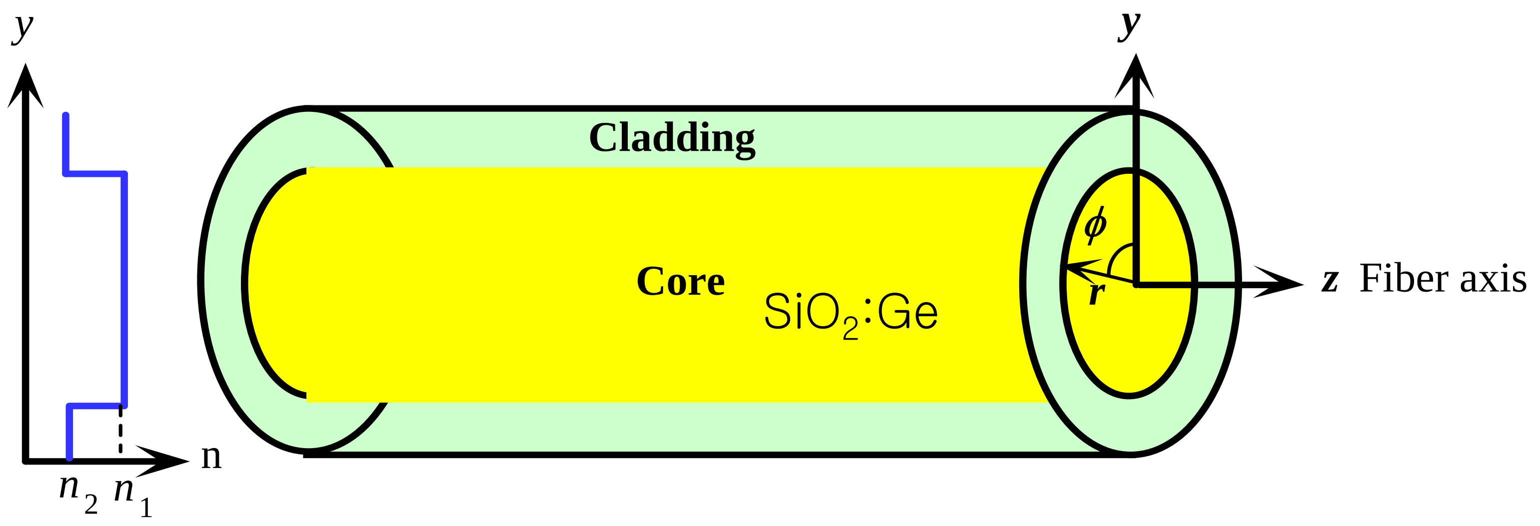
Lect. 15: Optical Fiber

Optical Fiber: Circular dielectric waveguide made of silica (SiO_2)



What is special about fiber?

- Extremely low loss: 0.2dB/km
- Can be very long: 100's of km

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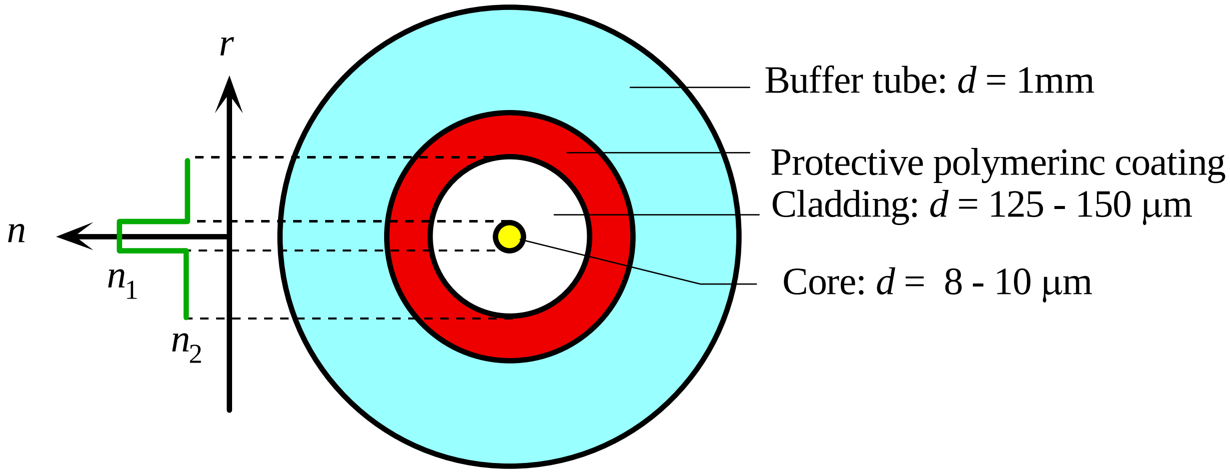

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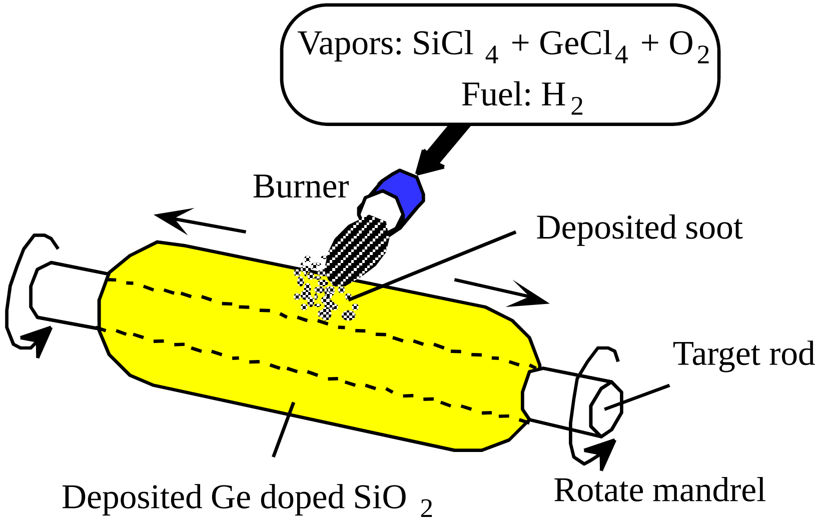
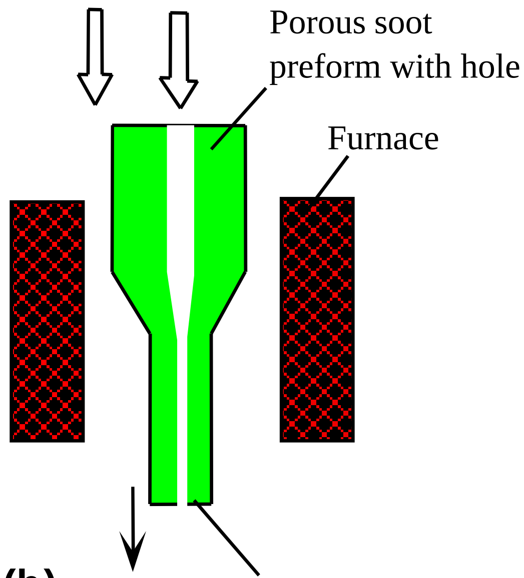


(a)



(b)

$SiCl_4 + O_2 \rightarrow SiO_2 + 2Cl_2$

$GeCl_4 + O_2 \rightarrow GeO_2 + 2Cl_2$

Sintering at 1400−1600 deg C

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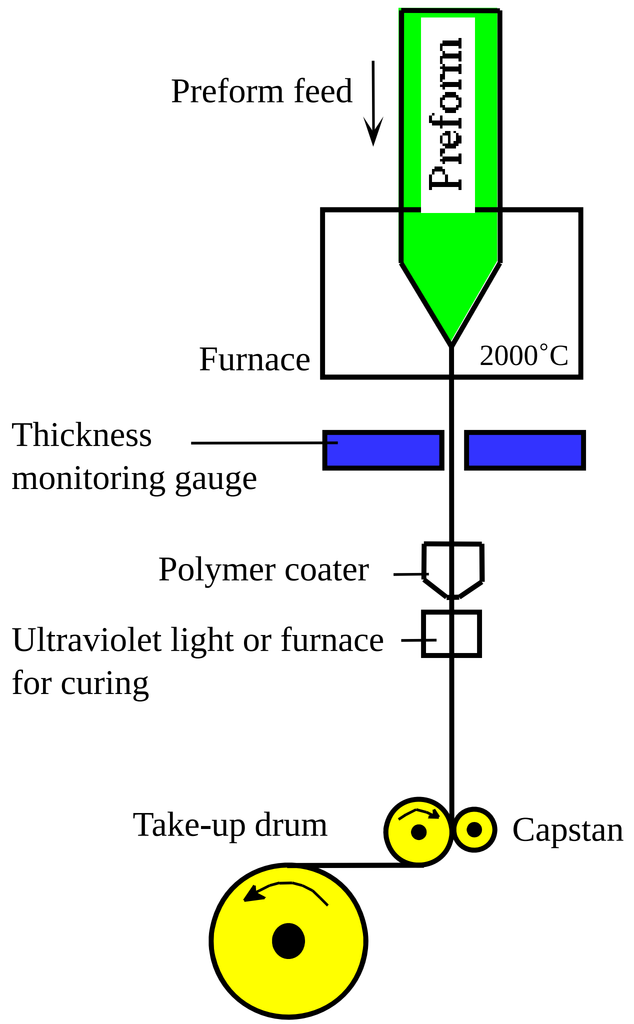

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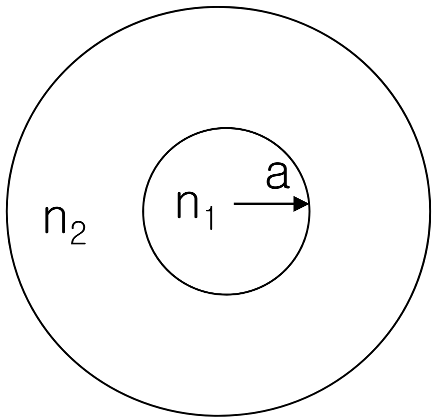
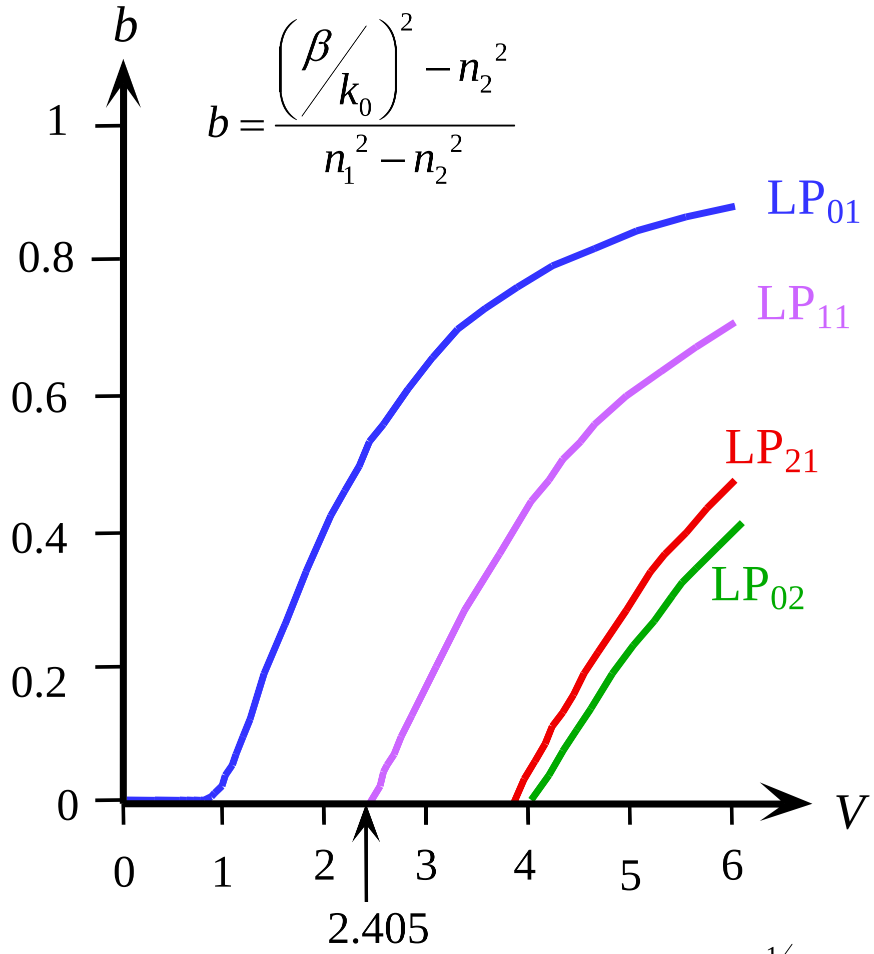


Solving for guided modes for circular dielectric waveguide problem in (r, f, z) coordinate is very complicated.
(Project topic)

It can be shown that with a little approximation, LP (linearly polarized) mode solutions are obtained.

$$E_{LP} = E_{lm}(r,\phi)\,e^{-j\beta_{lm}z}$$



$$b = \frac{\left(\beta/k_0\right)^2 - n_2^{\,2}}{n_1^{\,2} - n_2^{\,2}}$$

$$V = k_0 a (n_1^{\,2} - n_2^{\,2})^{1/2}$$

(a : fiber core radius)

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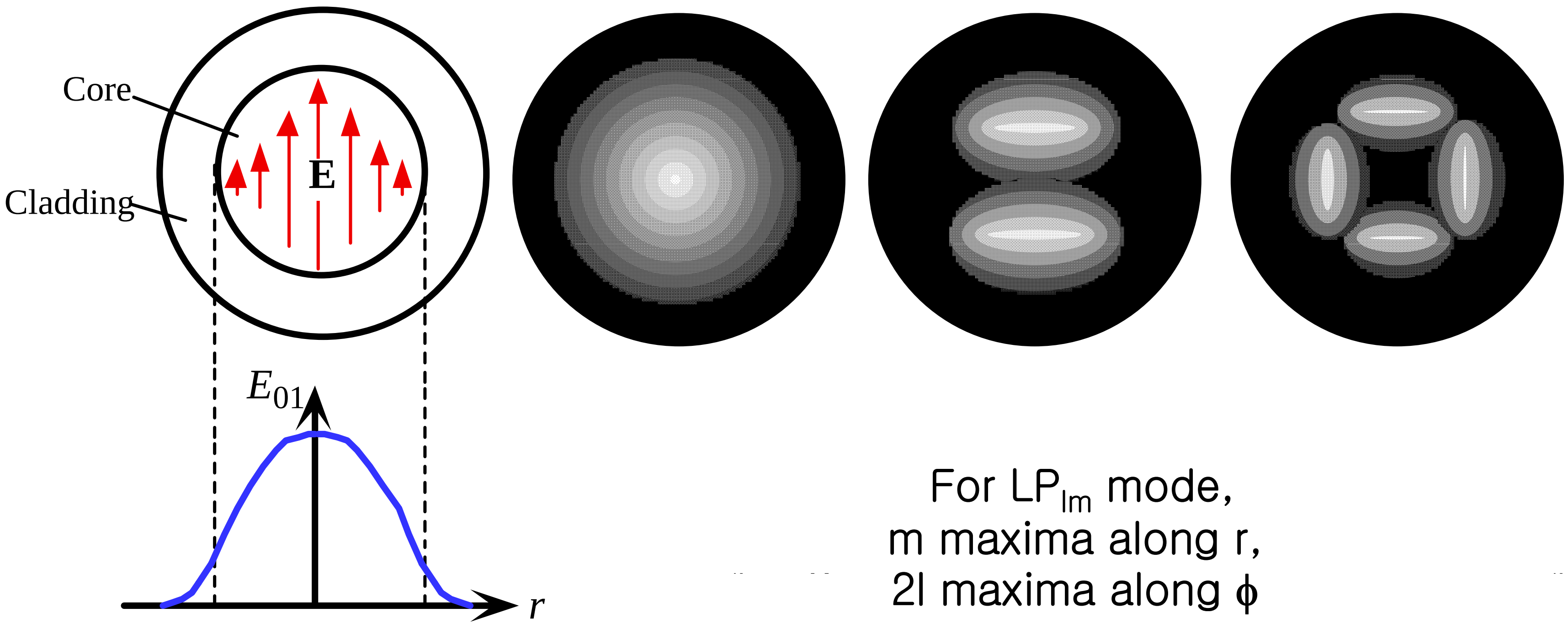
(a) The electric field of the fundamental mode

(b) The intensity in the fundamental mode LP_{01}

(c) The intensity in LP_{11}

(d) The intensity in LP_{21}



For LP_{lm} mode,
m maxima along r,
2l maxima along ϕ

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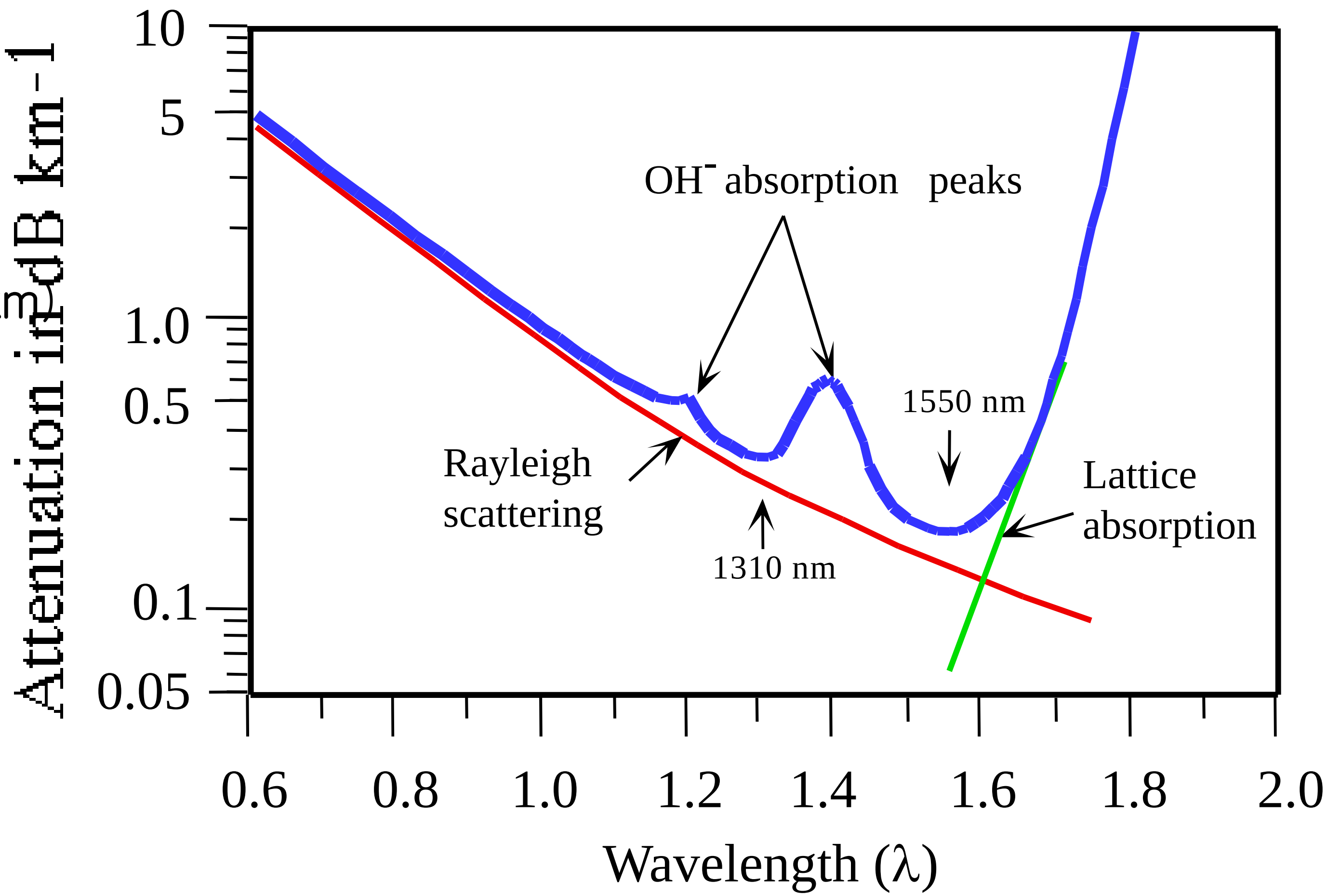
Loss in fiber

Loss
(dB/km)



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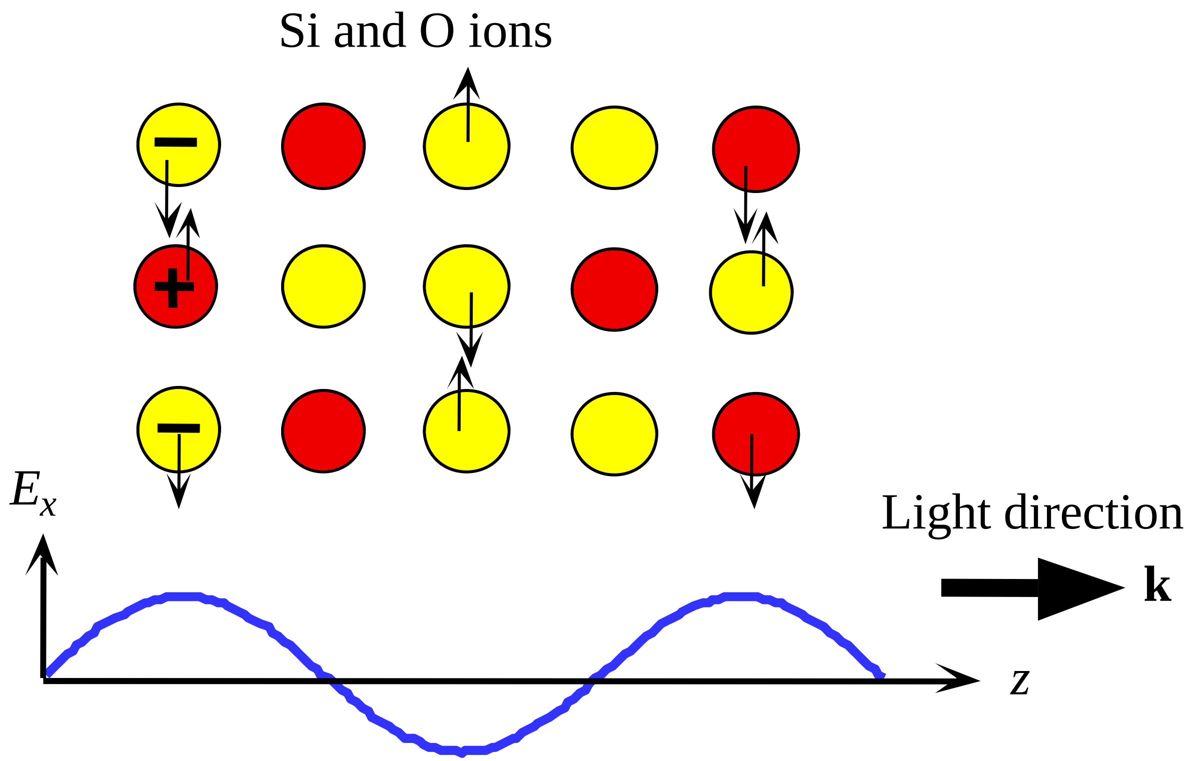
Lattice Absorption:
EM waves cause vibration of ions inside fiber.
Peak absorption occurs at around λ= 9 μm in Silica fiber.



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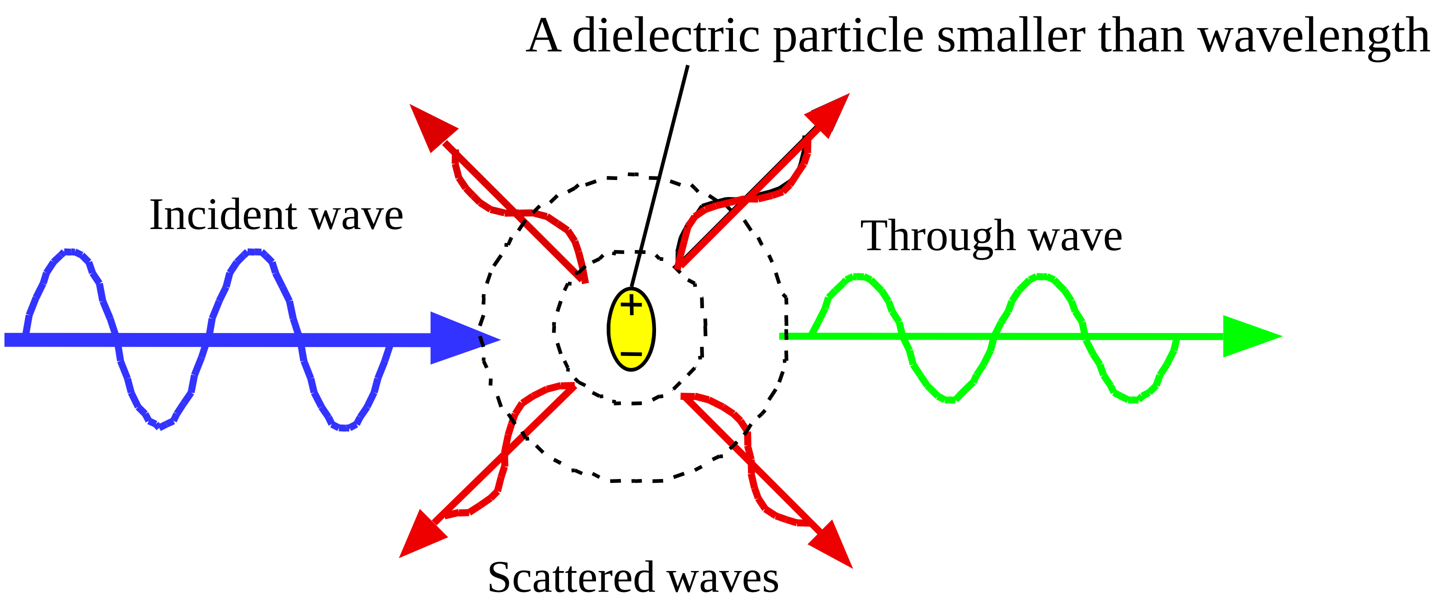
Rayleigh scattering
A small portion of EM waves get directed away from small dielectric particles that are due local fluctuation of fiber refractive index.
More scattering with smaller wavelength (inversely proportional to λ^3).

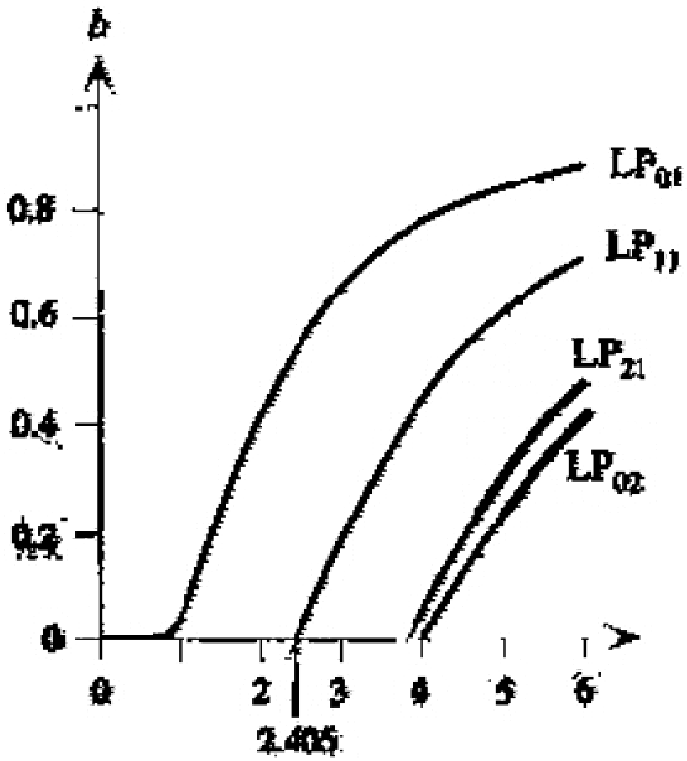


Homework (Optional): Prob. 1 in 2003 광전자 Test 2

A fiber has its core refractive index given as $n_1(z) = n_0 + \Delta n \sin[(2\pi/d) z]$ as shown below.

$n_2 = 1.497$

$n_1 = 1.5 + \Delta n \cdot \sin(\frac{2\pi}{d} Z)$, core radius: $5\mu m$



(a)(10) Using the attached fiber b-V diagram, determine the approximate value of the effective index for the fundamental guided mode. Assume $\Delta n = 0$, the cladding layer is infinitely thick and $\lambda = 1.5\mu m$.

(b)(10) With a very small amount of Δn so that the effective index of the guided mode does not change from the value obtained in (a), the fiber can reflect light having a specific wavelength of $1.5\mu m$. Determine the numerical value d (with its unit) so that the reflection efficiency is highest.