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REVIEW ON COMPARATIVE STUDY OF KERR EFFECT ON OPTICAL WDM NETWORK

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ABSTRACT

Non-Linear effects are continually the main degrading sources that occur in nonlinear optical material like photonic switch, glass fiber cable. Such interaction between waves causes interaction between channels. FWM (Four Wave Mixing) is one of the degrading factors in WDM (Wavelength Division Multiplexing) optical network along with different fiber non-linearity. SPM (Self-Phase Modulation) may be non-linear result of light-matter interaction. XPM (Cross Phase Modulation) are the main degrading factor in WDM optical network that causes cross talk and make the system least effective. Due to that it is necessary to investigate the impact of FWM, SPM and XPM on the planning and performance of WDM optical network. This paper describe the different types of non-linear impact supported first effect like self-phase modulation, cross-phase modulation and four wave mixing. Their applications and comparative study is also discussed.

Keywords: Cross-phase modulation, Four-wave mixing, Self-phase modulation, Kerr effect, Wavelength division multiplexing (WDM).

I. INTRODUCTION

The key objective is to check the fiber Kerr non-linear effects on optical fiber communication systems. One ancient approach to boost the system performance of WDM systems is to optimize the system parameters by reducing the non-linear interference from alternative channels. Three dominating non-linear effects in present WDM systems are Cross phase modulation (XPM), Self-phase modulation (SPM) and Four-wave mixing. Their effects on WDM systems are completely studied.

The term linear and non-linear (Figure 1), in optics, mean intensity-independent and intensity-dependent phenomena respectively. When optical fibers ar handling little power then the state of fiber is thought as linear and once there is increase in power then the glass fiber is vulnerable to non-linear effects [2]. Non-linear effects in optical fibers (Table 1) occur because of modification within the refractive index of the medium either optical intensity and inelastic scattering phenomenon. The ability dependence of the index of refraction is to blame for the Kerr effect. Depend upon the sort of input signal, the Kerr non-linearity manifests itself in 3 completely different effects such as Self-phase modulation (SPM), Cross phase modulation (XPM) and Four-wave mixing (FWM). At high power level, the inelastic scattering development will induce excited effects like excited Brillouin scattering (SBS) and excited Raman scattering (SRS). The intensity of scattered light weight grows exponentially if the incident power exceeds a precise threshold price. The distinction between Brillouin

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scattering (SBS) and excited Raman scattering (SRS) is that the Brillouin generated phonons (acoustic) square measure coherent and provides rise to large wave in the fiber, whereas in Raman scattering the phonons (optical) square measure incoherent and no large wave is generated.

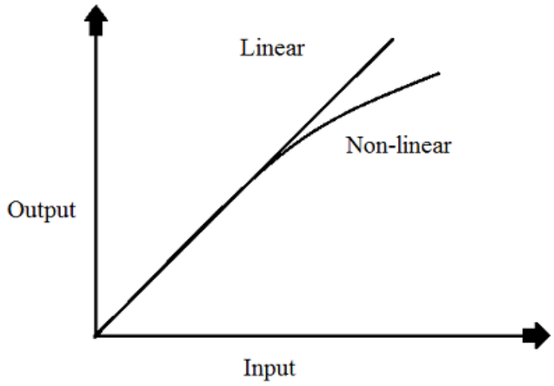

Figure (1) Linear and Non-linear interaction [2]

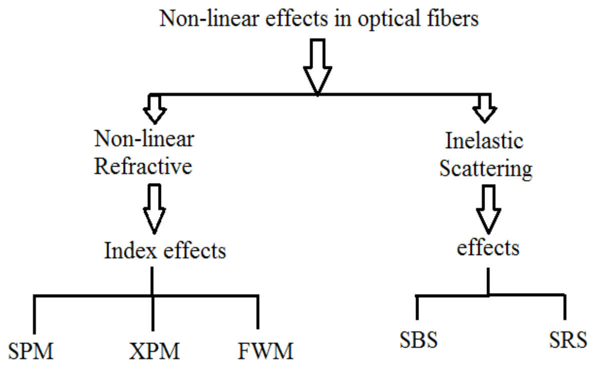

Table (1) Non-linear effects in optical fiber [2]

1.1. Non-linear Refraction:

The lowest order nonlinear effects in optical fibers originates from the third order susceptibility χ(3), that is answerable for phenomena like third harmonic generation, four-wave mixture, and nonlinear refraction. Unless special efforts square measured created to realize phase matching, the nonlinear processes that involve generation of recent frequencies (e.g. third-harmonic generation and four-wave mixing) are not economical in optical fibers. Most of the nonlinear effects in optical fibers thus originates from nonlinear refraction, a development referring to the intensity dependence of the index of reflection. In its simplest type, the index of reflection are often written as [3]

$$\tilde{n}(\omega,[E^2]) = n(\omega) + n_2[E^2]$$

1.1.1 Stimulated Inelastic Scattering:

The nonlinear effects ruled by the third-order susceptibleness χ(3) square measure elastic in the sense that no energy is changed between the magnetic force field and the nonconductor medium. A second category of nonlinear effects results from stimulated inelastic scattering in which the optical field transfer a part of its

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energy to the nonlinear medium. Two stimulated nonlinear effects in optical fiber fall in this category; each of them square measured associated with vibrational excitation modes of silica. These phenomena, called stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS), were among the primary nonlinear effects studied in optical fiber. The main difference between the two is that optical phonons participate in SRS whereas acoustic phonons participate in SBS [2].

1.1.2 Kerr Effect:

When an electrical field is applied across associate degree optical medium, the distribution of electrons among is distorted so the polarizability and thus the refractive index of the medium changes anisotropically. The modification within the ratio as a function of the applied field are often expressed as

$$\Delta\left(\frac{1}{n^2}\right) = rE + \rho E^2 \qquad (1)$$

Where r is the electro optic constant port p is the quadratic optic coefficient. In solids, the linear variation within the ratio related to initial term in eqn (1) is thought because the pockel impact whereas the variation arising fromthe quadratic term is termed as Kerr effect. Such solid when placed in an electrical field behave as uniaxial crystal with the axis parallel to the electric field. Behave as uniaxial crystal with the axis parallel to the electric field. Kerr impact was discovered by J Kerr in 1875 and in a very convenient kind, the modification with in the refractive index is expressed being proportional to the square of the electrical field as expressed by eqn (1). The difference in refractive indices of light polarized parallel and perpendicular to the induced axis is given by [3]

$$\Delta n = K\lambda E^2 \qquad (2)$$

Where λ is the wavelength of the light, K is the Kerr constant and E is that the strength of the electrical field. This distinction in index of refraction causes the material to act like a wave plate once light is incident on it in a very direction perpendicular to the electrical field. If the material is placed between two “crossed” (perpendicular) linear polarizers, no light are transmitted once the electrical field is turned off, whereas nearly all of the light are transmitted for a few optimum price of the electrical field. Higher values of the Kerr constant enable complete transmission to be achieved with a smaller applied field of force [3].

II. WAVE DIVISION MULTIPLEXING (WDM):

Wavelength Division Multiplexing (WDM) is that the basic technology of optical networking. It's a method for using a fiber (or optical device) to hold several separate and independent optical channels. The principle is similar to that used when we tune our receiver to 1 of the many TV-channels. Every channel is transmitted at a distinct radiofrequency and that we choose between them using a "tuner" that is just a electric circuit inside the receiving system. After all wave-length in the optical world is simply the manner we decide to see frequency and optical WDM is kind of similar to radio FDM. Another way of envisaging WDM is to contemplate that every channel consists of light of a distinct color. Thus a WDM system transmits a "rainbow". Really at the wavelengths involved the light is invisible however it is a great way of describing the principle [5].

- **What is WDM ?**

WDM is that the basic technology of optical networking. It is technique foe employing a fiber (or optical device) to hold many separate independent optical channel

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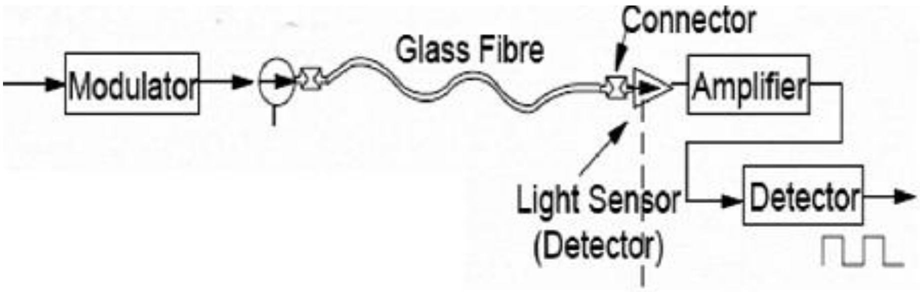

Fig 3. Overview of WDM [9]

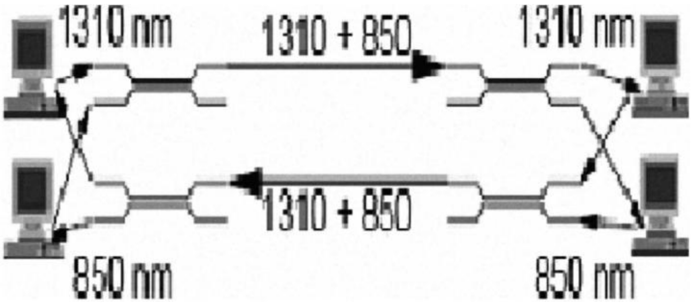

Fig 4. Use of Wavelength [9]

WDM is of many types. An easy kind will be made using 1310 nm joined wavelength and 1550 as the different or 850 and 1310. This Kind of WDM are often built using comparatively easy and inexpensive parts and some application are operational for variety of years using this principle. Dense WDM however is another factor. Dense WDM refers to the close spacing of channels. To some, a series of WDM channels spaced at 3.6 nm apart qualifies for the outline. Others use the term to distinguish systems wherever the wavelength spacing is 1 nm per channel or less. WDM is that the basic technology for full optical networking [9].

- **Simple WDM:**

Wavelength selective couplers are used each to combine (multiplex) and to separate (De-multiplex) the signals. The distinguishing characteristic here is that the very wide separation of wavelength used (different bands instead of totally different wavelengths within the same band). There are several variations around on this very straightforward theme. Some systems use a single fiber bi-directionally whereas others use separate fibers for each directions. Different systems use completely different wavelength bands. The most common systems run at very low information rates (by today's standards). Common application areas are in video transport for security observance and in process control.

- **Dense WDM**

Transmitters **Reciever**

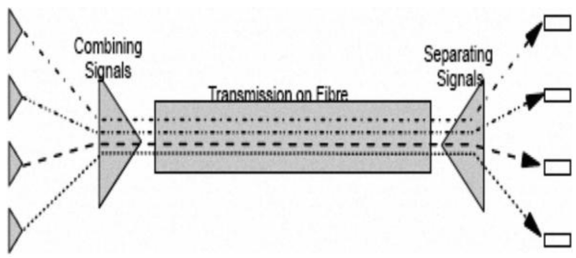

Fig 5 .Dense WDM [9]

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Figure shows the function needed to make an easy dense WDM shared optical link. Every optical channel is allocated its own wavelength or rather vary of wavelengths. A typical optical channel may be 1 nm wide. This channel is actually a wavelength vary inside that the signal should keep. It's usually much wider than the signal itself. The dimension of a channel depends on several things such as the modulated line dimension of the transmitter, its stability and the tolerances of the opposite components within the system.

III. CROSS PHASE MODULATION (XPM):

High power optical amplifier and dispersion management change increased length of inter-amplifier spans in multi-channel high bit-rate transmission system. The bit-rate distance product is restricted by the combined effects of fiber dispersion and nonlinear effects as a result of the high launched power into the fiber [4]. In the dispersion fiber, the combined effects of self-phase modulation (SPM), cross-phase modulation (XPM) and four-wave mixing (FWM) have an effect on the transmission performance. Phase-modulation due to XPM has important influence on a WDM systems because it affects channel over a continuous wavelength vary and is regenerate into distortion by residual dispersion. Only very little work has been done investigation the XPM induced pulse distortion consistently in dependence of a large vary of parameters. A symbol at wavelength λk experiences a nonlinear section shift depending upon the optical power at completely different wavelength. For a WDM system consisting of M channels the total nonlinear section shift Δϕk NL of the considered channel k is (factor a pair of parallel polarization.

$$\Delta\phi_k^{NL} = \gamma \cdot L_{eff} \cdot \left(P_k + 2 \cdot \sum_{i \neq k}^{M} P_i \right) \quad (2)$$

The first contribution during this expression Δϕk NL is a result of SPM looking on the ability of the detected channel alone. The summation takes into consideration XPM arising from the optical power within the neighboring channels whenever the integrated power within the fiber is relevant for the entire phase shift. Amplitude modulation of the pump channels ends up in phase modulation Δϕ(t) of the probe channel as a result of XPM. This nonlinear frequency chirp is regenerate into amplitude fluctuation in an exceedingly dispersive fiber. The impact of XPM also depends on the wavelength separation between the signal channel and also the neighboring channel. If the channel area unit separated wide, then the XPM effects are relatively weak as a result of the 2 bit stream walk-off from one another quickly. In case of the DWDM systems, the channels wavelength separation is narrow that ends up in strong XPM impact. Since XPM ends up in a lay channel noise, its effect, to some extent, and also depends on the bit pattern of the 2 channels.

3.1 Applications of XPM:

(a) OPTICAL SWITCHING:

Phase shift, in an optical pulse, as a result of CPM development may be used for optical shift. To require advantage of CPM-induced phase shift for ultra-fast optical shift several interferometric strategies have been used [7]. Think about a measuring system designed in such a way that a weak signal pulse, divided equally between its two arms, experiences identical part shifts in every arm and is transmitted through constructive interference. Once a pump pulse at totally different wavelength is injected into one among the arms, it'll modification the signal phase through CPM development therein arm. If the CPM-induced phase shift is large (close to π), this much phase shift leads to destructive interference and therefore no transmission of signal pulse. Thus an intense pump pulse will switch the signal pulse.

(b) PULSE COMPRESSION:

Like SPM induced frequency chirp, the CPM induced frequency chirp can also be used for pulse compression. The SPM techniques need the input pulse to be intense and energetic, however the CPM is in a position to compress even weak input pulses as a result of co-propagating intense pump pulse produces the frequency chirp. The CPM induced chirp is plagued by pulse walk-off and depends critically on the initial relative pump signal delay. As a result the use of CPM induced pulse compression needs a careful management of the pump pulse parameters like its dimension, peak power, wavelength and initial delay relative to the signal pulse.

Table 2. Comparison of nonlinear refractive effects

Nonlinear phenomenon ► Characteristics ▼	**SPM**	**XPM**	**FWM**
1. Bit-rate	Dependent	Dependent	Independent
2. Origin	Nonlinear susceptibility x^3	Nonlinear susceptibility x^3	Nonlinear susceptibility x^3
3. Effect of x^3	Phase shift due to pulse itself only.	Phase shift alone due to co-propagating signals	New waves are generated
4.Shape of broadening	Symmetrical	Symmetrical	-------
5.Energy transfer between medium and optical pulse	NO	NO	NO
6. Channel spacing	NO effect	Increases on decreasing the spacing.	Increases on decreasing the spacing.

IV. COMPARISON OF VARIOUS NONLINEAR EFFECTS

Different nonlinear effects supported Kerr-effect are compared in Table 2. The parameters taken are bit-rate, origin, effects of third-order susceptibility, form of broadening, energy transfer between medium and optical pulse and result of channel spacing [2].

V. CONCLUSION

This paper gives an idea on designing a wavelength converter and its performance analysis using Cross Phase Modulation technique at different bit rates. Also, this paper enlightens the comparative study of different

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modulation technique and merits of XPM instead of OEC, XGM and four waves mixing. XPM is a new, simple and robust technique used in wavelength conversion. In future long-span, high-channel-count wavelength division- multiplexed systems, cross-phase modulation will be one of the most severe obstacles to error free transmission.

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