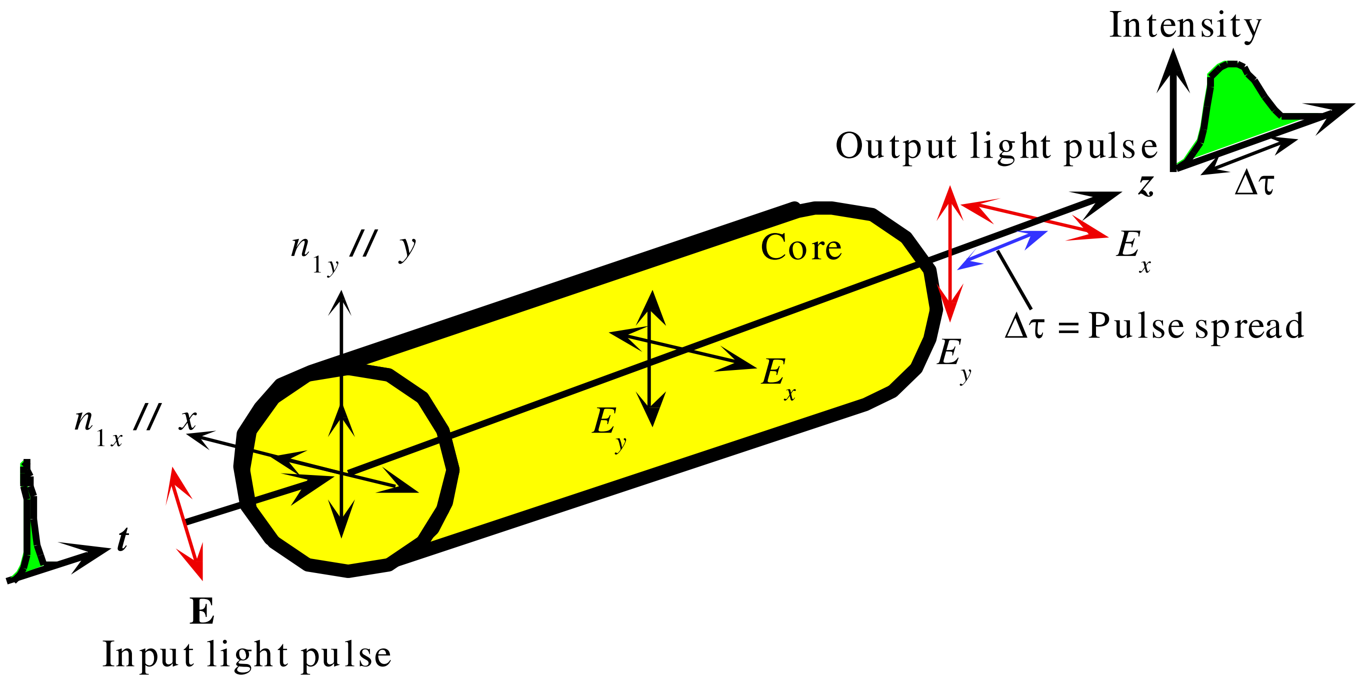
Unit-2

Lecture -6

Polarization mode dispersion, Overall Fiber dispersion in multimode and single mode fibers, Fiber dispersion techniques, Non linear Effect

Polarization Mode dispersion



Suppose that the core refractive index has different values along two orthogonal directions corresponding to electric field oscillation direction (polarizations). We can take x and y axes along these directions. An input light will travel along the fiber with E_x and E_y polarizations having different group velocities and hence arrive at the output at diferent times

Polarization Mode dispersion

- The effects of fiber-birefringence on the polarization states of an optical are another source of pulse broadening. **Polarization mode dispersion** (PMD) is due to slightly different velocity for each polarization mode because of the lack of perfectly symmetric & anisotropicity of the fiber. If the group velocities of two orthogonal polarization modes are v_{gx} and v_{gy} then the differential time delay $\Delta\tau_{pol}$ between these two polarization over a distance L is

$$\Delta\tau_{pol} = \left| \frac{L}{v_{gx}} - \frac{L}{v_{gy}} \right| \qquad [3\text{-}26]$$

- The rms value of the differential group delay can be approximated as:

$$\langle \Delta\tau_{pol} \rangle \approx D_{PMD}\sqrt{L} \qquad [3\text{-}27]$$

Chromatic & Total Dispersion

- Chromatic dispersion includes the material & waveguide dispersions.

$$D_{ch}(\lambda) \approx \left| D_{mat} + D_{wg} \right|$$

$$\sigma_{ch} = D_{ch}(\lambda) L \sigma_{\lambda}$$

[3-28]

- Total dispersion is the sum of chromatic , polarization dispersion and other dispersion types and the total rms pulse spreading can be approximately written as:

$$D_{total} \approx \left| D_{ch} + D_{pol} + \ldots \right|$$

$$\sigma_{total} = D_{total} L \sigma_{\lambda}$$

[3-29]

Total Dispersion, zero Dispersion

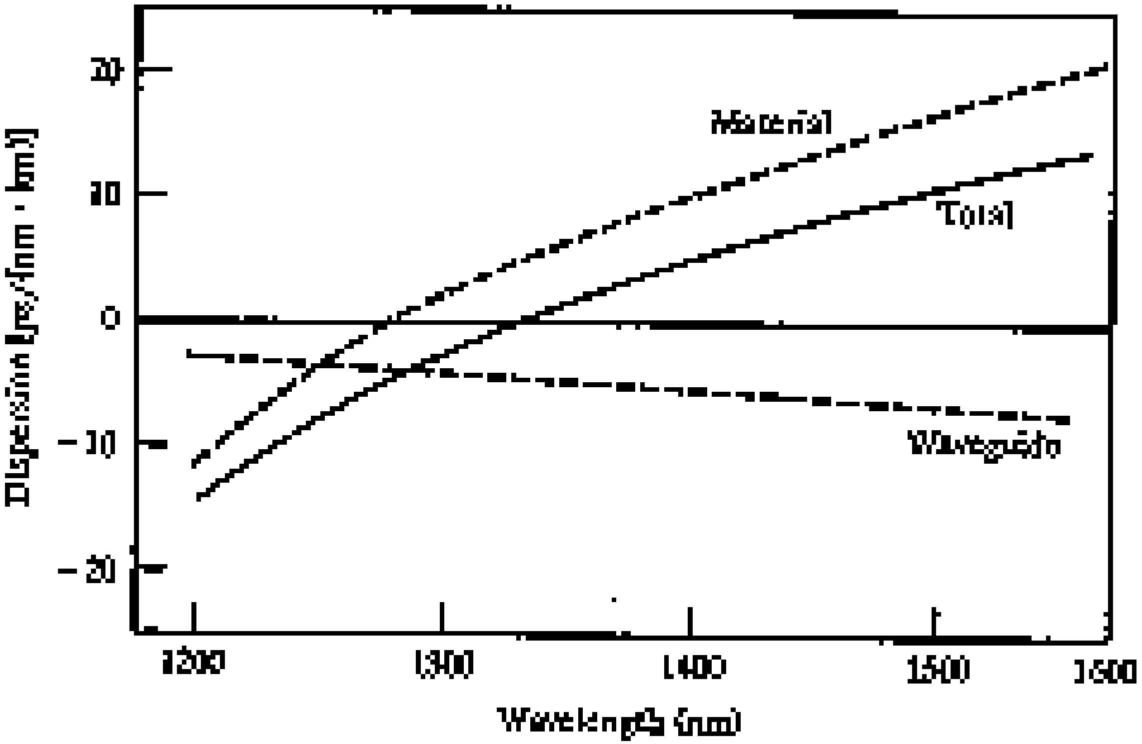


FIGURE 3-16
Examples of the magnitudes of material and waveguide dispersion as a function of optical wavelength for a single-mode fused-silica-core fiber. (Reproduced with permission from Keck,[16] © 1985, IEEE.)

Fact 1) Minimum distortion at wavelength about 1300 nm for single mode silica fiber.
Fact 2) Minimum attenuation is at 1550 nm for sinlge mode silica fiber.
Strategy: shifting the zero-dispersion to longer wavelength for minimum attenuation and dispersion.

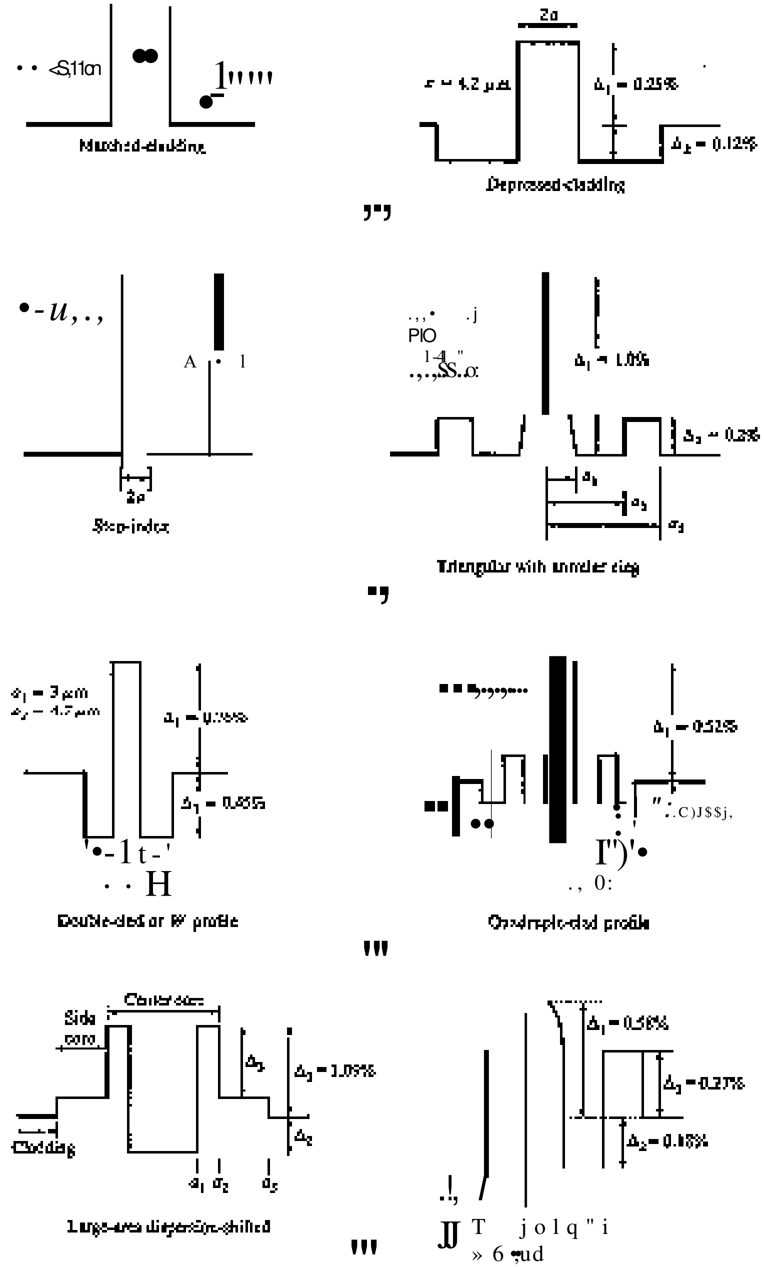
Optimum single mode fiber & distortion/attenuation characteristics

Fact 1) Minimum distortion at wavelength about 1300 nm for single mode silica fiber.

Fact 2) Minimum attenuation is at 1550 nm for sinlge mode silica fiber.

Strategy: shifting the zero-dispersion to longer wavelength for minimum attenuation and dispersion by Modifying waveguide dispersion by changing from a simple step-index core profile to more complicated profiles. There are four major categories to do that:

1. 1300 nm optimized single mode step-fibers: matched cladding (mode diameter 9.6 micrometer) and depressed-cladding (mode diameter about 9 micrometer)
2. Dispersion shifted fibers.
3. Dispersion-flattened fibers.
4. Large-effective area (LEA) fibers (less nonlinearities for fiber optical amplifier applications, effective cross section areas are typically greater than $100\mu m^2$).



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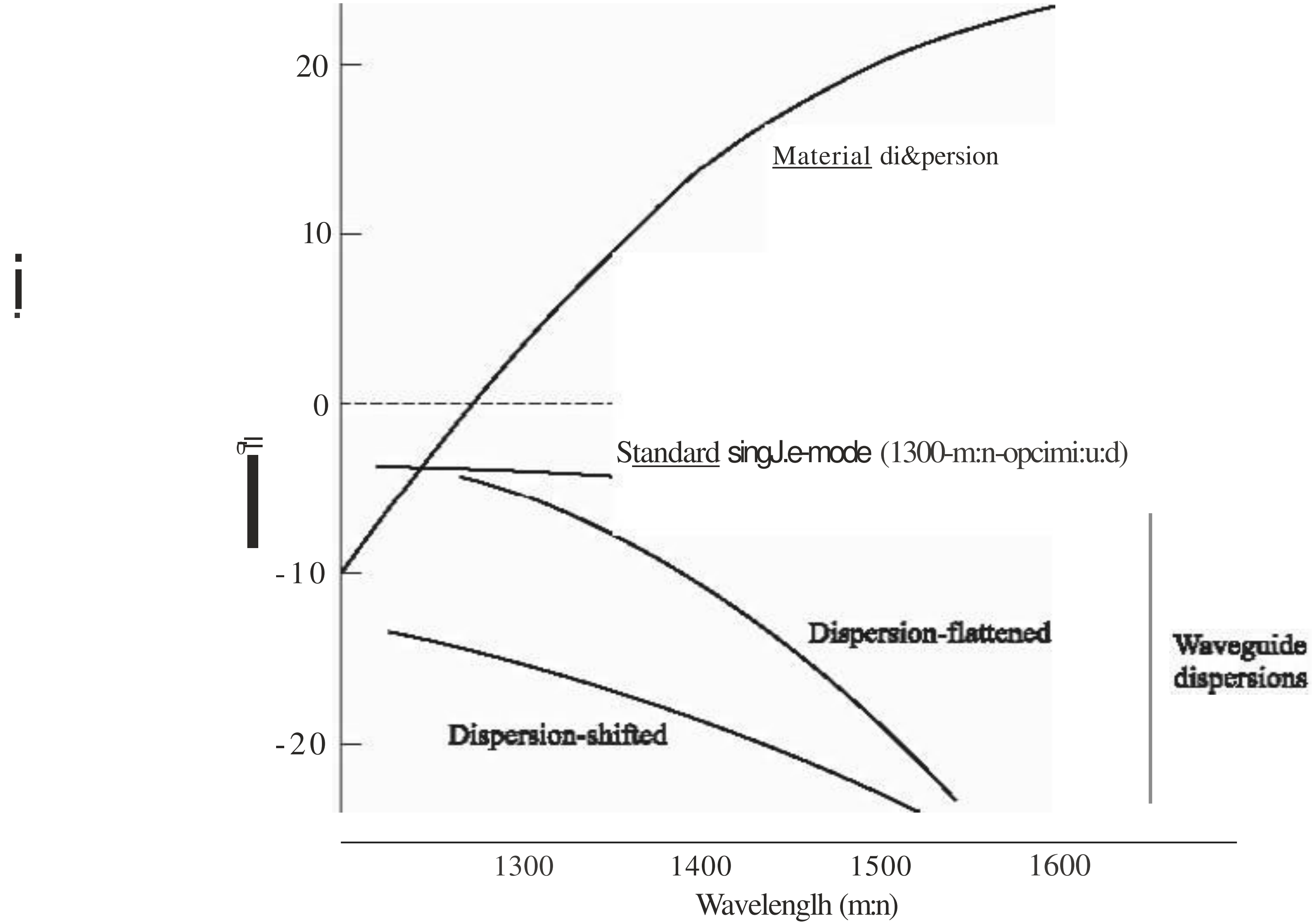
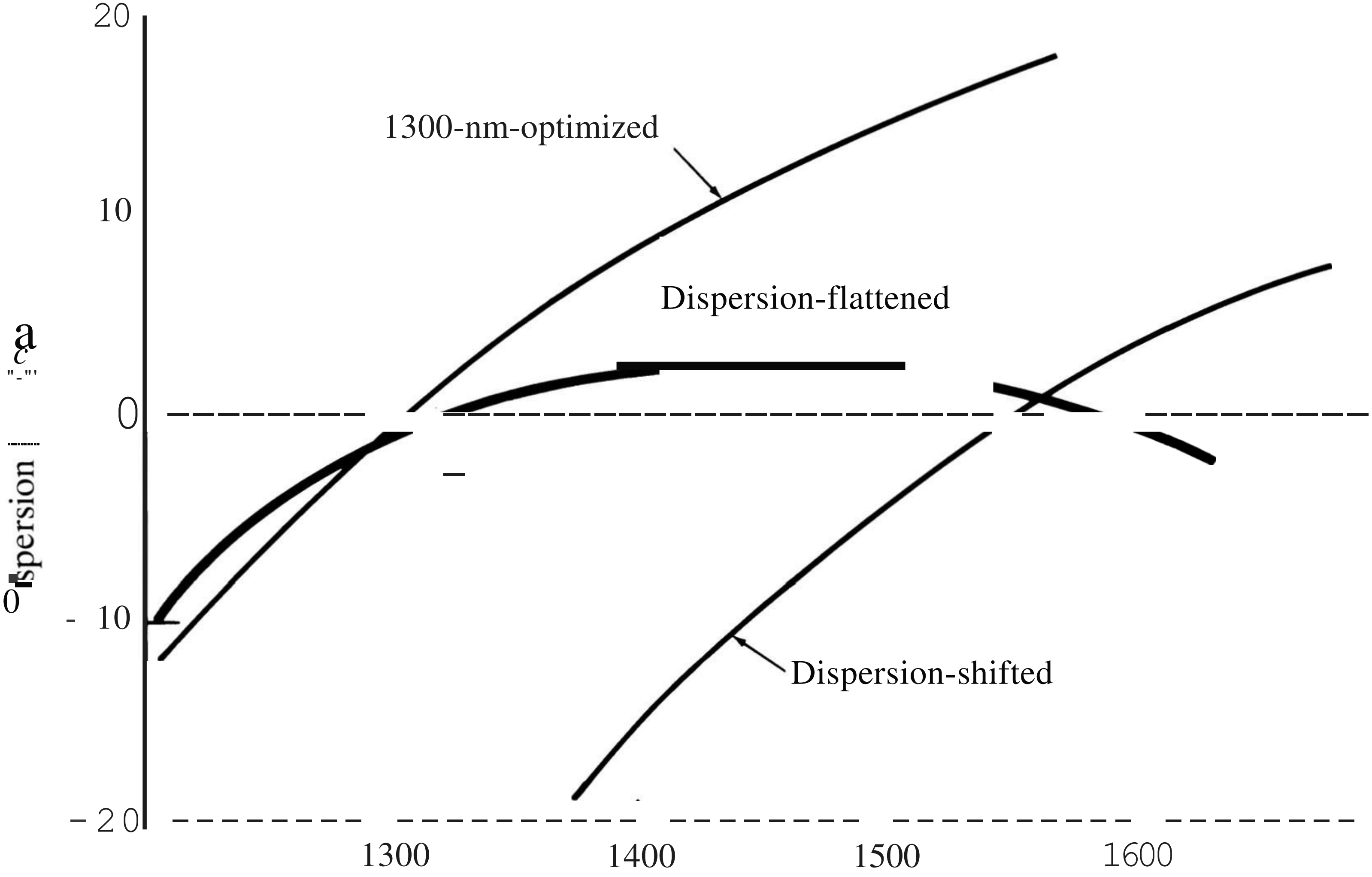
Single mode fiber dispersion



(a)

Single mode fiber dispersion



(b)

Single mode Cut-off wavelength & Dispersion

- Fundamental mode is HE_{11} or LP_{01} with V=2.405 and $\lambda_c = \frac{2\pi a}{V}\sqrt{n_1^2 - n_2^2}$ [3-30]
- Dispersion:

$$D(\lambda) = \frac{d\tau}{d\lambda} \approx D_{mat}(\lambda) + D_{wg}(\lambda)$$ [3-31]

$$\sigma = D(\lambda) L \sigma_\lambda$$ [3-32]

- For non-dispersion-shifted fibers (1270 nm – 1340 nm)
- For dispersion shifted fibers (1500 nm- 1600 nm)

Dispersion for non-dispersion-shifted fibers (1270 nm – 1340 nm)

$$\tau(\lambda) = \tau_0 + \frac{S_0}{8}\left(\lambda - \frac{\lambda_0^{\,2}}{\lambda}\right)^2 \qquad [3\text{-}33]$$

- τ_0 is relative delay minimum at the zero-dispersion wavelength λ_0, and S_0 is the value of the dispersion slope in $\mathrm{ps/(nm^2.km)}$

$$S_0 = S(\lambda_0) = \left.\frac{dD}{d\lambda}\right|_{\lambda=\lambda_0} \qquad [3\text{-}34]$$

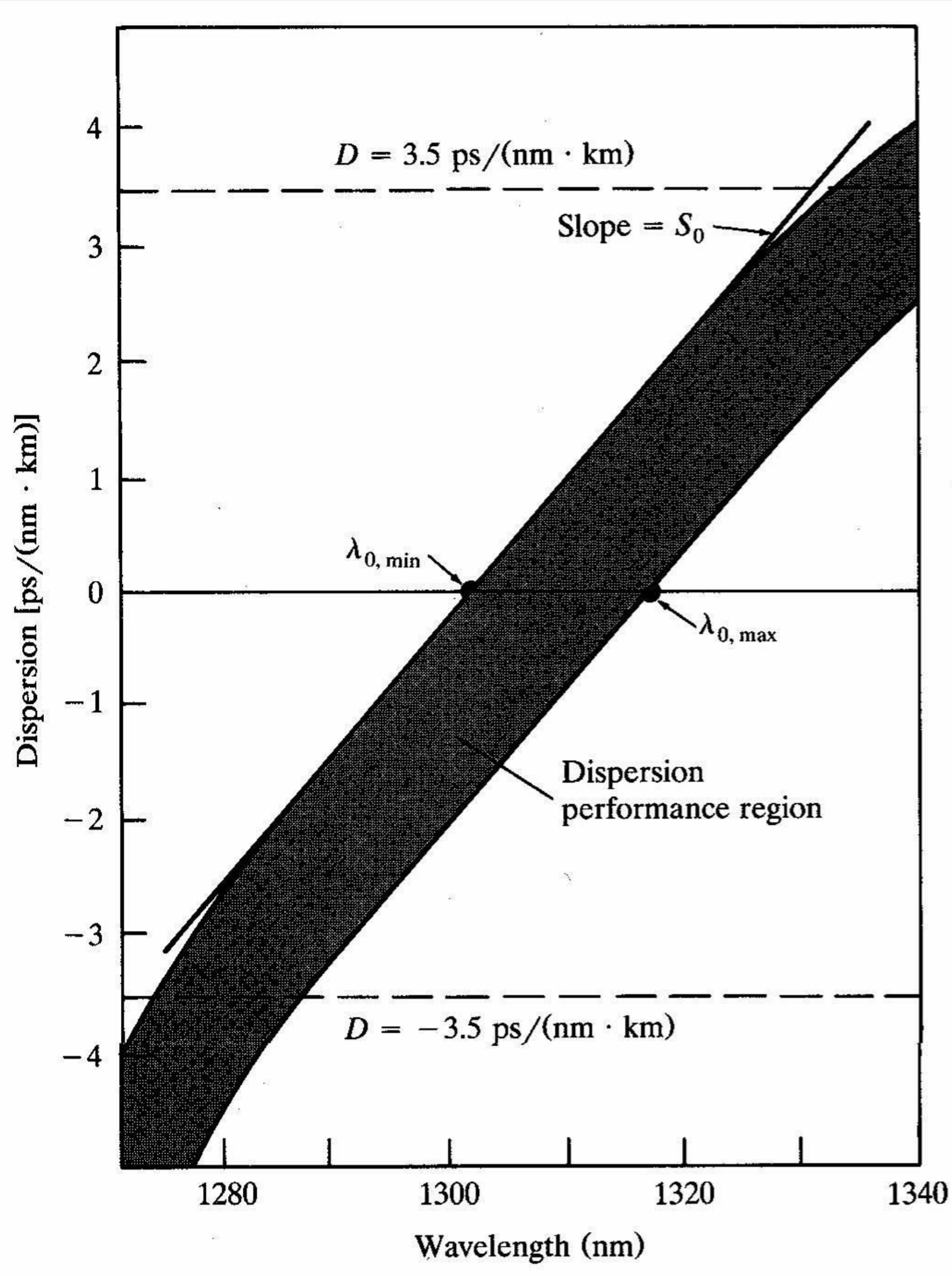
$$D(\lambda) = \frac{\lambda S_0}{4}\left[1 - \left(\frac{\lambda_0}{\lambda}\right)^4\right] \qquad [3\text{-}35]$$

Dispersion for dispersion shifted fibers (1500 nm- 1600 nm)

$$\tau(\lambda) = \tau_0 + \frac{S_0}{2}(\lambda - \lambda_0)^2$$ [3-36]

$$D(\lambda) = (\lambda - \lambda_0)S_0$$ [3-37]

Example of dispersion Performance curve for Set of SM-fiber



Example of BW vs wavelength for various optical sources for SM-fiber.