Bend Loss in Optical Fibers

- It is common to wrap optical fiber in communication systems

Bend Loss in Optical Fibers

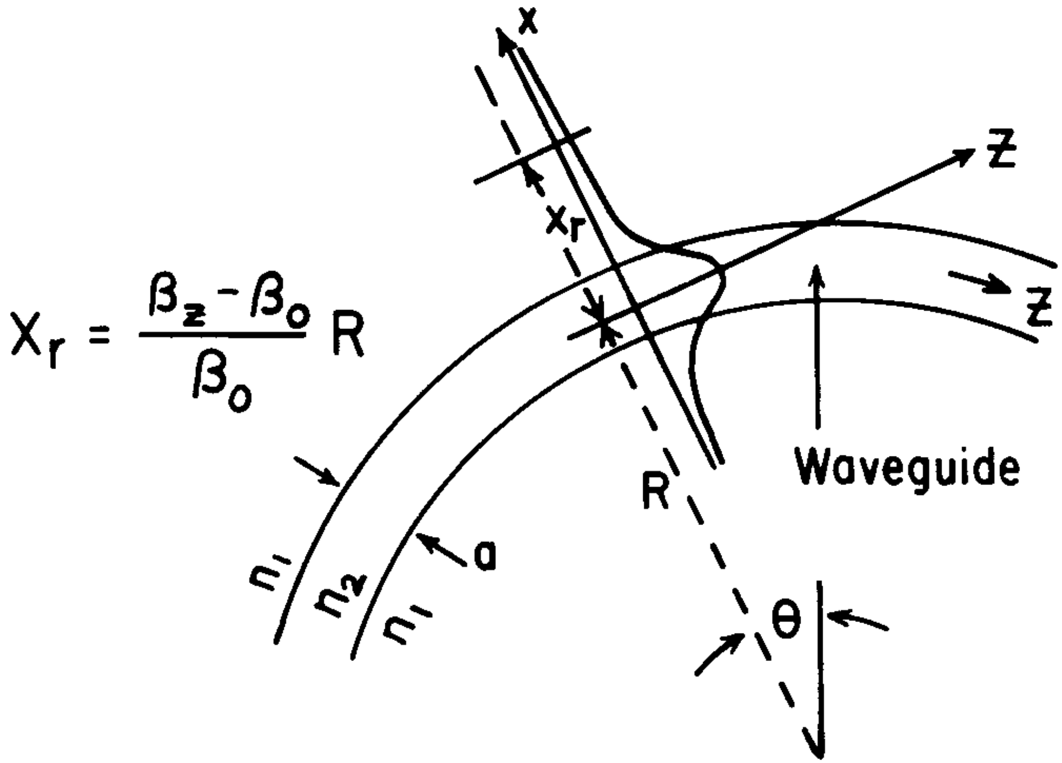
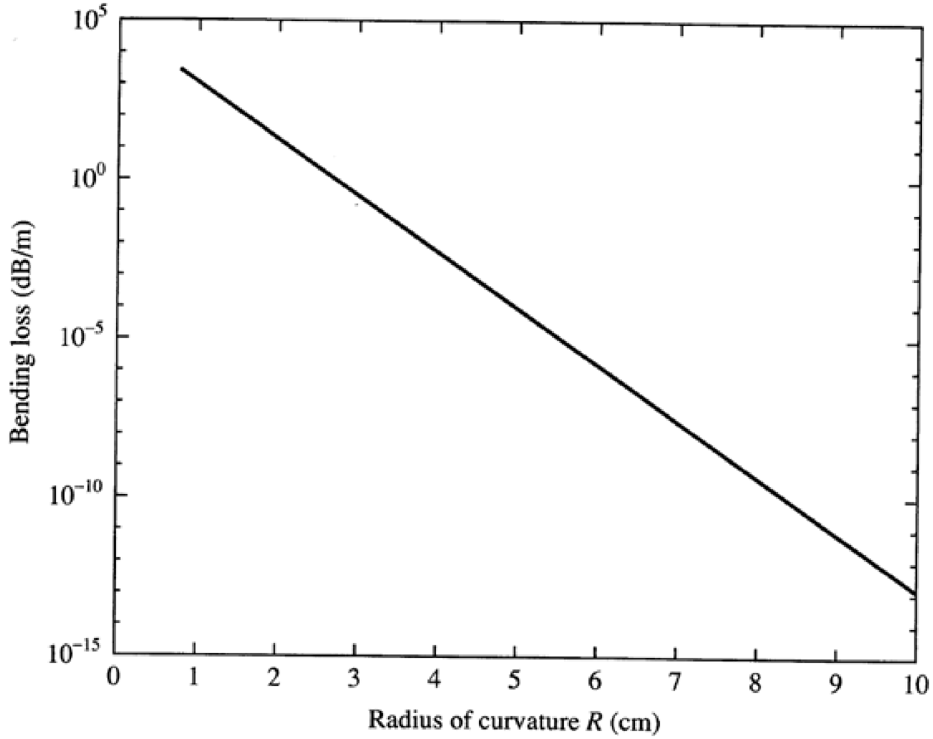


Fig. 5.4. Diagram illustrating the velocity approach to the determination of radiation loss

From *Integrated Optics*, Robert G. Hunsperger, 4th Edition, pp. 84-87.

- Power in the tail of the mode profile is lost.

Bend Loss in Optical Fibers



From *Photonics*,
Yariv and Yeh, 4th Edition

Figure 3.24 Attenuation coefficient due to bending as a function of the radius of curvature of bending, calculated using Equation (3.6-7). The fiber parameters used are: core index $n_1 = 1.4628$, clad index $n_2 = 1.4600$, core radius $a = 5.49\ \mu m$, $\lambda = 1.30\ \mu m$. These parameters lead to $V = 2.400$, $n_{eff} = 1.4614$, $ha = 1.6978$, $qa = 1.6969$, and $\beta a = 38.777$.

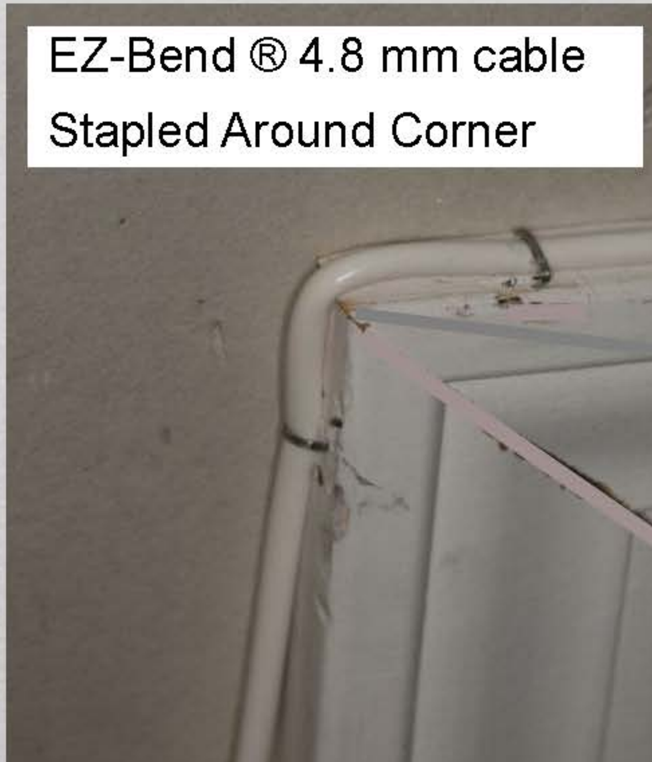
- Keeping bend radii greater than 10 cm makes bend loss negligible

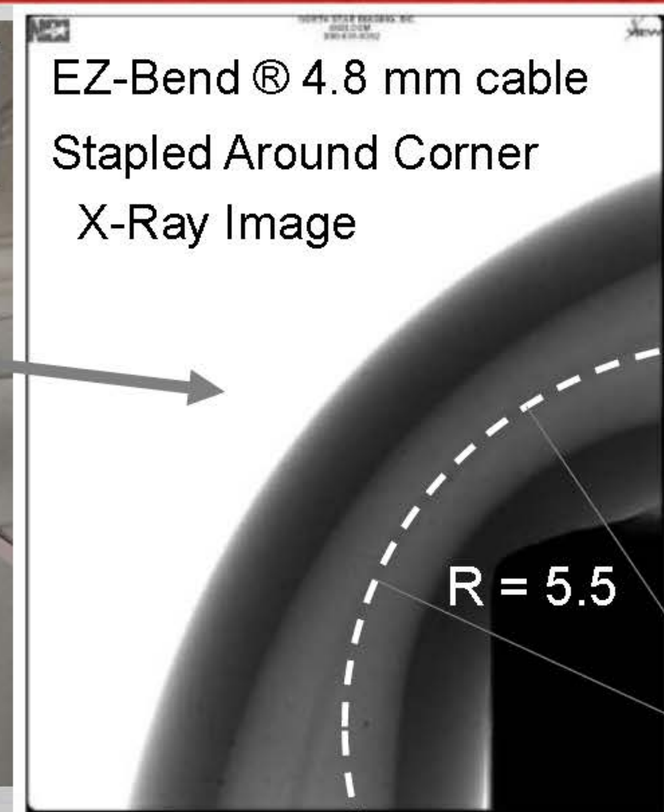
Emerging Fiber Optics Technologies for MDU & ILU Applications

verizon

David Z. Chen
Distinguished Member of Technical Staff
NEBS, Fiber & Energy Efficiency
Verizon Corporate Technology

4.8 mm cable under tight bend condition

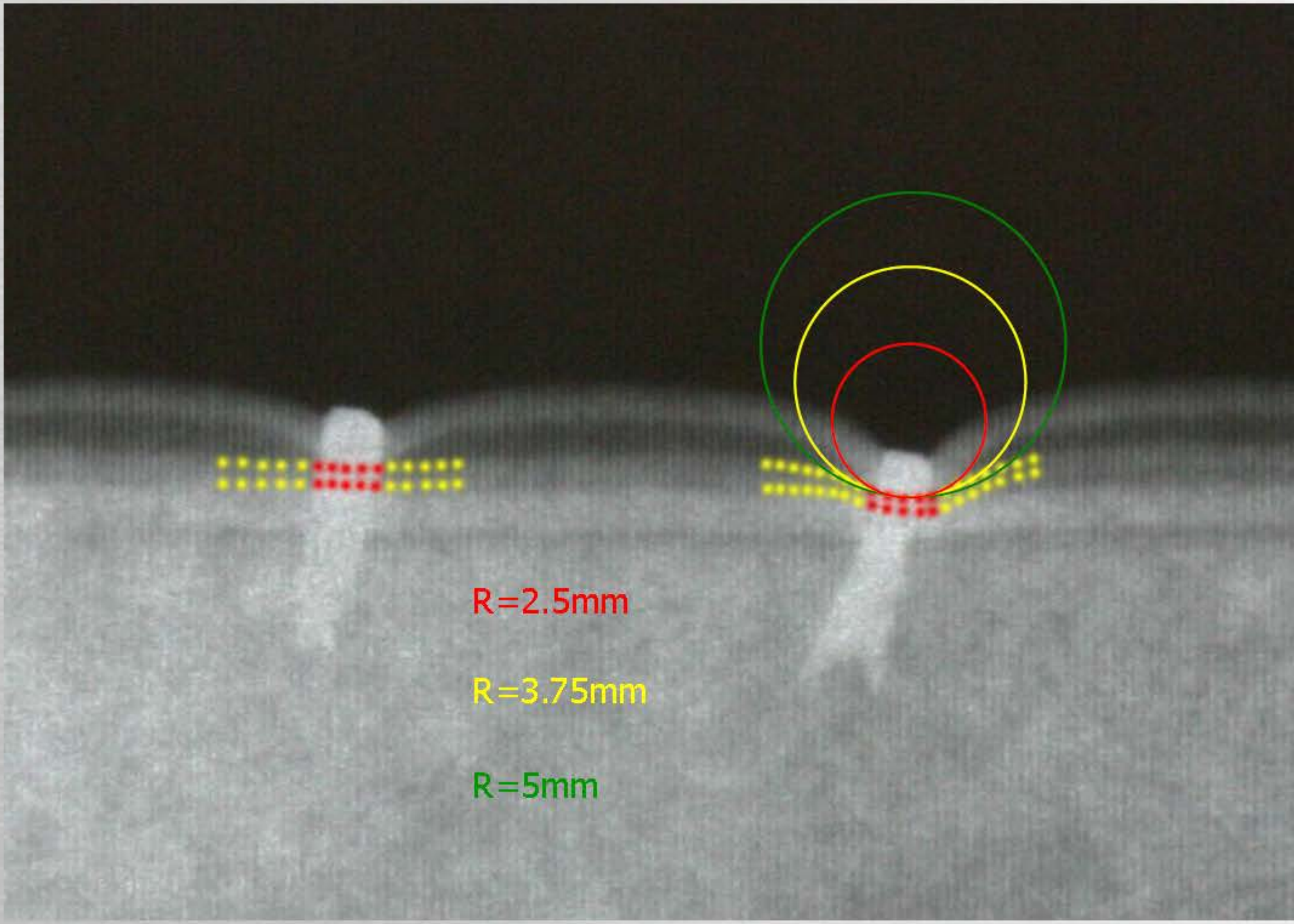




90 degree bend, stapled ¾" from corner
5 lb tension, 5.5mm fiber bend radius

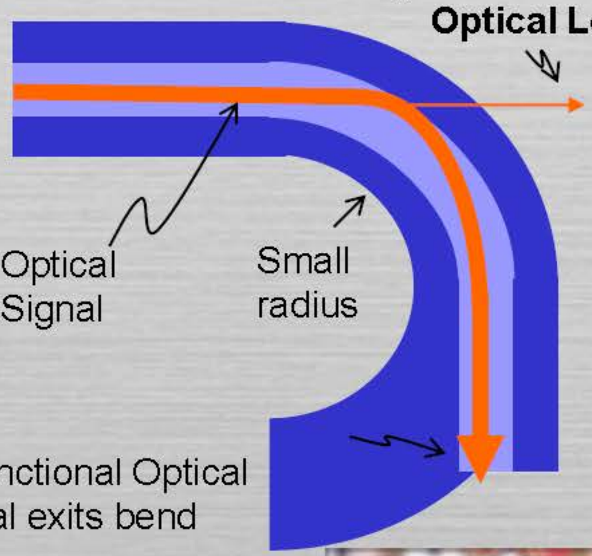
Estimating Bend Radius Near Tight Staples By X-Ray

- **The position of the fiber is obscured by the staple**
- **This complicates the location of the fiber which will definitely be forced into the 5 mm range**
- **The possible bend radius could be in the range of 2.5 and 3.75 mm**
- **The arc is approximately 60°**



Fundamental Challenge for Bending Fibers in Small Radius

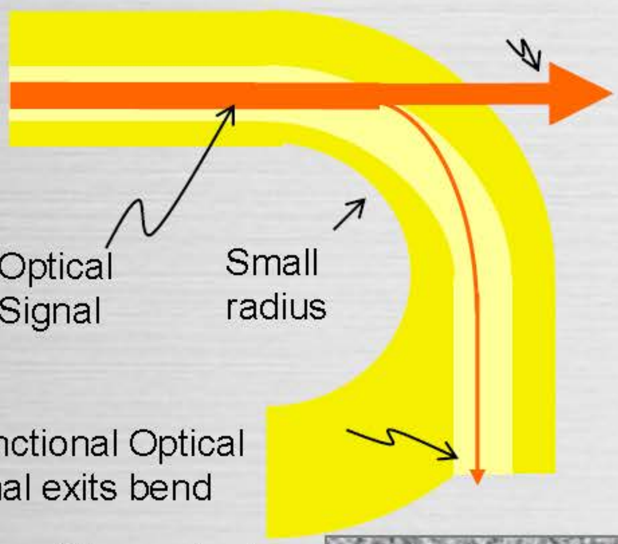
Bend Insensitive Single-mode fiber- G.657-B3



Fully Functional Optical Signal exits bend

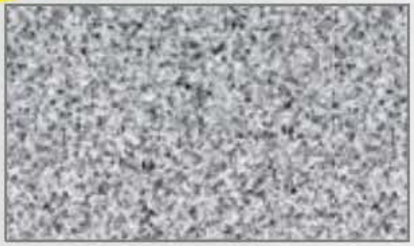
Service Maintained

Conventional Single-mode fiber- G.652-D



Dysfunctional Optical Signal exits bend

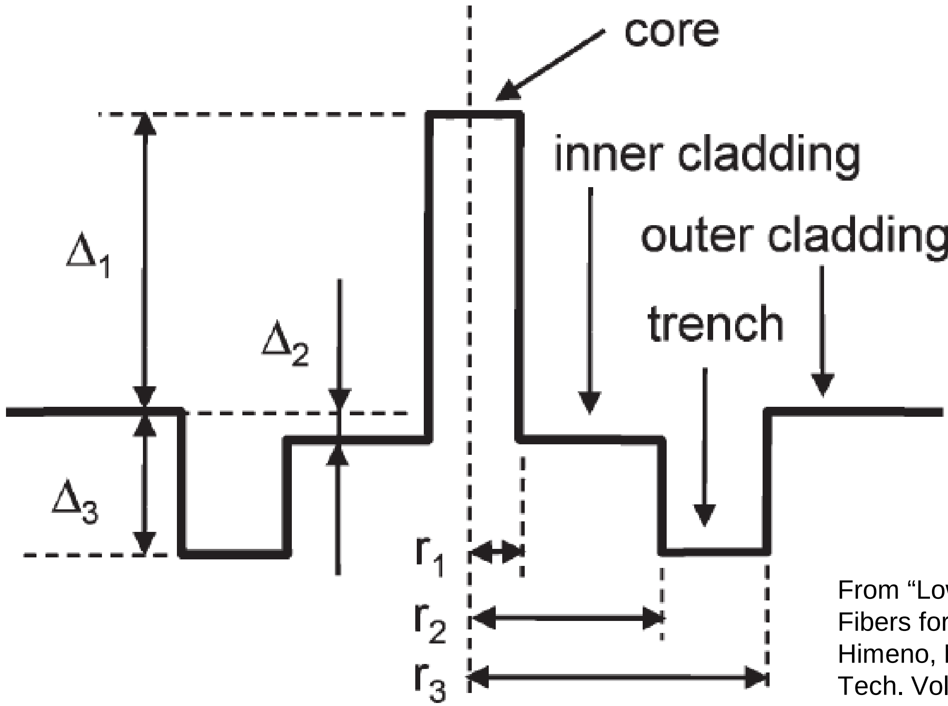
Service Disrupted



Draka BendBright-Elite Fiber (G.657.B3)

Attenuation with Bending			
Number of Turns	Mandrel Radius (mm)	Wavelength (nm)	Induced Attenuation (dB)
1	10	1550	$\leq$ 0.03
1	10	1625	$\leq$ 0.1
1	7.5	1550	$\leq$ 0.08
1	7.5	1625	$\leq$ 0.25
1	5.0	1550	$\leq$ 0.15
1	5.0	1625	$\leq$ 0.45

Low Bend Loss Optical Fiber



From "Low-Bending-Loss Single-Mode Fibers for Fiber-to-the-Home," Himeno, Matsuo, and Guan, J. Lightwave Tech. Vol. 23, (11) 2005, p. 3494

Fig. 3. Schematic of a trench-index profile and its parameters.

- Larger core-clad index difference minimizes bend loss, but smaller mode profiles increase splice loss
- Fiber with a trench-index profile minimizes bend loss while maintaining a larger mode profile

Nonlinear Impairments in Optical Fiber

- Self-Phase Modulation
- Four-Wave Mixing

Nonlinear Impairments in Optical Fiber

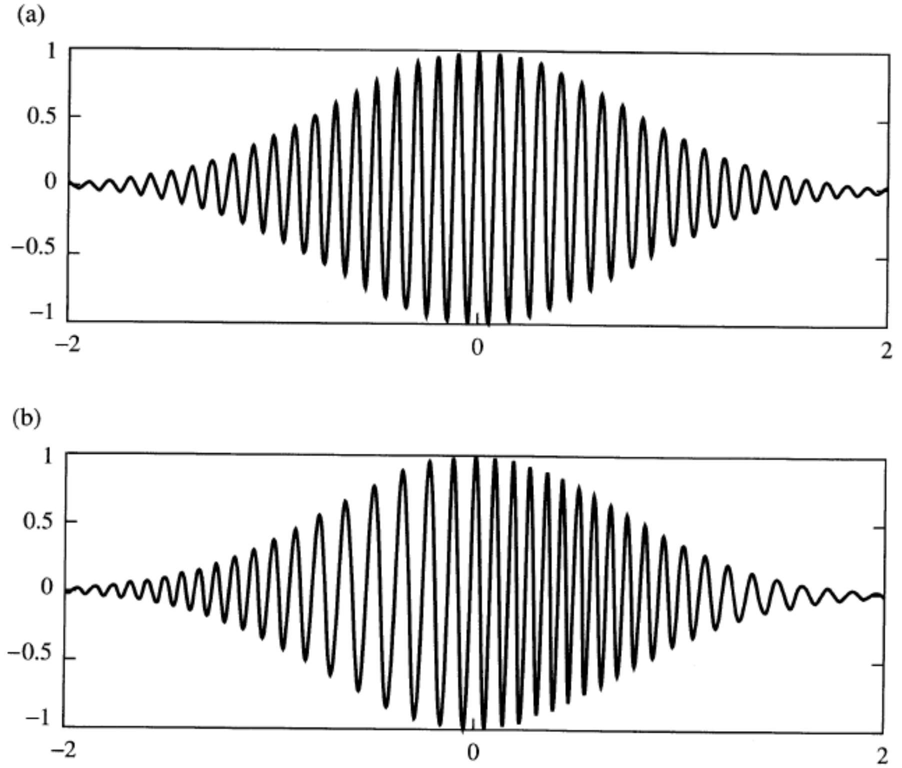


Figure 14.1 Electric field as a function of time: (a) at the input end of the fiber and (b) at the output end of the fiber. The parameters used are $A_{\text{eff}} = 100\ \mu\text{m}^2$, $P = 5$ mW, $L = 2500$ km, $\tau = 0.05$ ps, and $n_2 = 3 \times 10^{-20}\ \text{m}^2/\text{W}$.

$$n = n_0 + n_2 I$$

$$I(t) = I_0 \exp\left(-t^2 / \tau^2\right)$$

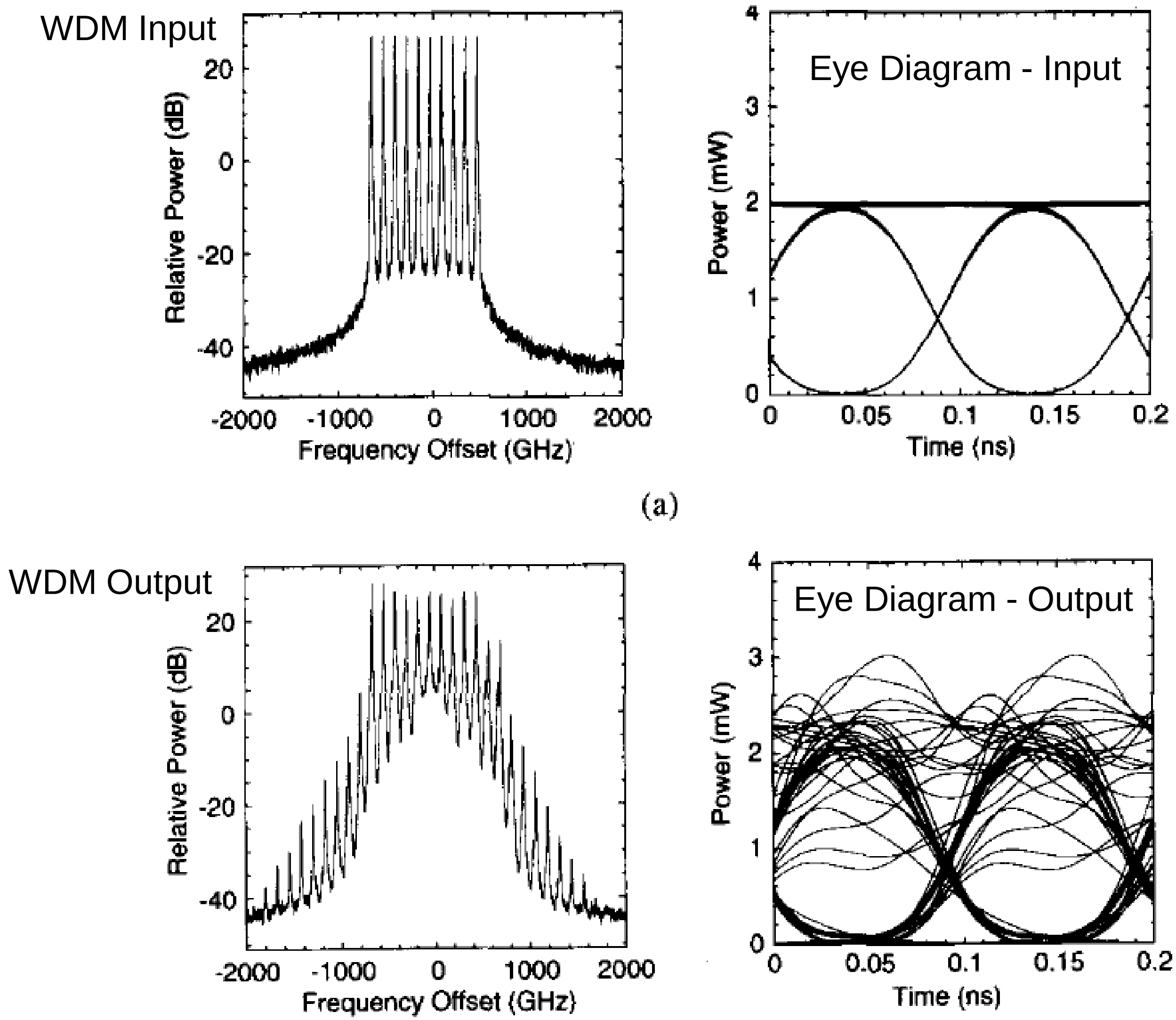
$$\Delta\omega = \omega(t) - \omega_0$$

$$= \frac{2\pi}{\lambda_0} n_2 L \frac{2t}{\tau^2} I_0 \exp\left(-t^2 / \tau^2\right)$$

From *Photonics*,
Yariv and Yeh, 4th Edition

- An increasing intensity, and refractive index, has the effect of increasing frequency (decreasing wavelength) and vice versa

Four-Wave Mixing



Simulations from “Four-Photon Mixing
And High-Speed WDM Systems, Tkach et al.
J. Lightwave Tech. Vol. 13 (5) 1995, p. 841