. Calculate the approximate number of guided modes in that fibre if we use the typical communication wavelength of 1550 nm. For which wavelength range, (theoretically) only one mode propagates in the FG025LJA fiber? Which core diameter should be used to create a single mode fiber for 1550 nm wavelength?

Additional questions that might help you preparing for the exam (Optional):

d) Write down the wave and Helmholtz equation assuming time harmonic wave propagation and explain the physical meaning of each quantity in the equation..

e) For cylindrical waveguides the Helmholtz equation can be rewritten in a special type of differential equation. Which one? Which function type solves this equation in the core and cladding respectively?

f) Draw the principle electric field intensity profile of the modes LP_{01}, LP_{21} and LP_{02}.

2 Attenuation

2.1 dB

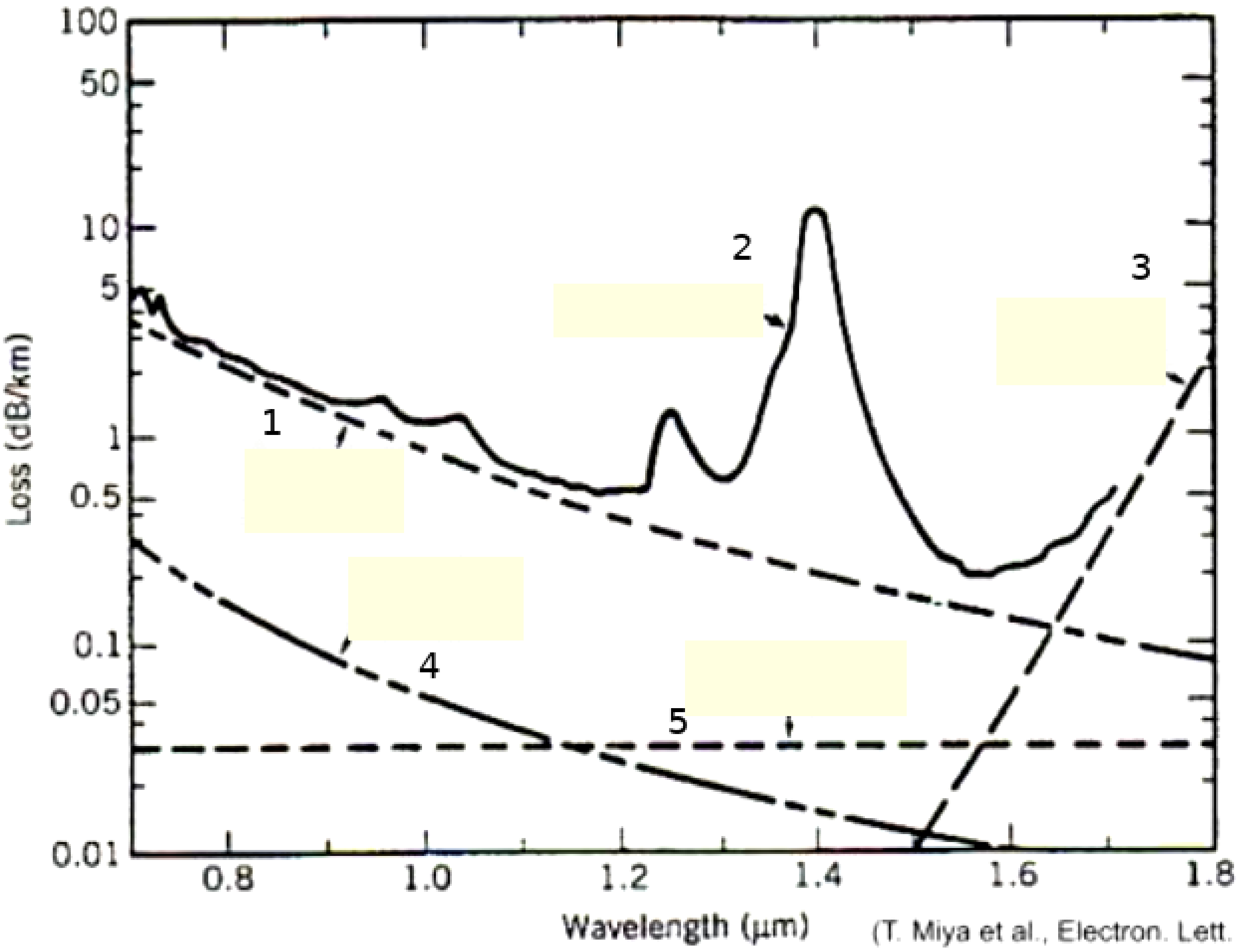
a) Write down the dB formula for power loss and dB formula for voltage gain.

b) The LED pumps into an optic fibre 174 petawatts of power. The theoretically minimum detectable power[1] at room temperature is -92.5 dBm [*]. With the attenuation of 0.2 dB/km, what is the maximum distance after which the signal will remain detectable?[2]

[1] https://en.wikipedia.org/wiki/Minimum_detectable_signal

[2] The length of one of the the transatlantic fiber optic cables TAT-14 (2001) is 15428 km.

2.2 loss reasons



(T. Miya et al., Electron. Lett. **15**, 106, 1979)

a) Fill in the areas 1-5. Explain the physical mechanism behind each attenuation reason.

b) State the frequency region where the effect of each attenuation type is most prominent.

c) Explain, how-to make as lossy optic fiber as possible. (Which still could be considered and used as an optic fiber).

3 Dispersion

3.1

A step index fiber of numerical aperture NA = 0.16, core radius a=45 μm, and core refractive index n_1=1.45 is used at λ _0=1.3 μm, where material dispersion is negligible.

a) Would modal dispersion occur in this fiber? Explain why.

b) If modal dispersion would occur in this fiber what is the broadening due to modal dispersion if a light pulse travels a distance of 1 km in this fiber?

3.2

Assume an optical fiber transmission system operates at B=10 Gbit/s data rate. If the dispersion coefficient is D=17ps/km·nm at λ =1550 nm, what is the maximum transmission length before the pulse will begin to overlap at 1550 nm?

Hint:
Consider the light pulse is Gaussian pulse.
You may find $\Delta f=(c/\lambda^2)\Delta\lambda$ *helpful.*

4 Devices

Explain briefly in maximum 3 sentences what these fiber optic devices do: (Minus points if more than 3 sentences)

a) Optical Isolator

b) Wavelength division multiplexer

c) Fuzed fibre coupler

d) Fiber-optical attenuator