Non-linear scattering effects in fiber optic cables: a comprehensive review

Nimarjit Kaur, Harmanjeet Singh Parmar

Abstract- In this article, Scattering phenomena and its classification has been demonstrated. Attenuation is the main loss mechanism in an optical fiber. Absorption and scattering of signals results in attenuation. There are two types of scattering losses. They are linear scattering and nonlinear scattering. In optics, the term linear and non-linear mean “power-independent” and “power dependent” phenomena, respectively. In linear scattering, attenuation occurs when optical power is transferred from one mode to another keeping frequency unaltered. There are two categories in linear scattering. They are Rayleigh scattering and Mie scattering. Rayleigh scattering is the main loss mechanism in the visible range. Rayleigh scattering loss can be minimized by choosing longest possible operating wavelength. If the size of the defect is greater than one-tenth of the wavelength of light, the scattering mechanism is called Mie scattering. Non linear scattering occurs when frequency is changed during optical power transfer. The two types of nonlinear scattering are stimulated Brillouin scattering and stimulate Raman scattering. Stimulated Brillouin scattering is a cause of concern in long distance systems, in wavelength division multiplexing (WDM) systems and remote pumping of an erbium doped fiber amplifier (EDFA) through a separate optical fiber. Stimulated Raman scattering creates problems in wavelength division multiplexing (WDM) systems.

Keywords- Optical Fiber, total internal reflection Scattering, Linear Scattering, Non-Linear Scattering, Stimulated Brillouin Scattering, Stimulated Raman Scattering.

◆

1. Introduction

Scattering in optical fiber is a process which is caused by the interaction of phonons within the glass itself. During the process of scattering, all or some of the optical power in a mode is transferred into another mode resulting in attenuation, since the transfer is often to the mode which does not propagate well and is known as a leaky or radiation mode. If there is an imperfection in a core material, a beam propagating at the critical angle or less will change the direction after it meets the obstacle. In other words, light will be scattered [1].

This scattering effect prevents attainment of total internal reflection at the core-cladding boundary, resulting in power loss since some light will pass out of core. So there are certain factors that are to be kept in consideration during planning of a light wave transmission system in order to make network which is reliable, and easy to operate and maintain.

These are factors are as follows,

Fiber selection

- Choice and tuning of optoelectronic components
- Optical amplifiers placement
- Path routing, etc [2].

The design must take into account all power penalties associated with optical signal-degradation processes. Otherwise scattering loss can severely limit the performance of multichannel lightwave systems.

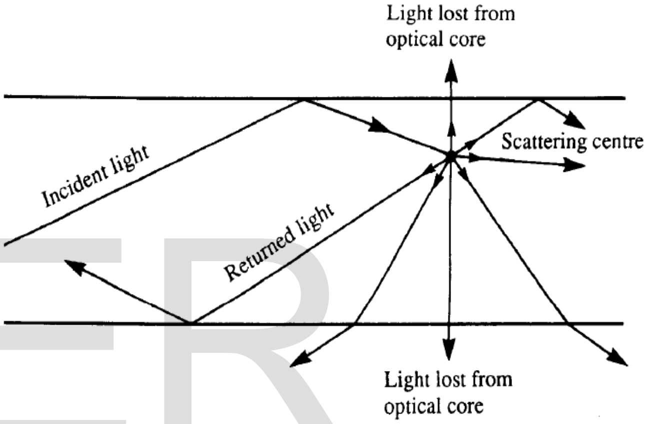

Figure 1.1: Schematic illustration scattering loss in optical fiber [1].

Following parameters govern the scattering phenomena :

The wavelength (λ) of the incident radiation

The size of the scattering particle, usually expressed as the non dimensional size parameter, x: r is the radius of a spherical particle, λ is wavelength.

$$X=2\pi r/\lambda \qquad (1)$$

The particle optical properties relative to the surrounding medium: the complex refractive index [3].

2 Classifications

There are two basic types of scattering:

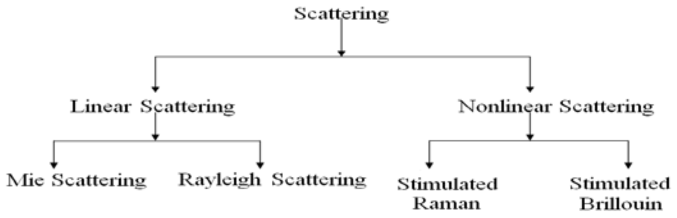

Figure 2: Classification of scattering [3]

In optics, linear scattering is "power-independent" whereas non-linear scattering is "power dependent" phenomena.

2. Non-linear scattering

This type of scattering processes are power dependent and occurs due to change in frequency during optical power transferring, which causes disproportionate attenuation at high optical power levels. The nonlinear scattering effects in optical fibers are due to the inelastic scattering of a photon to a lower energy photon. The energy difference is absorbed by the molecular vibrations or phonons in the medium. In other words one can state that the energy of a light wave is transferred to another wave, which is at a higher wavelength (lower energy) such that energy difference appears in form of phonons. The other wave is known as the Stokes wave. The signal can be considered as pump wave. Of course, high-energy photon at the so-called anti-Stokes frequency can also be created if phonon of right energy and momentum is available.

2.1 Stimulated Brillouin Scattering

The phenomenon of SBS was first observed in 1964.In Stimulated Brillouin scattering, the thermally generated fluctuations in the density of medium are responsible for scattering of light. Stimulated Brillouin scattering arises when a strong optical signal generates an acoustic wave that produces variation in the refractive index1,3,4-10. These index variations cause lightwave to scatter in backward direction toward the transmitter. This backscattered light experiences gain from the forward-propagating signals [17], which leads to depletion of the signal power. The frequency of the scattered light experiences a Doppler shift given by

$V_B = 2nV_s / \lambda$ … [17]

(where Vs is the velocity of sound in the material)

Once the Brillouin threshold is reached, backward propagating Stokes wave is generated that carries most of the input power.

In this process, nonlinear interaction between the pump and stokes wave through acoustic wave takes place.

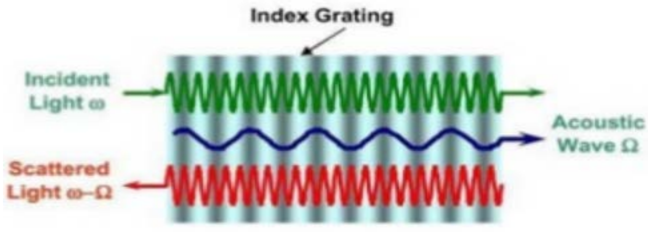

Figure 3: Index grating of the incident light, scattered light [18].

Scattered light is shifted down in frequency because of the Doppler shift associated with the grating moving of the acoustic velocity.

Most of the power reflected backward after SBS threshold is reached.

The threshold power of pump for Brillouin scattering depends on the spectral width associated with the pump wave.

2.1.1 Brillouin-Gain Spectrum

The spectral width of the SRS gain spectrum is very small because it is related to the damping time of the acoustic waves related to the phonon lifetime.

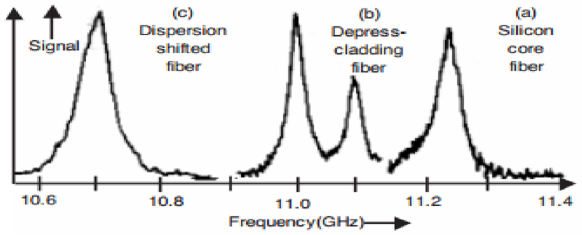

Figure 4: Brillouin gain spectra of three fibers for λp=1.525μm, (a) silica-core fiber, (b) depressed-cladding fiber, (c) dispersion-shifted fiber [19]

When acoustic waves decay as exp(-Γ_Bt), the Brillouin gain has a lorentzian spectrum given by

$g_B(\Omega)=g_p(\Gamma_B/2)^2 /(\Omega-\Omega_B)^2 + (\Gamma_B/2)^2$ …[20]

The Brillouin-gain spectrum depends on details of the fiber design and may contain multiple peaks that have their origin in different acoustic modes supported by the fiber. A three-peak gain spectrum was observed and interpreted to result from different acoustic velocities in the core and cladding regions of the fiber. Since each mode has a different acoustic velocity (represented as vA), it also has a different Brillouin shift and changes in gain spectra at high power are related to the onset of SBS.

3.1.2 Brillouin Threshold

Pump and stokes evolve along the fiber as

$$-\frac{dIs}{dz} = gBIpIs - \alpha Is\ ,$$

$$\frac{dIp}{dz} = gBIpIs - \alpha Ip$$

Ignoring pump depletion and using

$Ip(z)=I0\ \exp(-\alpha L)$

Integrating it over fiber length L, the stokes intensity is found to grow exponentially in the backward direction as

$$Is(L)=Is(0)\ \exp(gBI0Leff - \alpha L\ )$$

The stokes wave grows from the noise provided by the spontaneous Brillouin scattering occurring throughout the fiber. Brillouin threshold is obtained as

$gBPthLeff\ /Aeff \approx 21$ …[21]

Brillouin gain is nearly independent of the pump wavelength.

2.1.3 Techniques for controlling the SBS Threshold

The Brillouin threshold power is obtained assuming that the fiber core is perfectly circular and homogeneous across its entire length but most the times the fiber core is doped to enhance its refractive index during which its concentration varies along the radial direction and this variation leads to slight changes in the acoustic velocity in that direction. Due to this the SBS threshold can depend on various dopants used to make fiber core.

The variations in the fiber parameters are helpful in controlling the SBS threshold as the backward propagating Stokes wave grows exponentially along the fiber length. Thus SBS threshold can be forced to increases significantly by making the exponential growth interrupted [22].

A temperature gradient along the fiber length also increases the SBS threshold by shifting vB in a distributed manner.

Especially designed fibers needed to implement through which SBS suppression can be achieved by modulating the phase of the pump beam before it is launched into the fiber. As the modulating changes ΩB along the fiber length, the threshold increases by some factor.

Keep the power level per WDM channel much below the SBS threshold. In long-haul systems one may have to reduce the amplifier spacing.

To raise the Brillouin threshold, slight dithering the laser output in frequency is effective since SBS is a narrowband process.

2.1.4 Applications of SBS Phenomenon

Normally SBS puts limitations on optical communication systems, but with suitable system arrangement it can be useful for making many optical devices. These are described below.

2.1.4.1 Fiber Sensors

The fiber sensors are capable of sensing the temperature and strain over long distances. Whenever there is change in temperature or strain, the refractive index of silica changes in response to such variations. This change produces change in Brillouin shift and by registering the change in Brillouin shift the distribution of temperature and strain over long distances can be obtained. To improve sensing performance in different areas (special resolution, total sensing length, measurement-acquisition time etc.), several methods have been introduced. BOTDA (Brillouin optical domain analysis) technique provides improved resolution, accuracy and acquisition time.

2.1.4.2 Brillouin Fiber Amplifiers

The optical gain in SBS process can be utilized in amplification of weak signal provided the frequency shift of weak signal from pump frequency is equal to Brillouin shift. In Brillouin fiber amplifier, a part of pump power is transmitted to signal through the

SBS process and hence amplification in signal power occurs. When power level inside silica fiber exceeds the threshold level (Pth), the stimulated Brillouin scattering starts due to a positive feedback dynamics set up inside the fiber medium. This dynamics results in amplification of the signal.

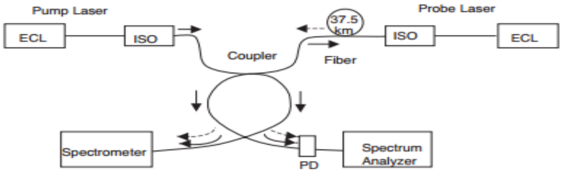

Figure 5: Schematic illustration of a Brillouin amplifier; ECL, ISO and PD stands for external-cavity laser, laser isolator and photodetector, respectively [23].

The Brillouin fiber amplifiers are less suitable as power amplifier, preamplifier or in-line amplifier in lightwave systems due to their narrow bandwidth. But this characteristic is advantageous in coherent and multichannel communication systems.

2.1.4.3 Brillouin Fiber Lasers

The Brillouin gain can be used for operating a Brillouin fiber laser. Such devices are often made as fiber ring lasers. Due to low resonator loss, they can have a relatively low pump threshold and a very small linewidth. The Brillouin Pump is injected into the ring cavity and then Photonic Crystal Fiber via the circulator to generate the backward propagating Stokes light at opposite direction. However, since the PCF length is not sufficient enough, the back-scattered light due to Rayleigh scattering is relatively higher than the Stokes light. Both back-scattered pump and the Stokes lights are amplified by the bi-directionally pumped Bi-EDF (Bismuth-based erbium-doped fiber) and oscillate in the ring cavity to generate dual-wavelength laser. However, the nonlinear gain by both PCF and Bi-EDF only amplifies the Stokes light and thus the Stokes light is more dominant and laser is generated at the Stokes wavelength [24].Optical isolators are used to block the Brillouin pump from oscillating in the cavity and also to ensure a unidirectional operation of the BFL. PC is used to control the birefringence of the ring cavity so that the power of the generated laser can be controlled.

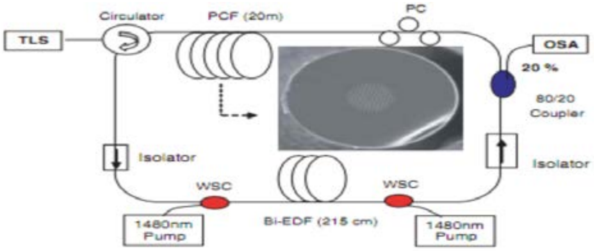

Figure 6: Configuration of the PCF-based BFL; TLS, WSC, OSA, PC stands for tunable-laser source, wavelength selective couplers, optical spectrum analyzer, polarization controller, respectively [25].

2.1.4.4 Pulse Delaying and Advancement

The stimulated Brillouin scattering process is helpful in controlling the group velocity of an optical pulse as it travels along fiber. The changes in group index of 10-3 in several kilometer length of fiber have been achieved experimentally. This leads to pulse delaying and advancement in the range of tens of nanoseconds [26]. These group delay changes can be obtained in conventionally used optical fibers.

2.1.4.5 Beam Combiner

Stimulated Brillouin scattering (SBS) can be exploited in passive combination of multiple beams in a fiber. This method may be helpful in increasing the brightness of array of fiber amplifiers. Four off-axis beams are combined in a long multimode optical fiber using a novel all-optical mount. The beam that comes out has spatial coherence properties of LP01 mode. By using off-axis pumps, the threshold of SBS can be raised several times in comparison to on-axis pump beams.

2.1.4.6 Pipeline Buckling Detection

A distributed Brillouin fiber sensor can be used to detect localized pipe-wall buckling in an energy pipe with internal pressure, concentric load, and bending load by measuring the longitudinal and hoop strain distributions. A localized pipe-wall buckling takes place away from the middle of the pipe. The locations of such buckling are found and distinguished using strain load data.

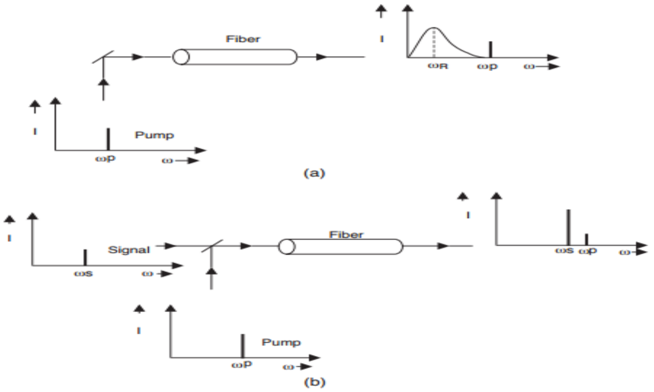

Figure 7: (a) Spontaneous Raman scattering phenomenon. (b) Stimulated Raman scattering phenomenon [26].

2.2 Stimulated Raman Scattering

Stimulated Raman scattering was discovered by Raman in 1928 thus it is known as Raman Effect. Stimulated Raman Scattering is an important nonlinear process as it can severely limit the performance of multichannel lightwave system. On the other hand by carefully monitoring this process can turn optical fibers into broadband Raman amplifiers and tunable Raman lasers.

During Stimulated Raman scattering, small fraction of power is transferred from one optical field to another whose frequency is shifted down. Near the right end, a significant part of the power is shifted into longer-wavelength components by stimulated Raman.

The incident light acts as a pump and generates the frequency shifted radiation called Stokes waves.

For intense pump fields Stokes wave grows rapidly inside the medium such that most of the pump energy is transferred to it.

It transfers some of the photons to new frequencies. The scattered photons may lose energy (Stokes shift) or gain energy (anti-Stokes shift). If the pump beam is linearly polarized, the polarization of scattered photon may be the same (parallel scattering) or orthogonal (perpendicular scattering) [27].

It can be described quantum mechanically as scattering of a photon of energy hwp by a molecule to a lower-frequency photon with energy hws, as the molecule makes transition to a vibrational state.

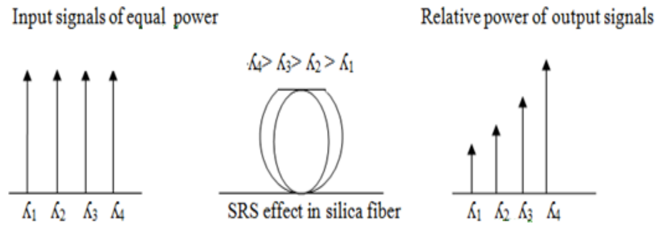

Figure 8: SRS transfers optical power from shorter wavelengths to longer wavelengths.

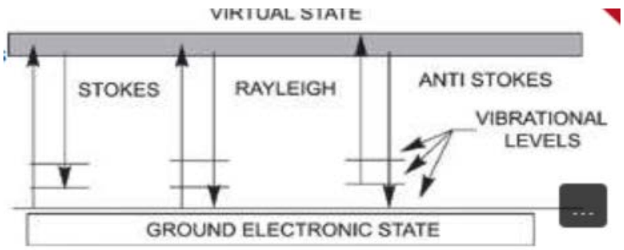

Figure 9: Schematic illustration of scattered photons lose energy (Stokes shift) or gain energy (anti-Stokes shift) [27].

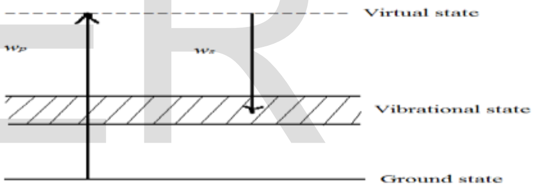

Figure 10: Schematic illustration of spontaneous Raman Scattering from a quantum-mechanical viewpoint. A photon of reduced energy hws is created spontaneously after a pump photon of energy hwp excites the molecule to a virtual state (shown as dashed lines) [28].

2.2.1 Raman-Gain Spectrum

The initial growth of the stokes wave is given by

$\frac{dls}{dz} = gRIPIS$ … [28]

Where Is is the Stokes intensity, Ip is the pump intensity, and the Raman-gain coefficient gR.

When a probe beam is introduced in the optical fiber, it will be amplified because of the Raman gain and as the Raman scattering generates photons within the entire bandwidth of the Raman-gain spectrum, all frequency components are amplified especially gR. When the pump power exceeds a threshold value gR builds up almost exponentially.

As a result, SRS leads to generation of the Stokes wave whose frequency is determined by the peak of the Raman gain.

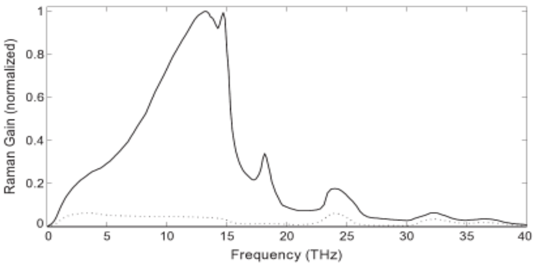

Figure 11: Normalized Raman gain when pump and stokes waves are copolarized and dotted line shows the situation when pump amd stokes waves are orthogonally polarized [28].

2.2.2 Raman Threshold

The pump power does not remain constant along the fiber and also fiber losses are to be considered when talking about Raman threshold thus it is governed by set of two coupled equation:

$$\frac{dIs}{dz} = gRIpIs - \alpha sIs,$$

Where αs and αp account for fiber losses at the Stokes and pump frequencies, respectively.

$$\frac{dIp}{dz} = -\frac{\omega p}{\omega s} gRIpIs - \alpha pIp,$$

One can readily verify that in the absence of losses,

$$\frac{d}{dz}\left(\frac{Is}{\omega s} + \frac{Ip}{\omega p}\right) = 0.$$

Integrating the equation over whole range of the Raman-gain spectrum.

$$Ps\ (L) = \int_{-\infty}^{\infty} h\omega \exp\left[gR(\omega p - \omega)IoLeff - \alpha sL\right]d\omega$$

Assuming $\alpha s \approx \alpha p$ the threshold condition becomes

Peff exp(gRP0Leff/Aeff)= P0,

Assuming a Lorentzian shape for the Raman-gain spectrum, the critical pump power, to a good approximation, is given by

$$\frac{gR\ P\ Leff}{Aeff} \approx 16 \quad \ldots [28]$$

A similar analysis can be carried out for the backward SRS. The threshold condition in that case is still given by the above Equation but the numerical factor 16 is replaced with 20.

2.2.3 Techniques for controlling the SRS Threshold

An additional amount of power is needed at the receiver to maintain the system as the nonlinear effect results in signal impairment. Given below are some methods employed to control the SRS threshold.

Presence of dispersion reduces the SRS penalty. In presence of dispersion, signals in different channels travel at different velocities and hence reducing chances of overlap between pulses propagating at different wavelengths [29].

By decreasing channel spacing SRS penalty can be reduced.

The power level should be kept below threshold level which requires the reduction in distance between amplifiers. The SRS imposed limitations on the maximum transmit power per channel.

2.2.4 Raman- Induced Crosstalk

The same Raman gain that is beneficial for making fiber amplifiers and lasers is also detrimental to WDM systems. The reason is that a short-wavelength channel can act as a pump for longer-wavelength channels and thus transfer part of the pulse energy to neighboring channels. This leads to Raman-induced crosstalk among channels that can affect the system performance considerably.

The two-channel system with the short-wavelength channel acts as a pump. The power transfer between the two channels is governed by equations that can be solved analytically if the fiber loss is assumed to be the same for both channels (αS-αP), an assumption easily justified for typical channel spacings near 1.55 μm. The association reduction in the short-wavelength channel power is obtained from the pump-depletion factor.

$$Dp = \frac{Ip\,(L)}{Ip\,(0)\exp(\alpha pL)} = \frac{1+ro}{1+roG} \qquad \ldots [30]$$

The power penalty can be written as (in decibels)
ΔR =10 log(1/DP)

2.2.5 Applications of SRS Phenomenon

The SRS process is considered in many applications, which includes,

2.2.5.1 Raman fiber lasers

Fiber based Raman lasers are developed by employing the SRS phenomenon. The partially reflecting mirrors M1 and M2 form a Febry-Perot cavity. Inside the cavity a piece of single mode fiber is placed in which SRS process occurs due wavelength-selective feedback for the Stokes light. This results in intense output. The spatial dispersion of various Stokes wavelengths allows tuning of the laser wavelength through an intracavity prism. The Raman amplification during a round trip should be as large as to compensate the cavity losses, and this determines the Raman threshold power. Higher-order Stokes wavelengths are generated inside the fiber at high pump powers. Again these wavelengths are dispersed spatially by the intra-cavity prism in association with separate mirrors for each Stokes beam. Such kind of Raman laser can be operated at several wavelengths simultaneously.

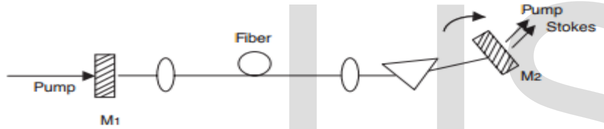

Figure 12: Schematic representation of a tunable Raman laser [31].

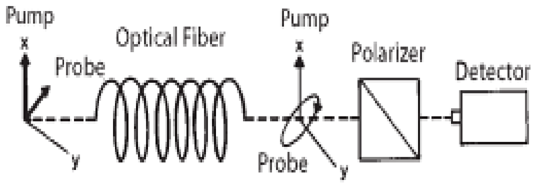

Figure 13: Schematic of a high-power all-fiber Raman laser.

2.2.5.2 Raman Fiber Amplifiers

The SRS phenomenon may be applied to provide optical amplification within optical fibers. The SRS process in fiber causes energy transfer from the pump to the signal. The Raman amplification may occur at any wavelength as long as appropriate pump laser is available. There are three basic components of Raman amplifier: pump laser, wavelength selective coupler and fiber gain medium. A schematic diagram is shown in Figure. Raman amplification exhibits advantages of self phase matching and broad gain-bandwidth which is advantageous in wavelength division multiplexed systems.

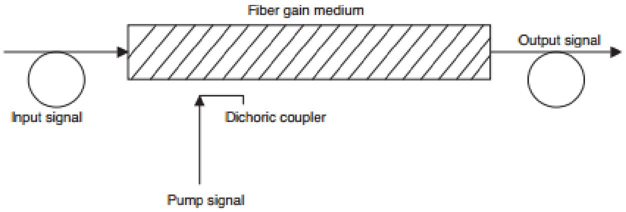

Figure 14: Schematic of Raman fiber amplifier [31].

Raman amplification may be realized as a continuous amplification along the fiber which let the signal never to become too low. Raman amplifier is bidirectional in nature and more stable.

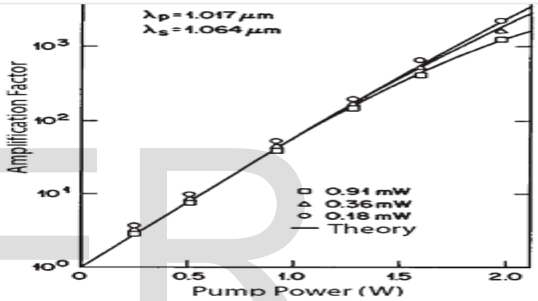

Figure 15: Variation of amplifier gain GA with the pump power P0. Different symbols show the experimental data for three values of input signal power. Solid curves show the theoretical prediction using gR=9.2*10-14 m/W [32].

2.2.6 Demerits of Stimulated Raman scattering

Raman gain introduces interchannel crosstalk in WDM systems.

Crosstalk can be reduced by lowering channel powers but it limits the number of channels.

Merits of Stimulated Raman scattering

Raman amplifiers are a boon for WDM systems as it can be used in the entire 1300–1650 nm range whereas EDFA bandwidth limited to ~40 nm near 1550 nm.

Distributed nature of Raman amplification lowers noise [33].

3. Comparison of Stimulated Raman and Stimulated Brillouin scattering

Sr. no.	Parameter	Stimulated Raman Scattering	Stimulated Brillouin Scattering
1	Originating Factor	The Raman scattering is result of individual molecular motion.	The Brillouin scattering occurs due to Bragg type scattering from propagating acoustic wave, i.e., bulk motion of large number of molecules are involved.
2	Threshold power	The threshold power is high in SRS as compared to SBS.	The threshold power level for SBS is quite low [34], i.e., 1 mW for a CW pump.
3	Propagation direction	SRS can occur in both directions, i.e., forward and backward.	The SBS occurs only in backward direction [35].
4	Stokes Shift	For SRS, Stokes shift is of higher order of magnitude.	The Stokes shift is smaller by 3 orders [36]of magnitude for SBS.
5	Material Disorder	The strength of Raman scattering is independent of the disorder of the material.	Brillouin scattering depends on the disorder of the material.
6	Gain Bandwidth	Raman gain bandwidth occurs over a broad range of frequencies.	The Brillouin gain bandwidth is extremely narrow.

4. CONCLUSION

Scattering phenomenon and its various types are discussed. Normally scattering phenomenon put limitation on optical systems. Fiber nonlinearities are feared by telecom system designers because they can affect system performance adversely. But with suitable system arrangement they can be exploited in many applications. . Fiber nonlinearities can be managed thorough proper system design. Typical threshold power for SBS is about 1.3 mW while for SRS, it is about 570 mW. The typical value of channel power in optical systems is below 10 mW. Therefore, SRS is not a limiting factor for single-channel lightwave systems while SBS puts limitations on such systems. When it is properly under control it can be enormously useful; but on other occasions it can intrude, disturb and degrade. Nonlinear effects are useful for many device and system applications: optical switching, soliton formation, wavelength conversion, broadband amplification, demultiplexing, etc. New kinds of fibers have been developed for enhancing nonlinear effects.

References

1.Gerald Farrell," Optical Communications Systems", Attenuation in optical fibers".

2. Govind P.Agrawal, Nonlinear fiber optics, fourth edition.

3. Min Zhong, "Light scattering by small particles", 2010.

4. P Chakrabarti,"Optical fiber communication", irregularities (Senior, 2008).

5. Dr. B.G.Potter," Attenuation in optical fibers", Module 3.

6. Alden, Princeton University, "The Rayleigh criterion", lecture 7, 2002.

7. Integrated publishing, "Introduction to fiber optis".

8. P Chakrabarti,"Optical fiber communication", irregularities (Senior, 2008).

9. Dirk Samiec," Distributed fiber optics temperature and strain measurement with extremely high spatial resolution".

10. Module 4, Signal distortion on optical fibers-Attenuation.

11. Djafar K. Mynbaev and Lowell L. Scheiner, "Fiber-optic communication technology".

12. Gerd Keiser,"Optical fiber communication", edition four, 428-432.

13. R. H. Stolen and A. Ashkin, "Optical Kerr effect in glass waveguide", Appl. Phys. Lett. 22, 294 (1973)

14. S.P. Singh, R. Gangwar and N Singh," Nonlinear scattering effects in optical fiber", Progress in electromagnetic research, PIER 74, 401, 2007.

15. S.P. Singh, R. Gangwar and N Singh," Nonlinear scattering effects in optical fiber", Progress in electromagnetic research, PIER 74, 379-405, 2007.

16. Gerd Keiser,"Optical fiber communication", edition four, 428-432.

17. S.Shahi and S.W.Harun, "Brillouin fiber laser with significant reduced gain medium length operating in L-Band region", Progress in electromagnetic Research letters, vol.8, 143-149, 2009.

18. Ming-jun Li, "Managing nonlinearity in optical fiber for high-power lasers"

19. R. W. Tkach, A. R. Chraplyvy, and R. M. Derosier, Electron. Lett. 22, 1011. , 1986.

20. G. P.Agrawal, "Nonlinear fiber optics", edition 4, chapter 9.

21. Govind P.Agrawal, "Nonlinear effects in optical fiber", ©2006.

22. J. Botineau, E. Picholle, and D. Bahloul, Electron. Lett. 31, 2032 , 1995.

23. N. A. Olsson and J. P.van der Ziel, Appl. Phys. Lett. 48, 1329 (1986).

24. S.P.Smith, F.Zarinetchi, and S. Ezekiel, Opt. Lett. 16, 393, 1991.

25. Progress in electromagnetic research letters, vol. 8, 2009.

26. S.P. Singh, R. Gangwar and N Singh, "Nonlinear scattering effects in optical fiber", Progress in electromagnetic research, PIER 74, 388, 2007.

27. Raman Spectroscopy, ANDOR (an Oxford Instruments company).

28. Govind P.Agrawal," Nonlinear fiber optics", Fourth edition.

29. S.P. Singh, R. Gangwar and N Singh, "Nonlinear scattering effects in optical fiber", Progress in electromagnetic research, PIER 74, 398-399, 2007.

30. Govind P.Agrawal," Nonlinear fiber optics", fourth edition.

31. S.P. Singh, R. Gangwar and N Singh, "Nonlinear scattering effects in optical fiber", Progress in electromagnetic research, PIER 74, 2007.

32. Govind P.Agrawal," Nonlinear fiber optics", fourth edition.

33. Govind P.Agrawal ,"Nonlinear fiber optics and its applications in optical signal processing",

34. G. P.Agrawal, Nonlinear fiber optics, fourth edition, chapter 9.

35. Rahul Umesh Kale, Pavan Mahadeo Ingale, Rameshwar Tukaram Murade,"Comparison of SRS & SBS (Non Linear Scattering) In Optical Fiber", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-1, March 2013.
36. G. P.Agrawal, Nonlinear fiber optics, edition 4, chapter 9.

Harmanjeet Singh Parmar, Persuing Electronics and Communications Engineering from Guru Nanak Dev University, Amritsar, Punjab, India, Gmail id- hjsp1994@gmail.com
ER. Nimarjit Kaur, Persued Electronics and Communications Engineering from Khalsa College of Engineering and Technology, Amritsar, Punjab, India, Gmail id- kaur1992nimar@gmail.com