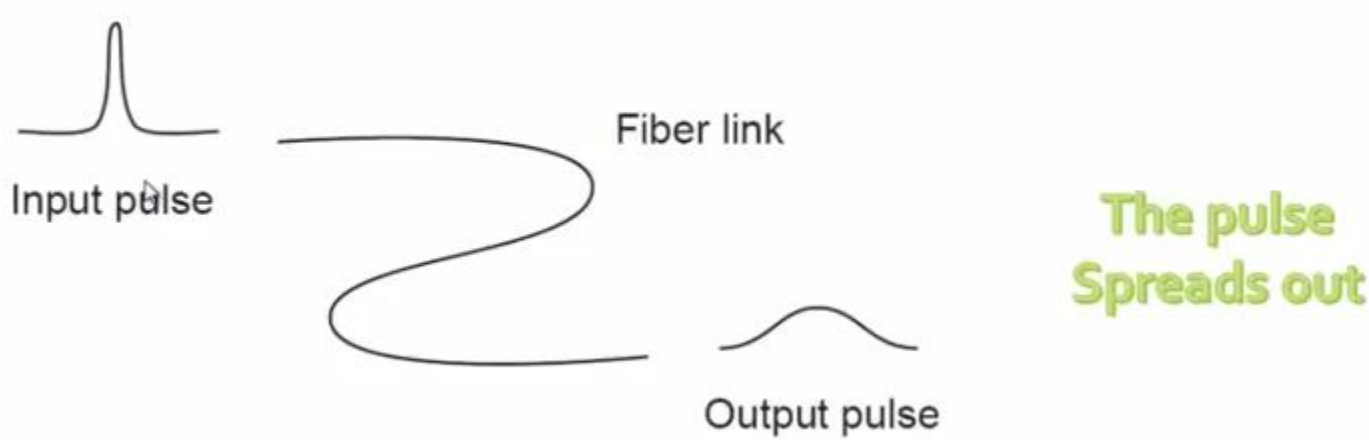
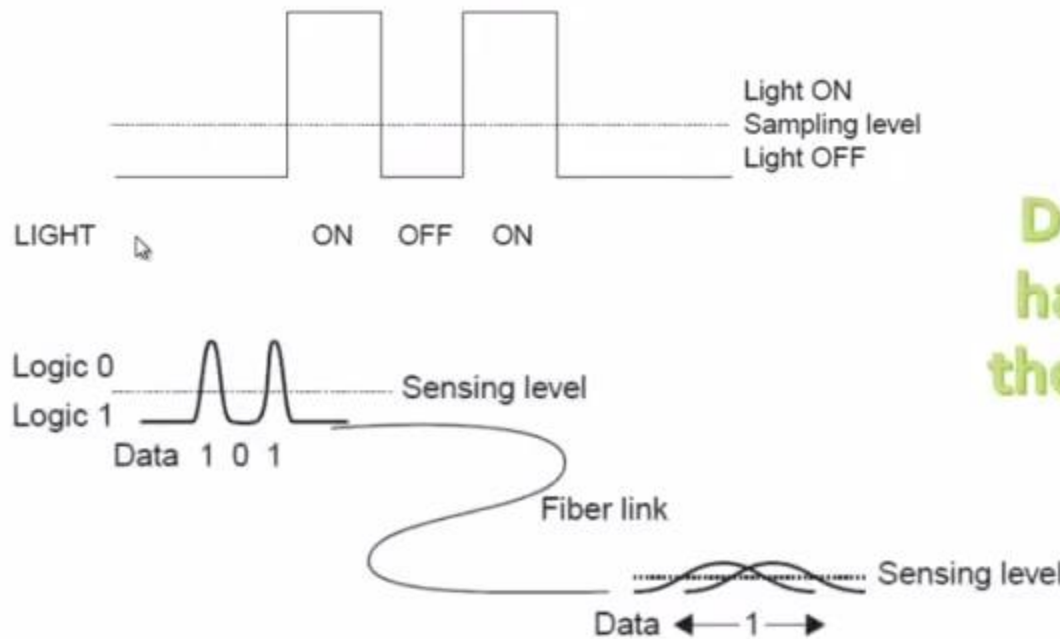
- Fiber optic communication system suffers from the following three major impediments
    - Dispersion
    - Attenuation
    - Nonlinear effects
- Dispersion
    - Spreading of light pulse as it travels down the length of an optical fiber

- Dispersion causes temporal pulse spreading
    - Pulse overlap results in indistinguishable data
    - Inter symbol interference (ISI)
- Dispersion is related to the velocity of the pulse

Dispersion

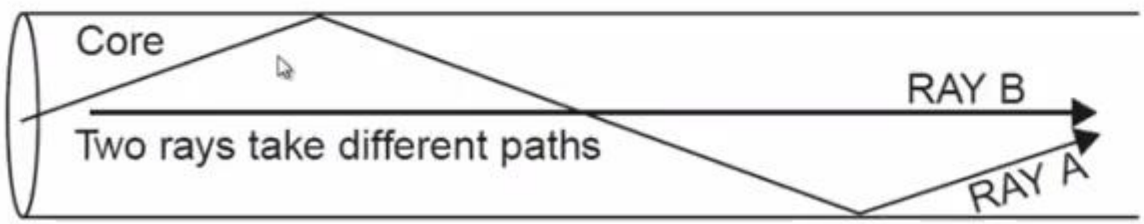


The effect on the data



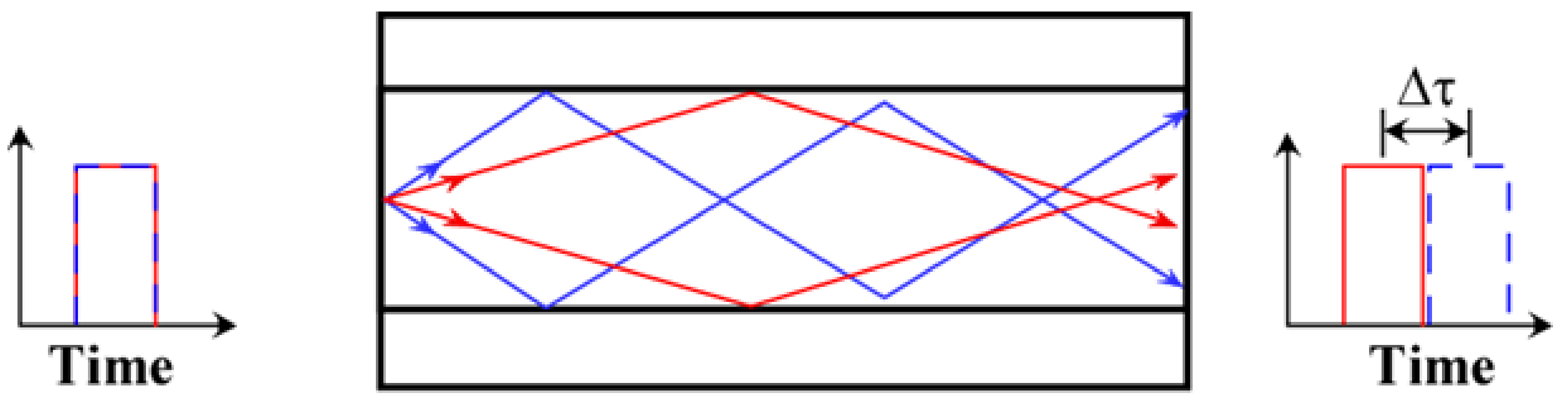
Dispersion has caused the pulses to merge

Intermodal dispersion

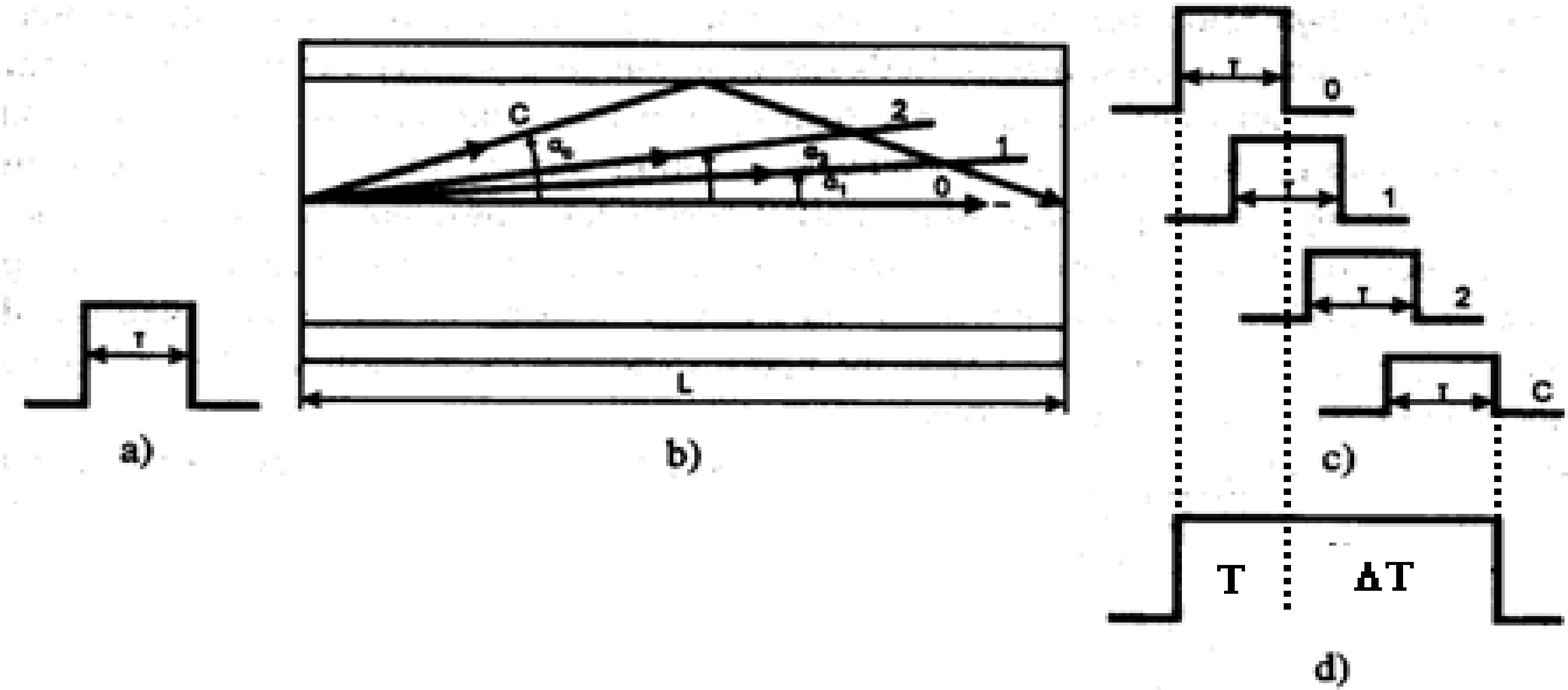


Ray B will arrive first

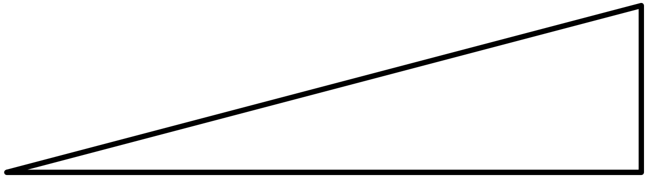
- There are two major types of dispersion in fiber-optics
  - Intermodal
  - Intramodal
- Intermodal
  - When an optical pulse is launched into the fiber, the optical pulse is distributed over all modes of fiber
  - Here we consider the propagation of light within the fiber in terms of guided electromagnetic waves called “modes”.
  - Different modes will travel with different propagation angles, hence these modes takes different routes but travel with the same velocity, but at the end of fiber they come at different timings.
  - This causes pulse widening
  - This is called intermodal dispersion or modal dispersion.



- Measuring intermodal Dispersion



- To ascertain this let us go for some mathematical calculations
- A zero order mode travelling along the fiber axis needs some time to reach the receiver it is given by



$$t_0 = L / v$$

L – length of the link

$v = c / n_1$ – velocity of light within the core

- The highest order mode propagating at critical angle needs time of

$$t_c = L / (v \cos \alpha_c)$$

Therefore, pulse widening due to intermodal dispersion is

$$\Delta t_{SI} = t_c - t_0$$

$$= [L / (v \cos \alpha_c)] - [L / v]$$

$$= L / v \, [(1/\cos \alpha_c) - 1]$$

$$= L / v \, [(n_1 / n_2) - 1] \qquad [\text{since } \cos \alpha_c = n_2 / n_1$$

$$= L / v \, [(n_1 - n_2) / n_2]$$

$$= Ln_1 / c \, [(n_1 - n_2) / n_2] \quad \text{since } v = c / n_1$$

Since $n_2 \approx n$ we can write the equation

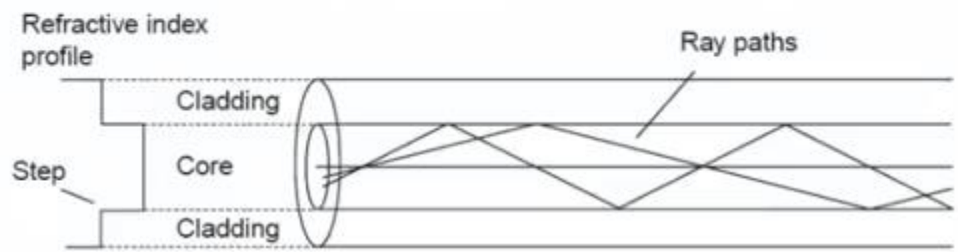
$$\Delta t_{SI} = Ln_1 / c \, [(n_1 - n_2) / n]$$

$$\Delta t_{SI} = [Ln_1 / c] \, (\Delta)$$

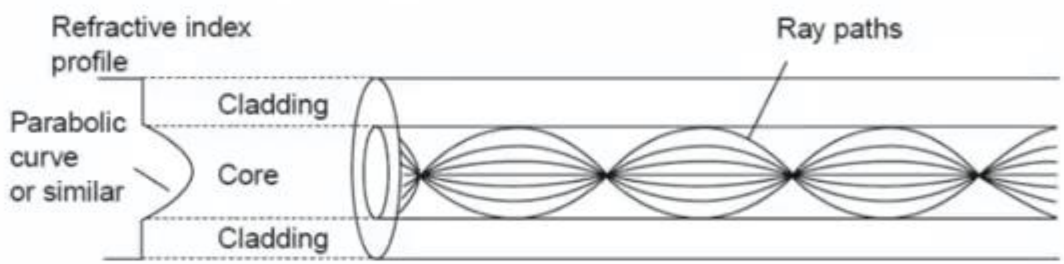
Where Δ is the relative refractive index

How to overcome intermodal dispersion

Typical step index fiber

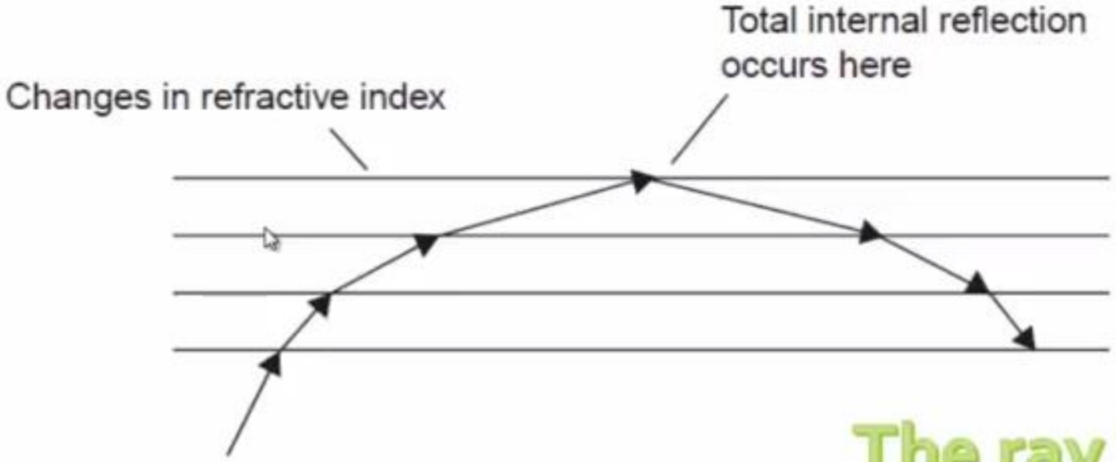


Graded index fiber



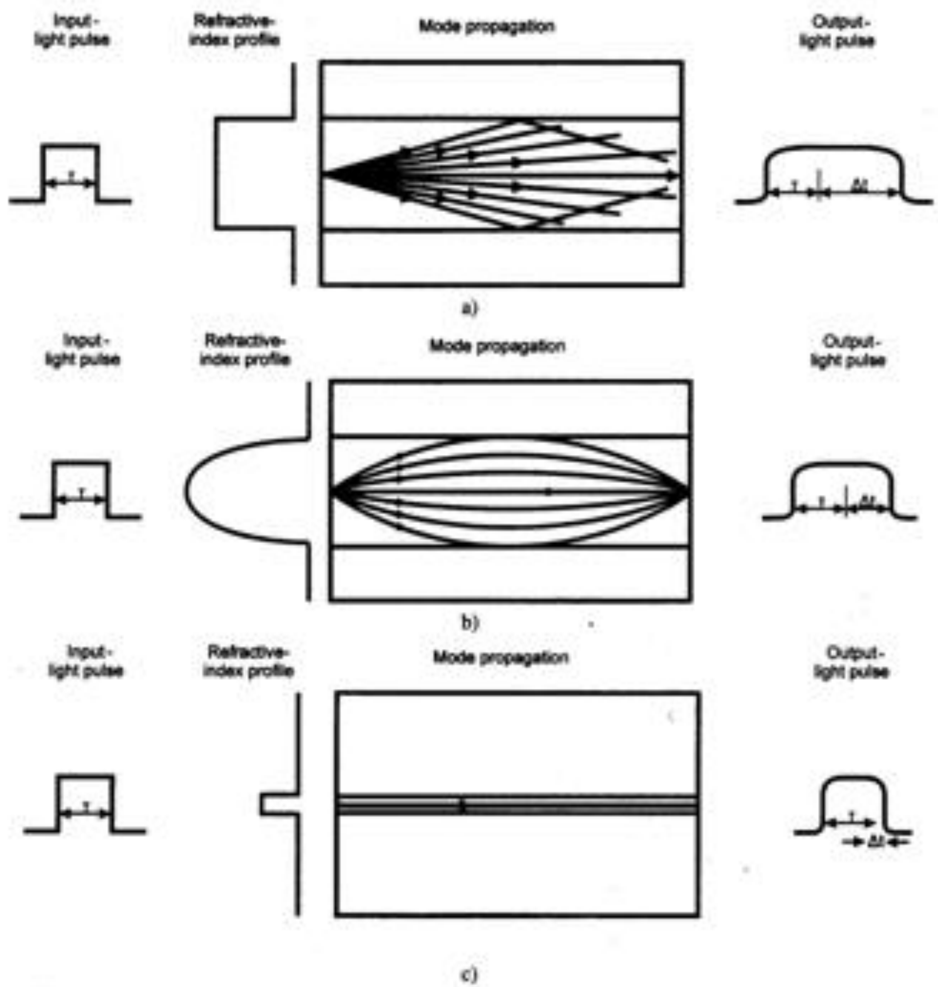
$$\text{speed of light in the material} = \frac{\text{speed of light in free space}}{\text{refractive index}}$$

How to overcome intermodal dispersion



The ray is refracted slightly at each boundary

- Solution to this intermodal dispersion was done with graded index fiber.
  - A graded index fiber has the center of the core having highest refractive index and gradually decreasing towards the end of the core.



- It is estimated that the modal dispersion of graded index fiber is $\Delta/8$

times less than in the case of step index fiber