Rajasthan Technical University, Kota
B.Tech. VI Semester ECE
Fiber Optics Communication

Unit 5: Lecture 02
Non Linear Effects

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Contents

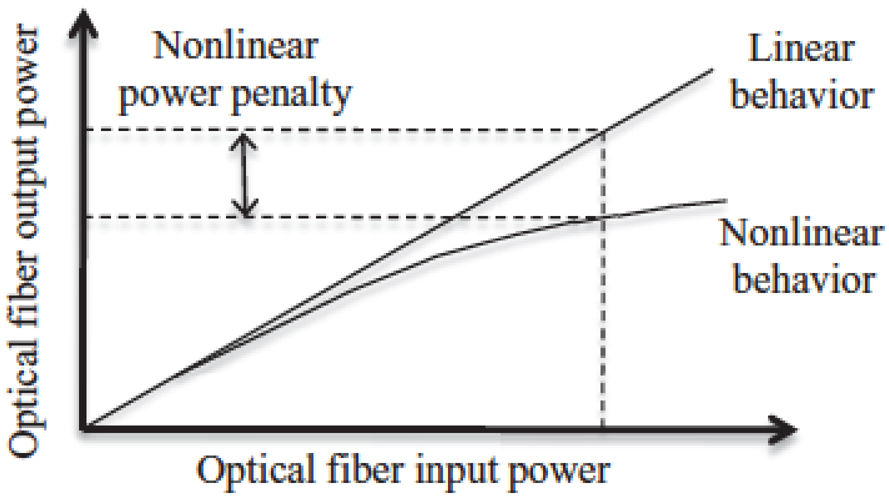
- Introduction to Nonlinearities in Optical Fiber Communication
- Effective Length and Area
- SRS, SBS, SPM, XPM, GVD and Solition to be discussed in next lectures.
- References

Introduction

- It is a system design objective to achieve improved BER at output of any communication system.
- Output power = Input power – System losses
- From above equation it seems natural that increasing input power may result in increased output power and thus improved BER.
- This assumption is valid as long as input power vs output power relationship is linear and system losses are constant which is not always the case.
- At input power levels beyond a threshold value, system losses are not constant but they varies according to value of input power.
- This makes input power vs output power relation non linear.

Power Penalty for Nonlinear Effects

- When any nonlinear effect contributes to signal strength reduction, the amount of optical power reduction (in decibels) is the power penalty for that effect



Nonlinear effects cause optical power reductions and lead to power penalties

- When input power increases beyond a threshold value following may take place :
  - Scattering
  - Refractive index variations

Introduction …….

- Nonlinear inelastic scattering processes include
  - Stimulated Raman scattering (SRS)
  - Stimulated Brillouin scattering (SBS)
- Nonlinear effects from intensity-dependent variations in the refractive index include
  - Self-phase modulation (SPM)
  - Cross-phase modulation (XPM)
  - Four-wave mixing (FWM)

Table 12.1 *Summary of nonlinear effects in optical fibers*

Nonlinearity category	*Single-channel*	*Multiple-channel*
Index related	Self-phase modulation	Cross-phase modulation Four-wave mixing
Scattering related	Stimulated Brillouin scattering	Stimulated Raman scattering

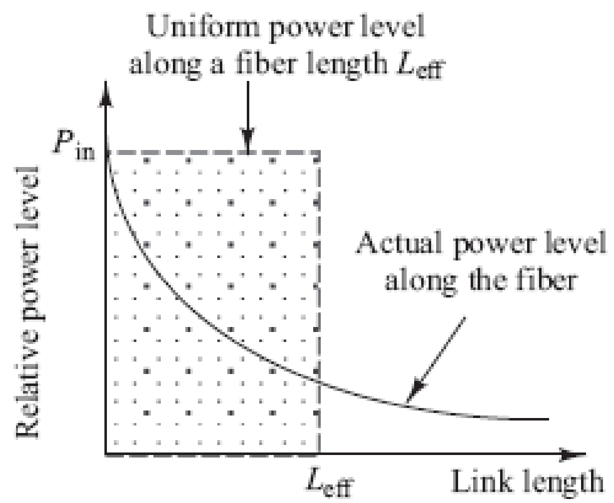
Basic Effects of Nonlinearities

- SBS, SRS, and FWM result in gains or losses in a channel.
  - The power variations depend on the optical signal intensity.
  - These processes provide gains to some channels while depleting power from others
  - These effects produce crosstalk between the wavelength channels.
- FWM can be suppressed through special arrangements of fibers having different dispersion characteristics.
- SPM and XPM affect only the phase of signals, which causes chirping in digital pulses. This can worsen pulse broadening due to dispersion, particularly in very high-rate systems, such as 40 Gb/s.
- When any of these nonlinear effects contribute to signal impairment, an additional amount of power will be needed at the receiver to maintain the same BER as in their absence. This additional power is the *power penalty* for that effect.

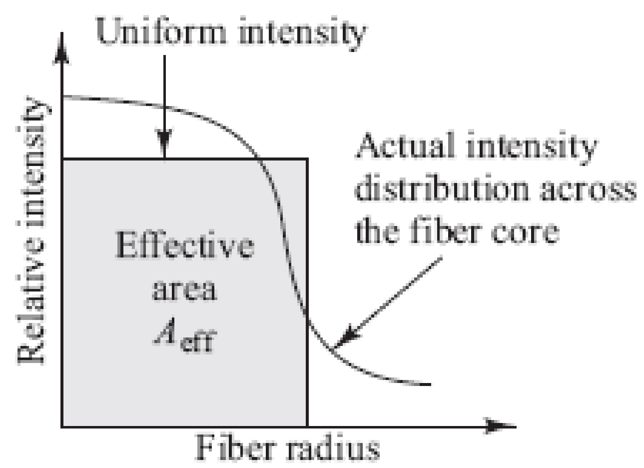
Effective Length and Area

- Nonlinear effects increase with distance, but are offset by the continuous decrease in signal power along the fiber due to attenuation
- A simple model assumes the power is constant over an *effective length* L_{eff} given by

$$L_{eff} = \frac{1 - e^{-\alpha L}}{\alpha}$$

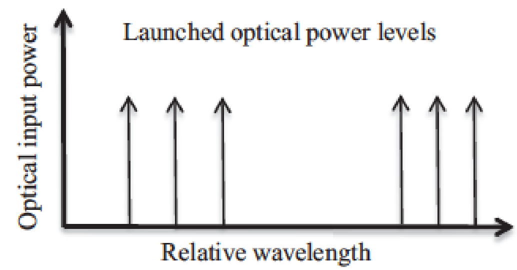


- Nonlinear effects increase with the light intensity. For a given optical power, this intensity is inversely proportional to the area of the fiber core.
- In practice one can use an *effective cross-sectional area* A_{eff}, which assumes a uniform intensity distribution across most of the core.



Stimulated Raman Scattering

- In *stimulated Raman scattering* a silica molecule absorbs energy from an incident photon giving it a lower energy and a longer wavelength
- The modified photon is called a *Stokes photon.*
- Because the optical signal wave that is injected into a fiber is the source of the interacting photons, it is called the *pump wave* because it supplies power for the generated wave.
- The power transferred to a higher-wavelength channel increases approximately linearly with channel spacing up to about 16 THz (or 125 nm at 1550-nm), and then drops off sharply for larger spacing.



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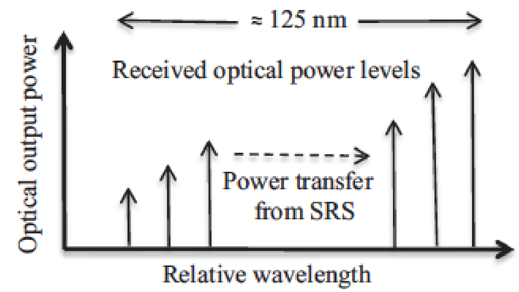

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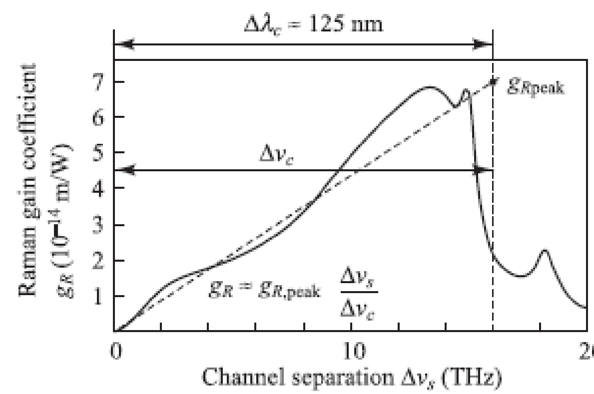


Stimulated Brillouin Scattering

- In *stimulated Brillouin scattering (SBS)* a strong optical signal generates an acoustic wave that *produces variations in the refractive index*.
- The index variations *cause lightwaves to scatter in the backward direction*.
- The backscattered light *experiences gain from the forward-propagating signals*, which leads to depletion of the signal power.
- Below a signal level called the *SBS threshold*, the transmitted power increases linearly with the input level and SBS is negligible.
- *Beyond the SBS threshold*, the % increase in signal depletion grows with signal strength
- Beyond the *SBS limit* any additional launched optical power is scattered backward in the fiber.

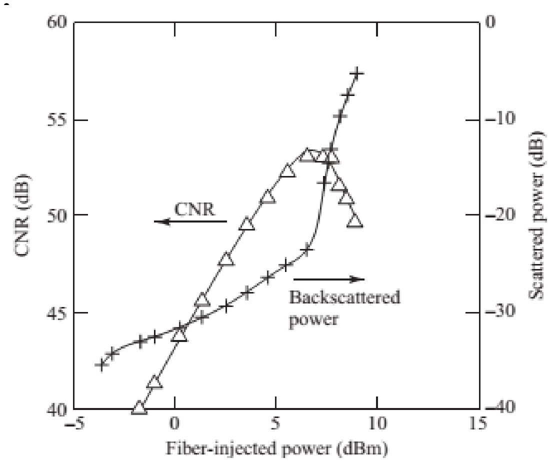
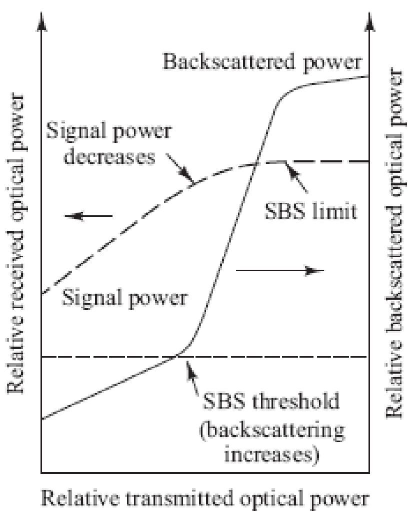


Fig. 12.7 *The SBS impairment on the CNR of an AM-VSB signal. The triangles are the CNR and the crosses represent the backscattered power. (Adapted with permission from Mao, Bodeep, Tkach, Chraplyvy, Darcie, and Dorosier,[11] © IEEE, 1992)*



The effect of SBS on signal power in an optical fiber

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Thank You