Some Investigations with Optical Fiber Nonlinearity

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Abstract— This manuscript explored performance evaluation with proposed fiber optic link for the key fiber nonlinearities, as Stimulated Brillouin Scattering and Stimulated Raman Scattering. Numerical simulations have shown higher output optical power accomplished for both scatter type of fiber nonlinearities, assumed to be not there. Whereas smaller amount of output optical power has been detected at the receiver end in the presence of the scatter based nonlinearities. Both of these effects have been realized with numerical simulations and demonstrated in the results. From the executions, it is presumed that, although stimulated Brillouin scatter is curse for long haul communication but can be applied to realize a distributed fiber optic sensor for the local temperature, strain and vibration over a certain fiber length.

Keywords- Stimulated Brillouin scattering (SBS); stimulated Raman scattering (SRS); Fiber optic communication (FOC); Brillouin scattering (BS);

Introduction

Communication is an indispensable need with contemporary world. For that numerous techniques evolved since olden days. Each of the schemes upcoming agreed with fulfillment of needs of human aspire of specific era. Along with growth of mankind and development of novel internet based applications there is crunch of bandwidth. Accordingly upcoming access communication networks used microwave links as the media access. Though for processing of the radio frequency signals to be transmitted with huge bandwidth. Moreover in traditional communication media attenuation rises swiftly for the augment in signal frequency. Conversely, fiber optic domain has evolved as the tremendous alternative along with its rich attributes. In which radio frequency modulated optical carrier could be modulated, transmitted and distributed with least loss. Thus a hybrid system provides good synergy in between radio and optics. However the optical fiber domain is highly nonlinear. In the optical fibers nonlinear scattering effects are caused by the inelastic scattering of a photon with a lesser energy photon. There is absorption of energy difference by phonons in the medium or the molecular vibrations. That is energy of a light wave signal is transported to other light wave. That is at a high wavelength or lower energy in such way that difference of energy emerges in the form of phonons [1-3].

An additional wave is referred to as the Stokes wave and can be regarded as pump wave signal. Evidently, high-energy photon is regarded as anti-Stokes frequency and could be produced if the phonon of right momentum and energy is accessible. Accordingly, the two key nonlinear scattering phenomenons in optical fiber are interrelated to vibrational excitation modes of silica fiber [4-12]. The two scatter based phenomenon referred to as Stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS). In between SBS and SRS basic difference is that, the optical phonons contribute in SRS, whereas in the SBS it occurs through the acoustic phonons. The Brillouin scattering in optical fiber illustrates the interaction with photon (an electro-magnetic field) with a characteristic density variation of the optical fiber. For the electric field amplitude of an optical beam, called as the pump wave signal and other wave launched at the downshifted Brillouin frequency named as the Stokes Wave. The beating in between the Pump and Stokes waves generates a customized density variation by means of the electrostriction outcome. Resultant is the stimulated Brillouin scattering. Though scattering may be in any direction in the bulk systems, in the light guiding structures for instance resonators or waveguides, optical fibers, the pump and Stokes fields (i.e., scattering) are either or counter-propagating (i.e., backward scattering) or co-propagating (i.e., forward scattering).The SBS effect arises in only one direction i.e., backward whereas the SRS effect is a bidirectional phenomenon, occurs in both directions that is in forward and backward directions [4-11.For the silica optical fibers, if the pump wave (at 1550 nm band) and Stokes fields are counter-propagating the acoustic frequency is 11 GHz. For Stokes and the pump wave co propagating and its range is from MHz to a few GHz. There is great interest in SBS owing to its fundamental physics and potential functions for instance Brillouin laser with ultra-narrow line width [12-16], nonreciprocal light propagation [17-18], slow and fast light generation [19-20], and microwave photonics [21-22], Brillouin opto-mechanics [23-24].

Accordingly, so many performance evaluations have been executed by sincere investigators on this track but still they lack on certain constraints. So, there is wide scope to unearth the side which is uncovered. In this sight, this article proposes the link for the investigation of the nonlinear effects presents with optical fiber and with key design parameters to optimize the links performance. The manuscript is organized in the way, begin with introduction, followed with the design presentation, results and discussion and conclusions.

The proposed design and theoretical presentation

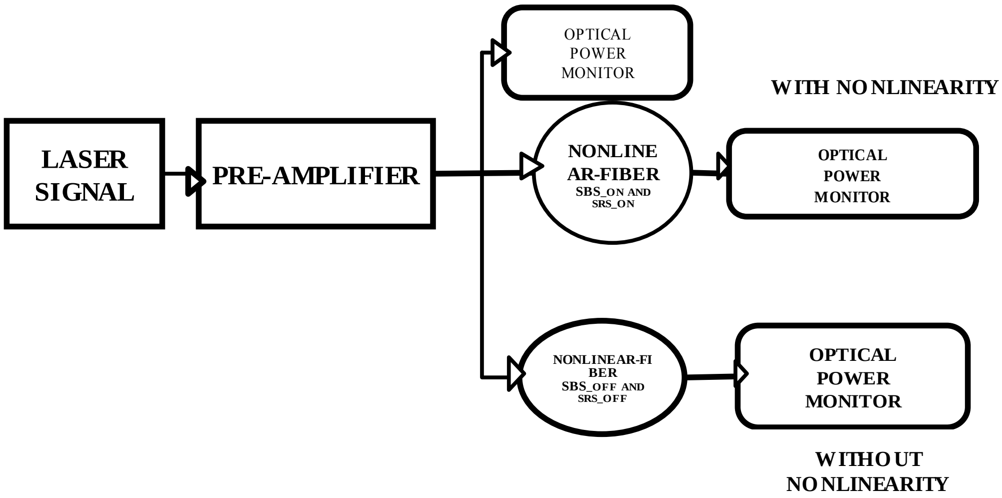

Figure 1. The proposed schematic

The proposed schematic is illustrated in the Figure1. In order to generate the laser signal of wave length 1.55E-6 with desired the laser output power is produced by the continuous wave laser. The CW laser signal is with RIN of -150dB/HZ, signal with time sequence and time steps as 1e-10/2^5 second, 12 as number of samples. The generated light wave signal is allowed to go through the optical pre amplifier as Erbium doped fiber amplifier with defined saturation power that is Psat. The pre amplifier is Erbium doped fiber amplifier, used to optically amplify the generated signal. Now the light wave signal is allowed to go through the nonlinear optical fiber paths with defined fiber length trunk(40km), with loss 0.25dB/km, refractive index as 2.6e-20 m^2/W, fiber diameter as 8.2e-6m,effective area as 1.425,. In one of the arms fiber nonlinearities is kept ON. For instance stimulated Brillouin Scattering, Raman scattering is ON and in other arms both nonlinearities are kept OFF, Subsequently, an optical power monitor is used to monitor the effect of nonlinearities.

The Brillouin scattering is a nonlinear practice which may arise in the optical fibers with higher light intensity. On account of the electric field also referred to as known as pump field the Higher intensity creates compression in the core of optical fiber by the practice electrostriction [3]. It generates density-oscillations in fiber medium and augments the material disorder. As a consequence modulates the linear refractive index of medium and outcome with an electrostrictive-nonlinearity [6]. There is modulation of the refractive index acts as an index grating that is pump-induced. The pump light scattering through Bragg diffraction through the pump induced index grating is referred to as Brillouin scattering (BS). With this time dependent muddle, there is shift in (Brillouin shift) in frequency due to scattered light by the frequency of the sound wave. There is no spatial overlap in between the pulse and acoustic wave for pulses smaller than 500 ps.It Results in insignificant electrostrictive nonlinearity [7].There as inelastic scattering with Raman scattering effect [3] of a photon through an optical phonon. It begins from materials fixed time response of the third order nonlinear polarization [25] .For propagation of the monochromatic light beam through an optical fiber, spontaneous Raman scattering occurs. It shifts few of the photons to at new frequencies. It is possible that scattered photons drop in energy, called as Stokes shift or anti-Stokes shift (gain energy). For the presence of photons at other frequencies then the scattering probability of to those frequencies is augmented. With stimulated Raman scattering (SRS), a concurrent photon at the downshifted frequency accept a gain. This Raman scattering attribute is exercised in the Raman Amplifiers for optical signal amplification.

Results and Discussion

In the modern era there is growing interest towards has development of long-reach fiber optical communication systems to attain larger spacing of repeaters. But with hike in bit rate and length of transmission, wavelengths, optical power level there is muck rise in of nonlinear fiber effects. Accordingly, proposed link has been designed to observe the effect of the significant nonlinearities and its performance evaluated effectively. For that the generated light wave signal before transmission is passed through the pre amplifier. That is through an optical amplifier and the output waveform is shown in the Figure2. Numerical simulations have been executed and as illustrated ion the Figures3-7.

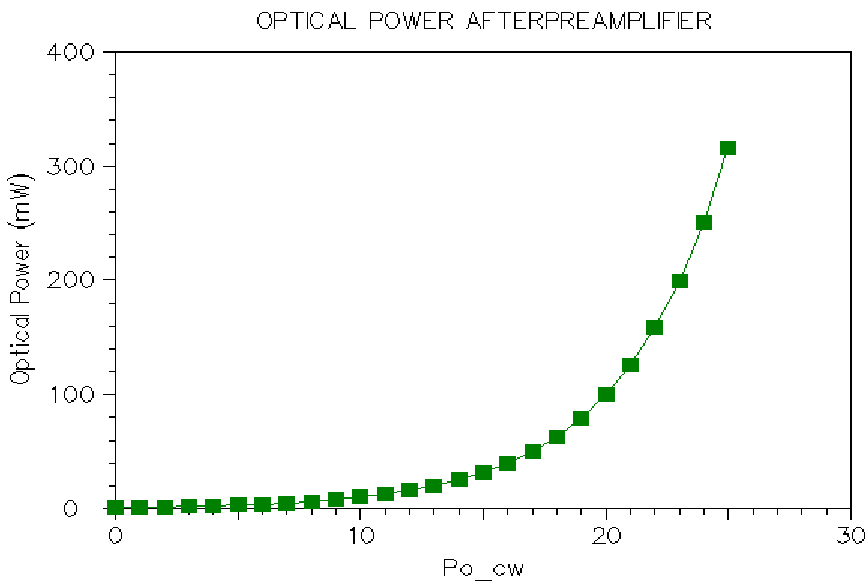

Figure2. Laser power vs. output optical power vs. data rate for SBS OFF after pre amplifier

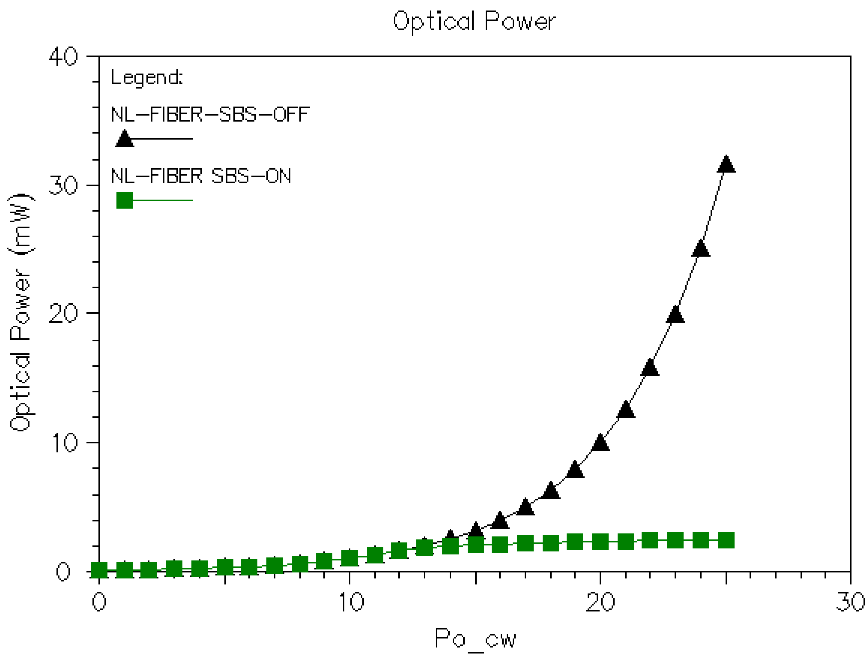

Figure3. Laser power vs. output optical power

Simulations of the designed link for the transmitted optical power through the nonlinear optical fiber under SBS ON, SBS OFF condition and its outcome as against the Erbium doped fiber amplifier saturation power is illustrated in the Figure3. It depicts that under SBS OFF state the output optical power is higher (more than 30mw) as compared to SBS_ON state condition.

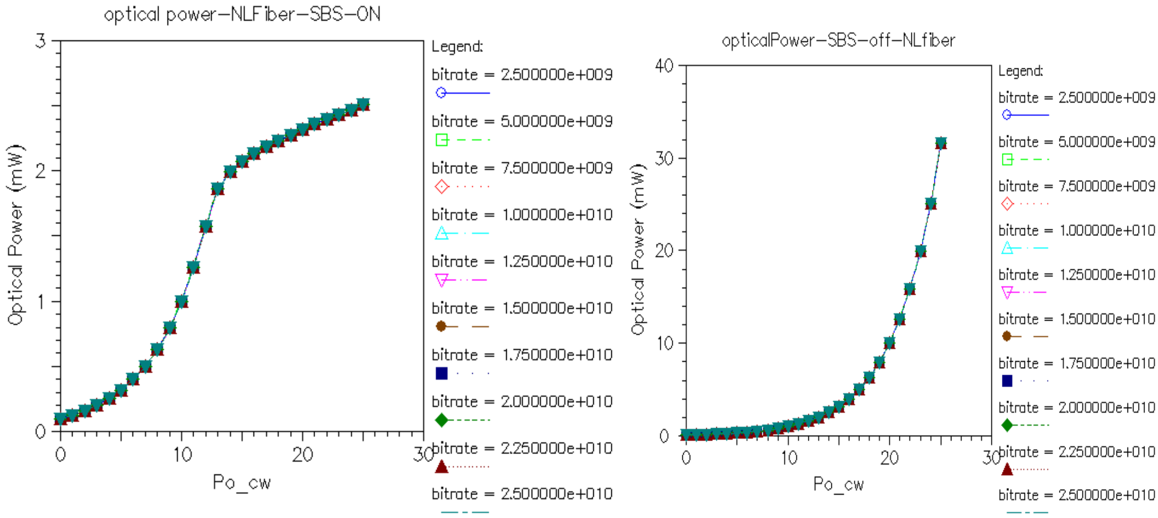

Figure4. Laser power vs. output optical power vs. data rate for SBS _OFF

Figure 4 illustrates performance evaluations for the EDFA saturation power vs. the bit rate and the output optical power under the Stimulated Brillouin scattering ON state and OFF state. Evaluated results depict that with increase of the data rate and saturation power of the EDFA the output optical power goes down for the nonlinearity ON condition and output optical power is higher for the OFF state of nonlinearity.

Figure 5 illustrates the evaluation for the hybrid nonlinearities SBS plus SRS on state and under off state under, as against the preamplifier EDFA saturation power. Results depict that when both nonlinearities or in the ON state the output optical power is lower as compared to under environment with both SBS plus SRS ON state

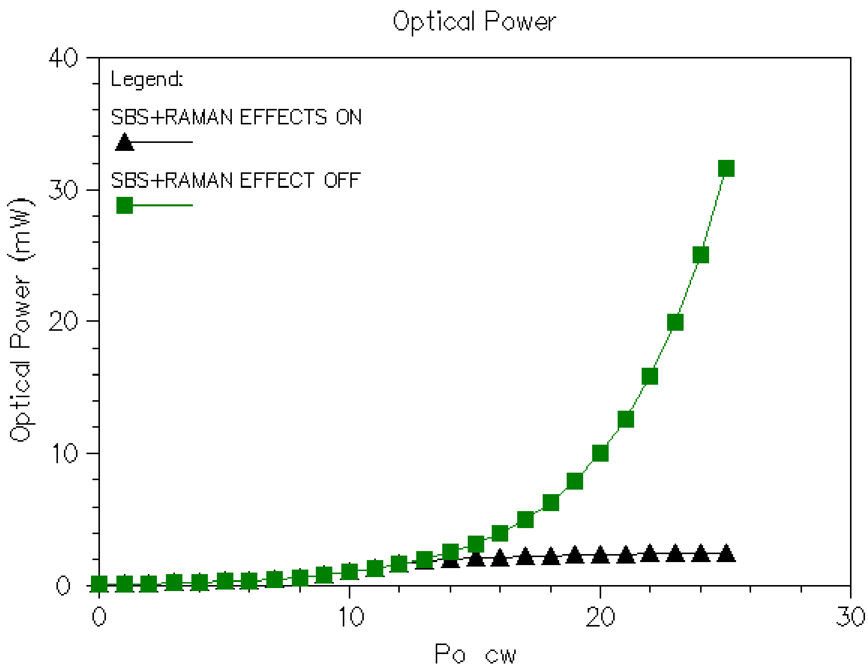

Figure5. Laser power vs. output optical power vs. data rate for SBS OFF

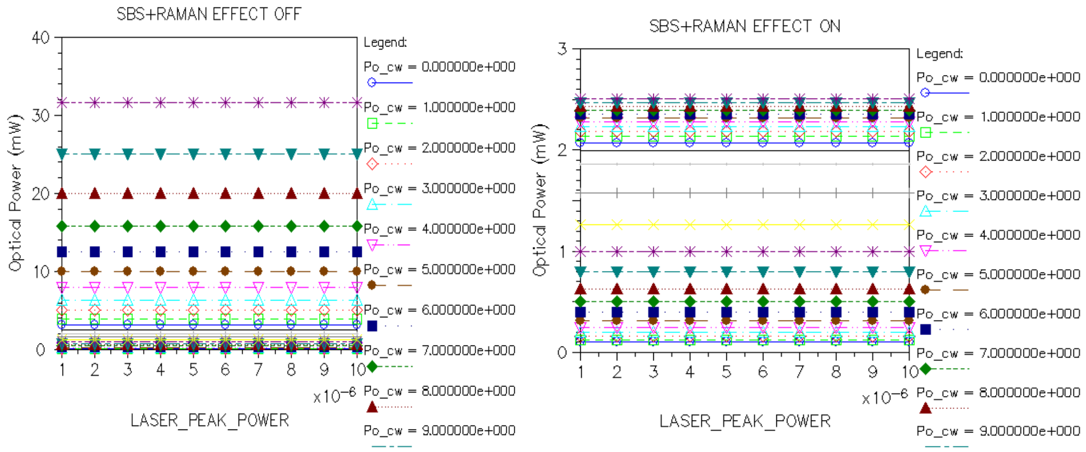

Figure6. Laser power vs. output optical power vs. data rate for SBS+SRS OFF and ON state

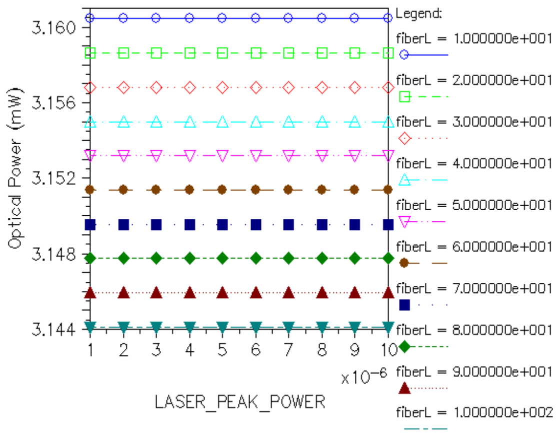

Figure7. Output optical power vs laser peak power vs. fiber length

The transmitted laser power is also one of the vital parameter .For that numerical evaluations of the laser peak power vs. the EDFA saturation power and the output optical power has been shown in the Figure6(a-b) when both nonlinearities SBS, SRS are not effective. It shows higher optical power that is more than 30mw of output optical power. Whereas with both effects ON state simulation is shown in figure. It depicts the optimum optical power of 2.5mw under both nonlinearities ON state. Figure 7 shows simulation for the transmitted laser peak power vs. the fiber length and the output optical power. It depicts the under o state nonlinearities the output optical power is lower.

However the nonlinearities are bifurcated into several categories. The first one category includes the nonlinear inelastic scattering practices for instance, Stimulated Raman Scattering (SRS) and Stimulated Brillouin Scattering (SBS). Another class of nonlinear effects is due to intensity-dependent alterations in the refractive index with optical fiber. It generates Cross Phase Modulation (XPM), Four Wave Mixing (FWM) and Self-Phase Modulation (SPM), [26].In response optical fiber nonlinearities stimulates noise in, produce distortions along with surplus attenuation of the transmitted optical signal. Therefore worsens systems performance, amongst Stimulated Brillion scattering is basic nonlinear optical process in fiber optic communication (FOC) systems owing to its short power threshold [27]. SBS is a more significant in fiber optical communication as it diminishes strength of signal by directing most segment of the transmitted light signal backward to the transmitter and in effect enhances attenuation, distortion and noise into both the backscattered and transmitted light. Consequently there is power loss of the transmitted wave [27-29].

Conclusions

The proposed link has been designed to investigate nonlinearities in optical fiber. Its Performance evaluations have been executed successfully for the elected link parameters. A simulation with nonlinearities (SBS and SRS) with and without has been executed for the trunk of nonlinear optical fiber of length of 40Km. It is concluded that with nonlinearity the received output optical power is lower .While the received output optical power is higher without the nonlinearity. Usually both phenomenon put restriction on the optical communication systems. However for a single channel light wave link SRS is not a limiting factor though SBS plants restrictions on such optical systems. In the upcoming era it is presumed that the SBS effect could be applied to deign fiber based sensors.

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