If you have any questions, please contact Järn Veli-Matti <veli-matti.jarn@aalto.fi>. After you finished, please also send the answers to Järn! Thanks.

Photonics

ELEC-E3240

Assignment (Total 10 points)
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Problem 1: Fiber loss (2 points)

You are given a silicon fiber of $1\,\mathrm{m}$ length with a huge loss of $50\,\%$ when a $633\,\mathrm{nm}$ laser shines though the fiber.

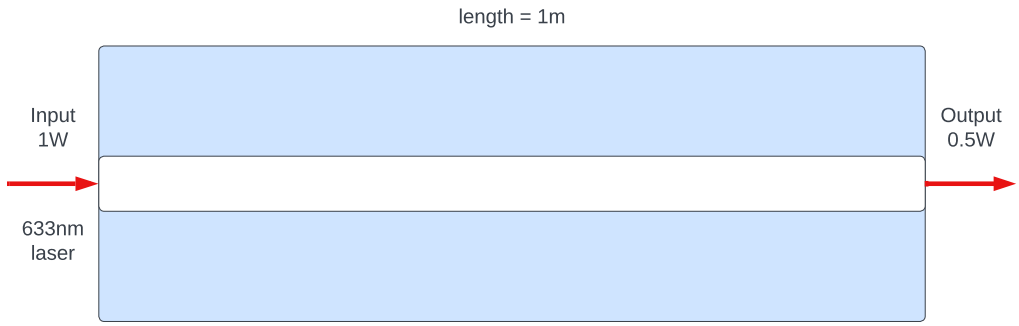

Figure 1: Fiber loss depiction

List what may result in the loss measured.
Describe, how the loss could be reduced during the manufacturing process (no more than 120 words).

Hint:
Keep the wavelength of the laser in mind!
How would you design a fiber of $2\,\mathrm{m}$ *in length with the same or less loss using the* $633\,\mathrm{nm}$ *laser?*

Problem 2: Fiber refractive index (2.5 points)

A telecommunication firm wants to create a single-mode optical fibre for long distances, and hence wants to minimize the attenuation.
If the core radius of the fibre is $3.5\,\mu\mathrm{m}$ and the core refractive index is 1.45, the engineers want to make the cladding out of silica class, due to abundance of it. When the silica glass is made as pure as possible, it has a refractive index of 1.47.
Is it possible to use that silica glass as a cladding material? If not, what changes do you recommend for the fibre?

Figure 2: Mt.Lister near McMurdo research station

Problem 3: Telescope connection (3 points)

You are part of the project team designing a high speed connection for the new telescope. Customer control center is located at the Halfmoon bay New Zealand, and owners want a high quality connection to the new telescope site on top of Mount Lister near McMurdo research station Antarctica.

You are a newly recruited project engineer in charge of engineering the optical fibre connection for the distance. Preliminary project plan for the kickoff meeting with clients and stake holders is the first big task in a company's to do list for the engineering department.

Your first task is to bring following knowledge in to the meeting table as a part of the bigger engineering team:
Estimate roughly the shortest 2D - distance on the map surface in kilometers from Halfmoon bay New Zealand to Mount Lister near McMurdo research station Antarctica. This would be preliminary estimation for the distance needed for the fiber connection.
Sketch also cross section of the fiber showing key features in the illustration and specify reason shortly for your choice:

- core features for the cable: core refractive index, material radius, cladding dimensions, refractive index material
- coating material and cross section radius

In addition choose a laser frequency to be used for the connection and its mode in the fiber. Describe shortly why that wave length is your choice along with other cable characteristics.
To help your reasoning; calculate normalized frequency for the fiber and number of guided modes.
Hint: use formulas for normalize frequency (V number) and number of guided modes. Comparing your choice values and V - number with the boundary value between multi-mode and single-mode operation fiber will be key for reasoning your choice for characteristics of the cable and the connection. Your may use computer aided drawing or hand drawing to help your task but do not make too complicated.

Problem 4: Readability of transmitted signals 2.5 points)

Explain why and what the second window in the following diagram is used for?

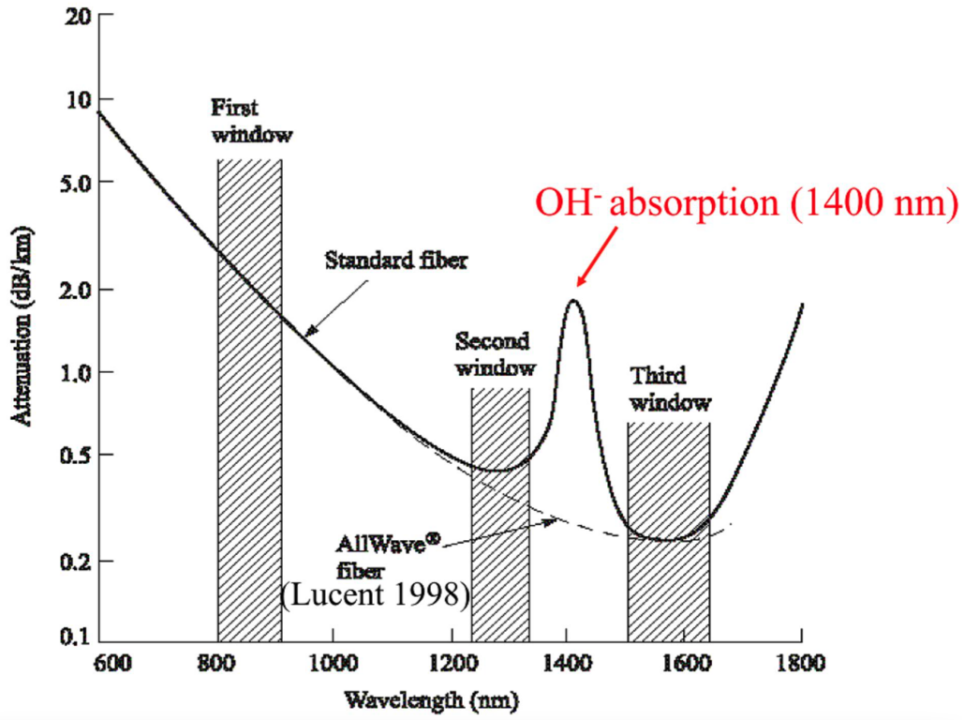

Figure 3: Extrinsic material absorption

$$\frac{d^2 n_{core}}{d\lambda^2} = (log(\frac{\lambda}{13}) + 7log(10))\frac{1}{\mathrm{km} \cdot \mathrm{nm}} \qquad D_{Waveguide} = -3.5\,\frac{\mathrm{ps}}{\mathrm{km} \cdot \mathrm{nm}}$$

$$\Delta\lambda = 0.3\,\mathrm{nm}$$

Imaging you want to transmit data over a fiber at a speed of $1\,\frac{\mathrm{Gbit}}{\mathrm{s}}$ ($1\,\mathrm{Gbit} = 1024\,\mathrm{Mbit}$). What is the maximum distance the fiber could be?

What would you do to increase the maximum range of the cable even further and explain how your method of choice functions.