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DIGITAL
COMMUNICATION
- Prof. N. B. Kanirkar
Good Morning
Dispersion in Fiber Optic Communication
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Dispersion

Effect of Dispersion on Pulse Transmission

A pulse with a given width and amplitude transmitted into one end of a fiber should theoretically arrive at the far end with its shape and width unchanged and only its amplitude reduced by losses.

However, several effects contribute to time dispersion of the pulse during transmission, which tend to widen out and flatten it, further reducing its amplitude. Besides reduced amplitude, the widening of the pulse may cause it to overlap adjacent pulses, causing **inter symbol interference** and reducing the upper limit on the pulse transmission rate. At low bit transmission rates the required repeater spacing will be dictated by the loss limits for the fiber. However, at some higher rate the dispersion effects will become predominant and further reduce the repeater spacing. **The product of bandwidth (the maximum allowable transmission rate) and dispersion, or bandwidth-dispersion product (BDP), is used as a quality factor for the fiber.**

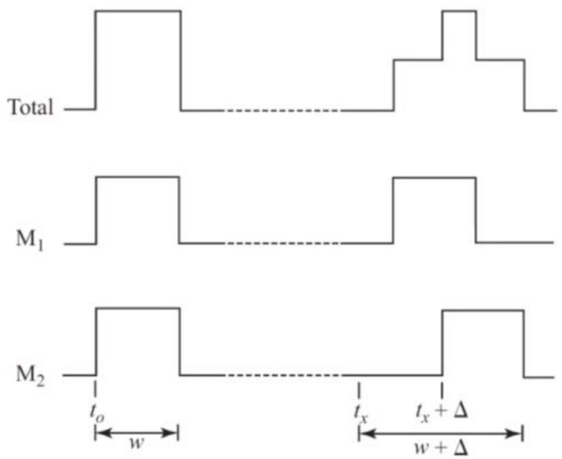
Three separate dispersion mechanisms exist in a fiber.

- Inter-Modal Dispersion
- Material or Chromatic Dispersion
- Waveguide Dispersion

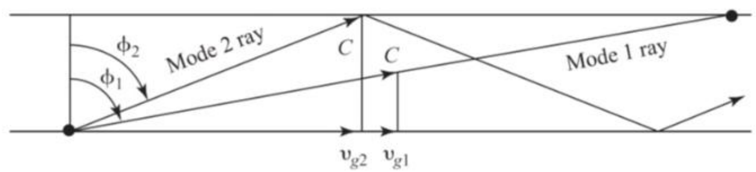
Intermodal Dispersion

Each mode that a step-index fiber supports has a different effective group velocity, even though the phase velocity in each ray path may be identical. This occurs because the total path followed by guided rays is zigzag in nature and has a different length for each mode. The shortest path coincides with the axial length of the fiber for the HE11 mode, while the longest path occurs for the mode nearest the cutoff limit.

A pulse coupled into several modes at the transmitting end becomes several pulses traveling in the several modes at different velocities, which arrive at the receiver at slightly different times. The received pulse is the summation of these mode pulses, each delayed by a different time. Figure shows the effect of dispersion on an ideal pulse transmitted by two modes. The effects of loss are omitted, and only dispersion is accounted for. The received pulse is the summation of the two received modal pulses and has a lower amplitude and wider pulse width than would be the case without dispersion.



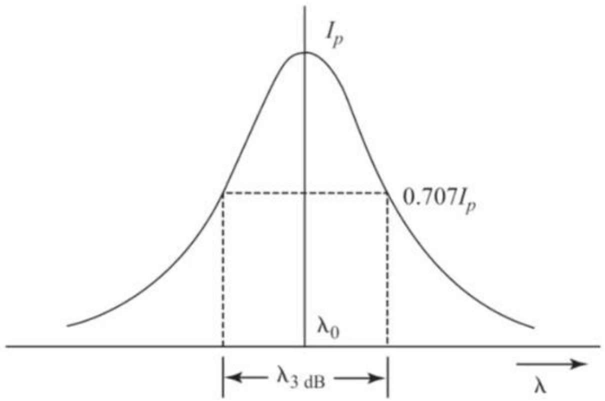
Effect of intermodal dispersion on a transmitted pulse.



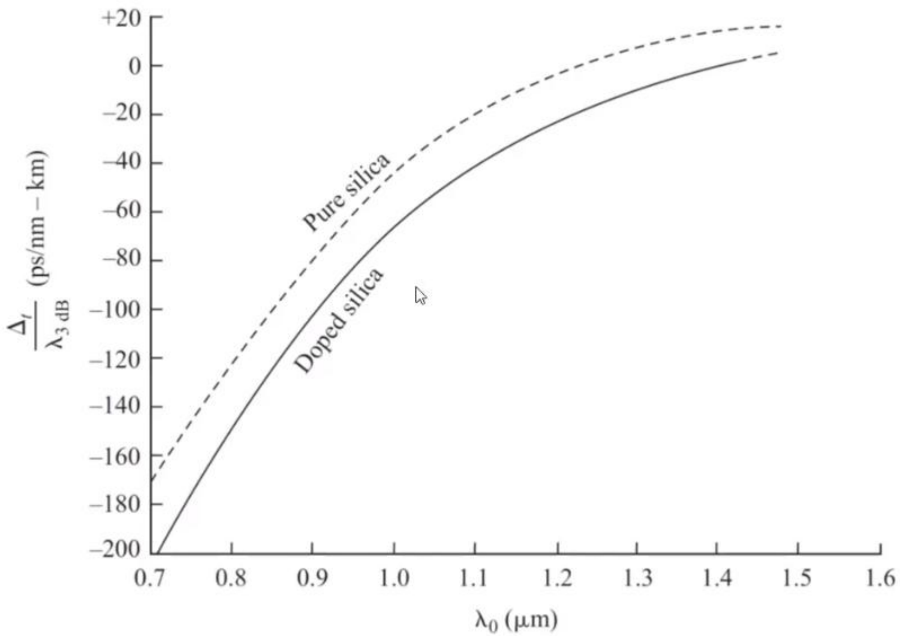
Group velocities for two modes.

Material (or Chromatic) Dispersion

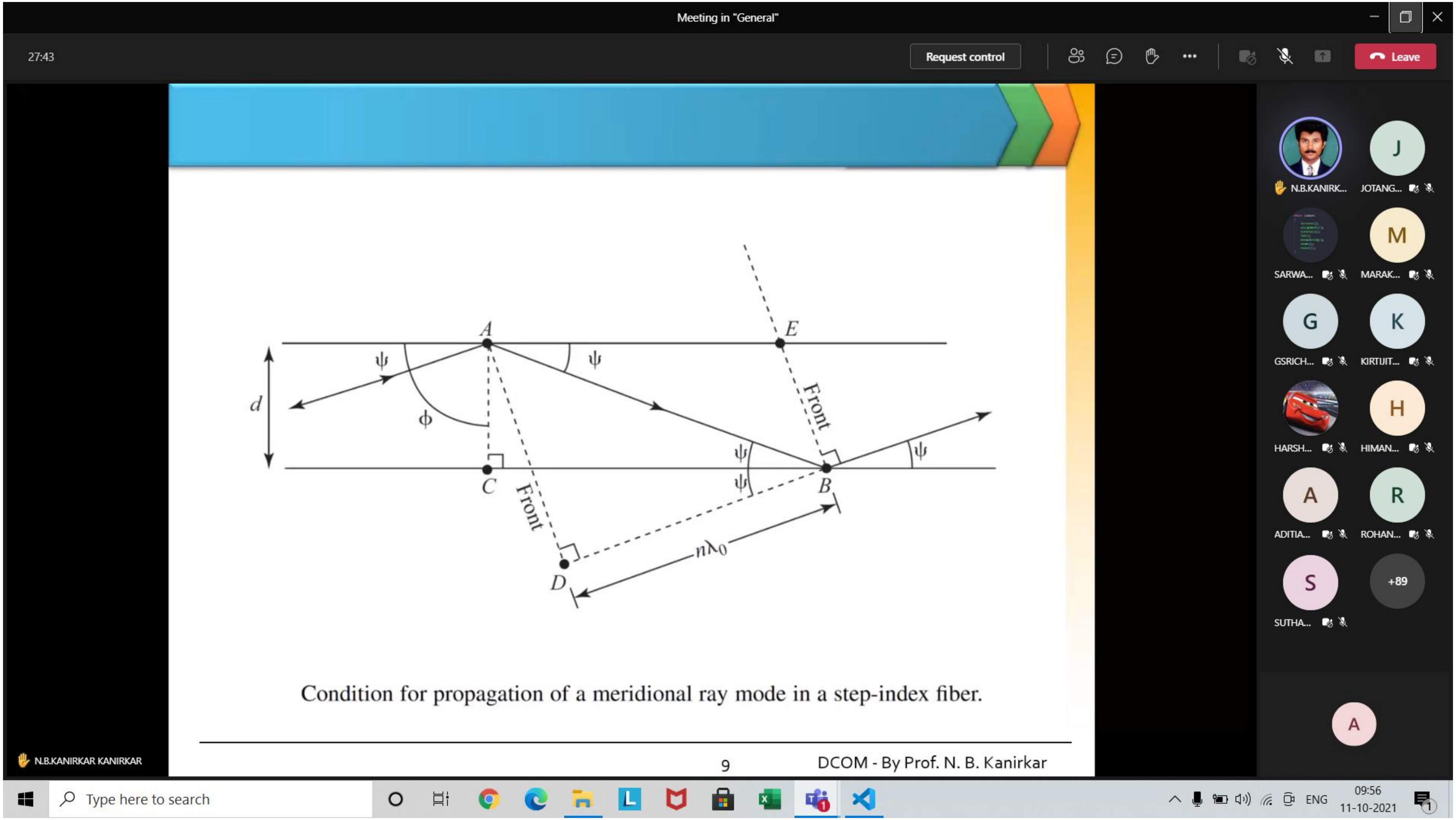
The index of refraction of the core glass is not the same for lights of different wavelengths, but varies across the spectrum. Practical light sources do not put out pure monochromatic light, but produce a spectrum distributed about a central wavelength 0 as shown in Fig. and having a spectral bandwidth 3 dB. Light components of a pulse with shorter wavelengths will experience more delay than will those components of the same pulse with longer wavelengths. The result will be a time dispersion of the pulse at the receiver end of the fiber. A narrow-bandwidth source will produce less dispersion than will a wideband source.



Spectral content of a light source.



Material dispersion coefficient as a function of wavelength for silica fibers.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Condition for propagation of a meridional ray mode in a step-index fiber.
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Waveguide Dispersion

If a fiber can be operated so that intermodal dispersion and material dispersion both disappear (as for a single-mode fiber operated near 1.3m), then a third dispersion mechanism will predominate. This is called *waveguide dispersion* and results only from the guiding characteristics of the fiber.

All practical light sources contain light components of different wavelengths distributed over a spectral bandwidth, as shown in Fig. ι slight spectral shift to higher wavelength will slightly lengthen the path length between successive reflection points (see Fig. and increase the corresponding incidence angle for each supported mode. This in turn will increase the corresponding group velocity.

Thus each supported mode will suffer a dispersion effect dependent on the spectral width of the source so that, even if the other effects cancel, this one still remains. It too would disappear if a truly monochromatic light source could be developed, but that is not possible.