A REVIEW OF OPTICAL WAVE APPLICATION IN WIRELESS SIGNAL PROPAGATION

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Abstract

Optical wave communication systems have emerged as the forefront technology within the communication industry. Since the introduction of optical signal transmission, this method has gained immense significance. Its prominence in the communication sector stems from its remarkable speed and capacity to transmit significantly larger volumes of data compared to conventional copper-based transmission mediums. While copper transmission exhibits a propensity for carrying extensive communication data, it falls short in comparison to fiber optics or optical communication. This research aims to delve into the realm of optical communication systems. Over time, it has been observed that the optical means of signal transmission encounter issues attributable to optical or Rayleigh scattering. These scattering phenomena tend to impact the effectiveness of optical transmission. Nevertheless, this study involves an evaluation of optical power, as well as optical dispersions and compensations, seeking to address these concerns

KEYWORDS: Optical Amplifier, Communication, Transmitting, Fiber Optics, Signals

I. Introduction

Fiber optic communication stands out as an exceptionally swift method for transmitting telecommunication data. To address the attenuation issues caused by long-distance transmission, optical repeaters have been widely employed in enhancing optical transmissions. The primary concern regarding optical transmission is signal attenuation, where signals experience reductions in intensity as they traverse the optical fiber. This attenuation stems from factors like light scattering in the fiber, influenced by the fiber's material or bending conditions. Researchers have made significant strides in mitigating optical attenuation, introducing various optical amplifiers like Semiconductor Optical Amplifiers and Raman Optical Amplifiers [1]. The surging demand for telecommunication capacity has prompted the adoption of Wavelength Division Multiplexing (WDM), enabling the multiplexing of multiple optical carrier signals onto a single fiber using distinct wavelengths of laser light [2].

Lasers have been pivotal in optical communication, finding utility in diverse communication applications. Initially employed in space communications in the 1960s, lasers were acknowledged for their potential in transferring data at exceptionally high rates. However, it became evident that specific enhancements were essential in component performance and systems engineering, particularly for space-qualified hardware. Subsequent advancements in system architecture, data formatting, and component technology spanning three decades have rendered laser communications in space not only feasible but also appealing for inter-satellite link applications [3]. The data rates and information throughput achievable through laser communications substantially exceed those attainable through radio frequency (RF) systems.

II. Literature Review

As per [3], the primary objective of their study was to pinpoint the most efficient amplifier for transmission while identifying the predominant degradation factors affecting transmission distances. Raman-EDFA emerged as the top-performing amplifier among those investigated. The primary limiting factor for transmission was the noise produced by the amplifiers, notably more pronounced in the case of the SOA. In systems employing discrete Raman amplifiers, inter-channel crosstalk acted as the chief inhibitor, attributed to the Four Wave Mixing nonlinear effect. The variation in accumulated inter-channel crosstalk is primarily linked to differences in signal intensity at the amplifier output [3].

Conversely, the nonlinear response of the semiconductor optical amplifier, combined with its small effective area and high nonlinear coefficient, significantly impacted transmission quality, constraining the achievable link length. Adjustments to the SOA parameters were made to enhance amplification while minimizing signal distortions [3].

The study adopted the Dense Wavelength Division Multiplexing (DWDM) technique, widely favored in high-speed communications. DWDM operates as a multi-carrier system, multiplexing diverse carriers onto a single fiber, allowing signals at distinct frequencies within the fiber and maximizing bandwidth utilization. Meeting the surging bandwidth demands necessitates extensive bandwidth capacity, while service providers grapple with fiber exhaustion in their networks [3][7]. Integrating various technologies economically into a single physical infrastructure poses a significant challenge for carriers. DWDM emerges as an optimal solution addressing these challenges. This paper aims to evaluate amplifier effectiveness within a DWDM transmission system, with simulations conducted using Optisim ver.5.3.

According to [20], their study primarily centered on employing optical amplifiers within a multichannel wavelength division multiplexing (WDM) optical communication system and network. The investigation aimed to enhance transmission distances and amplify signals within extensive bandwidth optical networks by optimizing optical amplifiers. The performance of diverse optical amplifiers was assessed based on transmission distance and frequency [5]. Various configurations of optical amplifiers were experimented and simulated to scrutinize their behavior. Findings indicated that with a lower number of channels, SOA exhibited superior outcomes. However, as the number of channels increased, SOA's performance deteriorated due to induced non-linearity. To mitigate this issue, the RAMAN amplifier emerged as a more viable alternative. Further optimization of the RAMAN amplifier involved varying parameters such as Raman fiber length, Raman pump wavelength, Raman pump power, EDFA noise figure, and EDFA output power. Using this optimized optical amplifier, maximum single-span distances were achieved for various dispersions [8][13].

The simulated system was analyzed using three different amplifiers (EDFA, Raman, and SOA amplifier) to enhance received power across all optical networks. These amplifiers are instrumental in amplifying the total power in optical communication systems and contribute to error reduction while offering power equalization capabilities [6]. The conclusions drawn from the comparison and analysis of the three system simulation results are as follows: the received power in the optical network using the basic optical amplifier was notably high, significantly greater than -29.324dBm (received power without amplification). When applying EDFA, Raman, and SOA and comparing their output power, the power output of EDFA and Raman amplifiers increased initially, but after a certain length, it stabilized. On the other hand, the SOA amplifier exhibited markedly superior output power (SOA at 11.811dBm, EDFA at -10.697dBm, and Raman at -26.424dBm). However, as the length increased, the output power of the SOA steadily declined. When altering input frequencies from 193.1 to 193.4 THz, the SOA amplifier outperformed the EDFA and Raman amplifiers.

In line with [1], the escalating demand for high-bandwidth and high-data-rate communication systems while ensuring information integrity has led to the prevalent preference for optical communication systems. Over long distances, optical amplifiers like Erbium-doped fiber amplifier (EDFA), Semiconductor Optical amplifier (SOA), Raman Amplifier, and Parametric Amplifier are extensively used at the receiver end. Analyzing these amplifier parameters is critical to enhancing performance in specific optical communication applications [14]. Additionally, the receiver-side pumping scheme stands as a promising option for 'last-mile' transmission. This paper evaluates the Erbium-doped fiber amplifier's performance in the L-band range of 1520-1610 nm, focusing on parameters such as bit rate, bit error rate, fiber length, Signal to Noise ratio (SNR), Q-factor, gain, Noise figure using optsim5.0 software. The aim is to optimize receiver signals at higher bit rates and showcase the impact of parameter variations on system performance, aiming for efficient optical communication [17].

Moreover, as per [12], the research delved into investigating and analyzing the performance of radio frequency (RF) signals transmitted over optical fiber for wireless communication systems. Factors such as bit rate, bit error rate (BER), quotient factor (Q-factor), signal strength, and transmission length were scrutinized. The transmission of RF signals over optical fiber was executed utilizing the direct Intensity Modulation – Direct Detection (IMDD) technique. Simulations encompassed bit rates within the 0.5Gbit/s to 15Gbit/s range and transmission lengths of 30km, 50km, and 70km. The outcomes indicated that increasing bit rates for a fixed length of optical fiber corresponded to higher minimum bit error rates (BER) and reduced maximum Q-factor. Furthermore, longer optical fiber lengths resulted in decreased maximum Q-factor and eye height [18]. Hence, it's advisable to effectively convey RF signals with lower bandwidth (0.5 - 5Gbit/s) over shorter distances using direct intensity modulation. For higher bandwidths (above 5Gbit/s), feasible transport is attainable within design limits, yet incorporating a regenerator (repeater) at periodic intervals (at least every 50km) along the optical fiber is advisable [19]. The utilization of the Optiwave System as a simulation tool was found beneficial for software implementation to generate BER patterns for the direct IMDD technique [16].

In their study, [3] proposed a sixteen-channel dense wavelength division multiplexing (DWDM) optical transmission system employing semiconductor optical amplifiers (SOAs) to counteract signal attenuation in optical communication. Three techniques—pre-SOA, post (booster)-SOA, and In-line SOA—were modeled, analyzed, and compared for their performance in addressing attenuation effects within the DWDM system [19]. The system, designed for a 10Gbps network using non-return-to-zero (NRZ) modulation format, included a 14km dispersion compensation fiber (DCF) and a 70km single-mode fiber (SMF), simulated using Optisystem7.0. The performance was evaluated in terms of eye diagrams, Q-factor, and bit error rate (BER) by varying the input power (mw) parameter of the CW laser source, with In-line SOA amplifiers exhibiting the most effective attenuation compensation [9].

Their paper extensively evaluated the performance of a 16×10Gbps DWDM optical transmission system utilizing different semiconductor optical amplifiers (pre-SOA, booster-SOA, and In-line-SOA). Performance parameters were assessed across the designed 84km optical link, focusing on eye-diagrams, BER, and Q-factor variation based on input power (mW). The study compared the performance of each channel using various SOA topologies and found that the optimized In-line SOA amplifier topology outperformed pre- and booster amplifiers, exhibiting superior Q-factor and lower BER. These proposed techniques could be applied in complex optical transmission systems with a larger number of channels to mitigate attenuation complexities [10].

As per [2], it was noted that an analytical method for understanding noise in semiconductor optical amplifiers (SOAs) has not been established. [13] highlighted the challenge of introducing quantized optical fields with Langevin noise sources in the open waveguide of SOAs, given that these devices lack facet mirrors to confine the optical field. An approach was introduced to define the finite size of photons based on quantum mechanical properties of spontaneous emission, defining longitudinal modes for the traveling optical field and the generated spontaneous emission [14]. Subsequently, the intensity (IM) noise, frequency (FM) noise, and spectral linewidth were theoretically calculated, with the characteristics of this noise experimentally confirmed.

Moreover, [2] analyzed the intensity and frequency noise of semiconductor optical amplifiers (SOAs) in their research. They introduced an important feature—incorporating amplified spontaneous emission (ASE) by defining the longitudinal mode even in open boundary waveguides, considering intrinsic quantum mechanical properties of spontaneous emission. Relative intensity noise (RIN) increased with low input optical power but reduced with higher power due to a lower amplification rate for noise compared to CW light. Frequency (FM) noise exhibited a minimal increase in the low-frequency region but rapidly increased in the high-frequency region. Additionally, the spectral linewidth did not increase with amplification, as confirmed experimentally [5][16][11].

Research Gap of the Study

Haven gone through several research works, it was observed that the authors have done an intensive work in the areas of optical communication. However, this research work will be reviewing the optical means of wireless signal propagation.

III. Method

1. Optical Wave (Laser) Analysis

When exposed to a laser beam, the target material undergoes a sequential heating process, transitioning from room temperature to the melting point. Based on laser intensity and material characteristics, the molten portion is subsequently vaporized upon reaching the vaporization point, leading to the formation of a vapor-filled cavity (Figure 1). At the interface between the molten state and the vapor, there exists a thin Knudsen layer where the state variables undergo abrupt changes.

Once the incident laser intensity surpasses a specific threshold, the resulting vaporization culminates in plasma creation, absorbing a fraction of the laser energy. Higher intensities lead to denser plasmas with increased absorption rates. Introducing an assisting gas jet disperses the plasma plume laterally, reducing plasma density; however, residual plasma effects remain [20]. A corrective coefficient is incorporated into the laser intensity model to address these plasma effects. The model disregards molten material motion due to the Marangoni effect.

The energy balance governing equation, accounting for heat diffusivity (α), density (ρ), axial distance (x), and radial distance (r), is formulated. Material enthalpy, representing the total heat content, comprises sensible heat ($h = cpT$, where cp is heat capacity and T is temperature) and latent heat (ΔH). This ΔH varies with L_mv, the latent heat for melting, or remains zero. This enthalpy formulation enables tracking the melting boundary over time without recalculating the grids. At the melt–vapor interface, the Stefan boundary condition is employed [21].

$$\frac{\partial h}{\partial t}+\frac{\partial \Delta H}{\partial t}=\frac{\partial}{\partial x}\left(\frac{\partial h}{\partial x}\right)+\frac{1}{r}\frac{\partial}{\partial r}\left(r\alpha\frac{\partial h}{\partial r}\right)$$
(3.1)

$$Q+K\left(\frac{\partial T}{\partial x}+\frac{\partial T}{\partial r}\right)+p_i v_i L_v-p_v V_v\left(c_p T_i+E_v\right)=0$$
(3.2)

$$E_v=\frac{RT_v}{(\gamma-1)M_v}+\frac{1}{2}v_v^2$$
(3.3)

$$Q=C(1-Rl)I(t)\exp\left(-\frac{\gamma^2}{b^2}\right)\exp(-\beta x)$$
(3.4)

Q, the laser heat flux, relies on reflectivity (Rl), absorptivity (β), and the plasma correction coefficient (C). Laser intensity, I, a function of time, associates with the laser beam radius (b). Subscripts denote liquid (l), vapor (v), and vapor–liquid interface (i). Gas energy (Ev) accounts for internal and kinetic energy, with parameters including heat conductivity (k), velocity (v), universal gas constant (R), specific heat ratio (), latent heat of vaporization (Lv), and molecular mass (Mv).

Heat and energy fluxes, laser intensity, and heat conduction flux align along the cavity profile's normal direction. The vapor–liquid boundary is identified by temperature tracing. Grid points exceeding vaporization temperature signify the gas phase, initiating calculations from the updated vapor–liquid boundary. A photodiode sensor captures real-time laser intensity distribution. During simulation, I(t) adopts coefficients. For pure copper at a certain wavelength, this process accurately models laser-material interactions.λ=0.355 μm, n = 1.34, and k =1.93, the absorption coefficient is given by

$$\beta=\frac{4\pi k}{\lambda}$$
(3.5)

Illustrated in figure 3.1 is a singular transmission channel of a DWDM semiconductor optical amplifier. This setup multiplexes 6 channels, passing through the DCF module and ultimately amplified by an enhanced optical amplifier.

The basic diagram of the optical communication system is shown in the figure

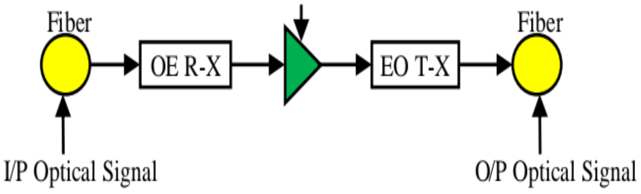

Fig 1 Basic Principle of Optical Communication systems [4]

2. Evaluation of Optical Dispersion Compensation

Supervising dispersion is crucial in the design of optical DWDM transmission systems because dispersion can hinder the performance of longer optical transmission links due to fiber nonlinearity. To mitigate this, dispersion compensation fiber (DCF) serves as a widely used technique. It involves a specialized single mode fiber designed to counteract the adverse effects of dispersion, enhancing the overall transmission quality of optical fiber. DCF effectively compensates for group velocity dispersion (GVD) and minimizes nonlinear effects within the fiber, particularly when optical power levels are kept low. The pulse propagation equation governing the optical signal passing through segments of SMF and DCF over a transmission distance L can be expressed as follows:

$$V(L,t)=\frac{1}{2\pi}\int_{-\infty}^{\infty} L \quad p\left(\frac{i}{2}\beta\omega^2 I=i\omega t\right)d\omega$$
(3.6)

In this equation, I represents the Fourier transform of the pulse amplitude V(0,t), while β denotes the parameter associated with group velocity dispersion (GVD), a measure related to dispersion effects. The deterioration of the optical signal caused by dispersion is attributed to the phase component $\exp\left(\frac{i}{2}\beta\omega^2 I\right)$, acquired by the signal as it traverses the optical fiber. If the lengths of the two fiber segments, L_SMF and L_DCF, correspond to the single mode fiber (SMF) and dispersion compensation fiber (DCF) respectively, then according to Equation (3.6):

$$V(L,t)=\frac{1}{2\pi}\int_{-\infty}^{\infty} I \qquad p\left(\frac{i}{2}\omega^2\begin{pmatrix}\beta_{SMF}L_{SMF}\\ \beta_{DCF}L_{DCF}\end{pmatrix}-i\omega t\right)d\omega$$
(3.7)

In this scenario, the total length of the fiber segments is represented as L = L_SMF + L_DCF, where β_SMF and β_DCF signify the GVD parameters for fiber lengths L_SMF and L_DCF, respectively. When selecting DCF, the ω2 term vanishes, allowing the original pulse shape to be restored. Hence, the ideal condition for dispersion compensation using DCF can be expressed as:

$$\beta_{SMF}L_{SMF}+\beta_{DCF}L_{DCF}=0$$
(3.8)

$$D_{SMF}L_{SMF} + D_{DCF}L_{DCF} = 0$$
(3.9)

$$D = \frac{2\pi c}{\lambda^2}\beta$$
(3.10)

In the context of single mode fiber (SMF), where DSMF > 0, Equation (3.10) indicates that the dispersion coefficient DCF (in ps/nm.km) of the dispersion compensation fiber (DCF) needs to be negative for effective dispersion compensation at a specific wavelength λ in nm. Additionally, the length L_DCF (in km) of the DCF must adhere to the following condition:

$$L_{DCF} = -L_{SMF}(D_{SMF}/D_{DCF})$$
(3.11)

Further, to overcome remaining dispersion in very high speed optical transmission systems, the dispersion slop SDCF of DCF must be satisfy as:

$$S_{DCF} = S\left(\frac{D_{SMF}}{D_{DCF}}\right) = L_{DCF} = S_{SMF}(D_{DCF}/D_{SMF})$$ [21]:
(3.12)

In the equation, SSMF represents the dispersion slope of the single-mode fiber (SMF). As per the analysis, the dispersion compensation fiber (DCF) offers extensive bandwidth performance, greater stability, and minimal sensitivity to temperature fluctuations. Hence, DCF emerges as the most suitable method for addressing dispersion issues. Consequently, the physical configuration of SMF and DCF can be positioned in three different manners within an optical DWDM transmission system: for dispersion pre-compensation, post-compensation, and symmetrical compensation.

3. Optical Power Amplifier

Moving to the discussion on optical power amplifiers, the material gain within the active region can be characterized by a complex refractive index. If we consider the real part of the refractive index of the active region as n_a, the material group index as n_{ag}^M , the group index of the waveguide optical mode as n_g, the material gain as g, and the mode confinement factor as F_a, then the alteration in the propagation vector (Δβ) of the waveguide optical mode due to gain in the active region can be described using waveguide perturbation theory.

$$\Delta\beta = \frac{\omega}{c}F_a\left(\frac{n_g}{n_{ag}^M}\right)\Delta n_a = -iF_a\left(\frac{n_g}{n_{ag}^M}\right)\frac{g}{2} = -iF_a\frac{\tilde{g}}{2}$$
(3.13)

Where,

$$\tilde{g} = \left(\frac{n_g}{n_{ag}^M}\right)g$$
(3.14)

With the introduction of gain, the light field's amplitude will progressively grow over distance, expressed by $e^{F_a\widetilde{(g/2)}z}$, and the optical power will similarly increase as $F_a\tilde{g}P(z)$. This parameter, $F_a\tilde{g}$, is termed the modal gain. If we denote P(z) as the optical power measured in units of energy per second, a straightforward equation can be formulated to depict the rise in optical power concerning distance of optical power with distance,

$$\frac{dP(z)}{dz} = F_a\tilde{g}P(z)$$
(3.15)

A time dependent form of the above equation for power propagating in the +z-direction will be,

$$\left[\frac{\partial}{\partial z} + \frac{1}{v_g}\frac{\partial}{\partial t}\right]P(z,t) = F_a g\widetilde{P(z,}t)$$
(3.16)

As the optical signal strengthens within the waveguide and the pace of stimulated emission accelerates accordingly, the carrier density within the active region undergoes alterations, deviating from its state in the absence of an optical signal within the waveguide. In the subsequent section, we will elaborate on the rate equations concerning the carrier density in the active region.

4. Determining Optical Power

It's necessary to establish a relationship between the photon density, represented by p_n, inside the active region and the optical power denoted as P. The mode confinement factor reflects the ratio of the average mode energy density within the active region (measured in energy per unit length) to the overall average mode energy density W (measured in energy per unit length) throughout the entire waveguide [21].

$$P = v_g W$$
(3.17)

The effective area A_{eff} of the optical mode is defined by the relation,

$$A_{eff} = \frac{A_a}{F_a}$$
(3.18)

Definition of the photon in the active region can be written as

$$n_p = \frac{P}{h\omega v_g A_{eff}}$$
(3.19)

IV. Optical Wave Discussion

1. Principle of Optical Wave Amplifier

Atoms exist solely in discrete energy states, transitioning between these states through absorption and emission of light. These transitions involve the energy difference (E) between higher energy state (E2) and lower energy state (E1) [30]. When an atom encounters photon energy (E), it can elevate to higher energy state (E2) through photon absorption, shown as absorption in the figure. As the atom in energy state (E2) isn't stable, it randomly returns to a lower energy state, emitting a photon; this process is known as spontaneous emission [14]. Optical amplification utilizes stimulated emission, akin to laser operation [29]. Stimulated emission occurs when an incident photon (with energy E = hv/ λ) interacts with an electron in the upper energy state, causing its return to the lower state and generating a second photon. Light amplification happens when the incident and emitted photons are in phase, releasing two additional photons [22]. Achieving optical amplification necessitates a population inversion, wherein the upper energy level's population (N2) surpasses that of the lower level (N1); this can be attained by exciting electrons to higher energy levels using an external source called pumping [12].

2. Security Challenges in Optical Network Management

Managing optical networks encounters extra security hurdles due to the use of transparent optical components in communication systems. Noteworthy aspects encompass [18]: i. Establishing a robust and adaptable optical control plane to manage network resources, provisioning, and sustaining connections across multiple control domains. ii. With larger transparent domains, physical limitations on connectivity and transmission become progressively concerning for the optical control plane. iii. Addressing security concerns arising from the unique behavior of fiber transmission mediums and transparent optical components. iv. Agreeing upon expert techniques and monitoring methods for measuring optical parameters. v. Specifying a comprehensive synthesis of optical parameters and attributes applicable in an appropriate management information model for AONs. vi. Devising suitable functionalities to manage the distinct features and requirements posed by AONs, considering network and system scalability, as well as interoperability among different vendors' equipment and components.

One of AONs' key promises lies in establishing a robust and adaptable optical control plane to handle network resources, connections, and provisioning across multiple control domains [11]. This control plane should select light paths for requested end-to-end connections, allocate wavelengths to these paths, and configure suitable optical resources in the network. Furthermore, managing multiple data links between core OXCs efficiently uses a single out-of-band control channel rather than managing them individually [25][26]. However, efficient connection provisioning goes beyond advertising available wavelengths and routes; it involves considering additional information about supported light paths' characteristics and performance measurements [17]. Therefore, combining Routing and Wavelength Assignment (RWA) with performance data shared among network elements allows simultaneous assessment of all connections [24][27]. This underscores the need to enhance routing protocols to update and advertise attributes and parameters essential for computing routes for requested connections and pre-computing corresponding restoration paths [28].

To meet this criterion, understanding the transmission impacts linked to the unique behaviors of diverse transmission links and transparent optical components is imperative not only during network design but also in continuous monitoring during regular operation due to the following reasons [15]: i. The transparency within AONs can introduce significant diverse transmission impairments, which, when accumulated, may adversely affect signal quality, potentially lowering the Quality of Service (QoS) without entirely obstructing all network services. ii. Malicious users can exploit vulnerabilities in AONs, executing service disruption attacks despite meticulous network design. iii. An attack erroneously identified as a failure can swiftly propagate throughout the network, potentially leading to inappropriate action by the Network Management System (NMS) if the attack types and locations remain unidentified.

3. Six Transmission Channel Optical Signal

Illustrated in Figure 2 is a 6-channel DWDM enhanced optical amplification system. The outcome showcases signals from the initial to the final channel, each operating within different bandwidths [21], ranging from 100 GHz to 600 GHz. The system demonstrates its capability to concurrently transmit six distinct optical signals utilizing DWDM multiplexing and de-multiplexing. These signals traverse the dispersion coefficient system and are subsequently amplified by an enhanced semiconductor optical amplifier [21]. The results further affirm that this semiconductor optical amplifier compensates for optical losses incurred by conventional amplifiers, utilizing its robust amplifying capacity to cover a distance of 154 km.

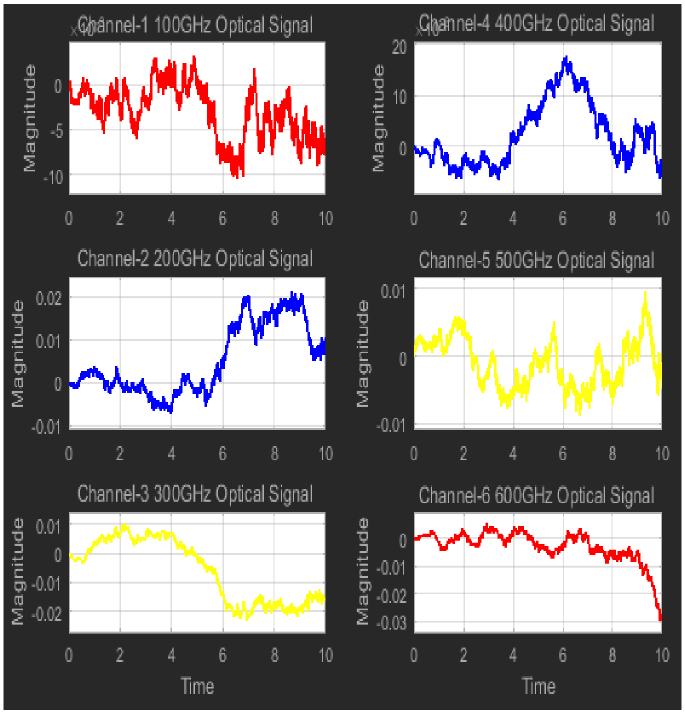

Fig 2 six channel optical signal [21]

4. Diminished Optical Signal Propagation in the Channel

While optical signals traverse the single-mode fiber optic channel, their intensity tends to diminish, attributed to various factors [21,22]. These factors encompass bending losses, Rayleigh scattering, or inadequate optical amplification, among others. As depicted in Figure 3, the results visibly illustrate the deterioration of the optical signal over time, primarily attributed to insufficient optical amplification [21].

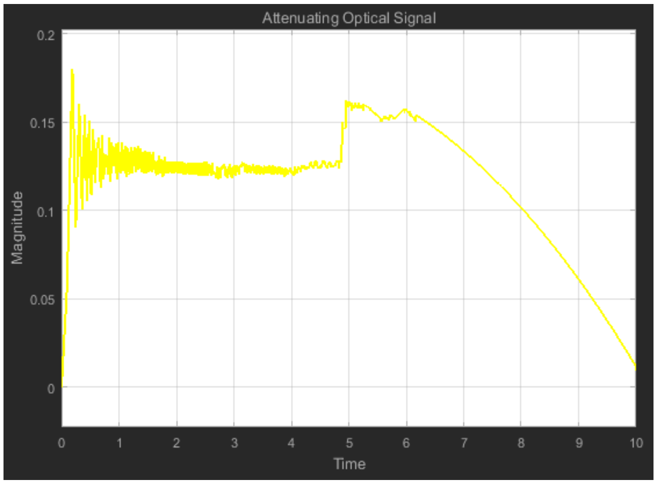

Fig 3 attenuating optical signal [21]

5. Comparative Results of Different Optical Amplifiers

Figure 4 distinctly demonstrates that among the showcased optical amplifiers, the enhanced semiconductor amplifier used in conjunction with the DWDM system exhibits the most extensive coverage distance [23]. The outcomes reveal that the conventional optical amplifier has the shortest maximum reach, limited to 69 km, followed by the semiconductor optical amplifier and the Raman amplifier, succeeded by the Raman SOA amplifier at 121 km. In contrast, the improved SOA displays the highest amplification rate owing to its cascaded amplification methodology [21][24].

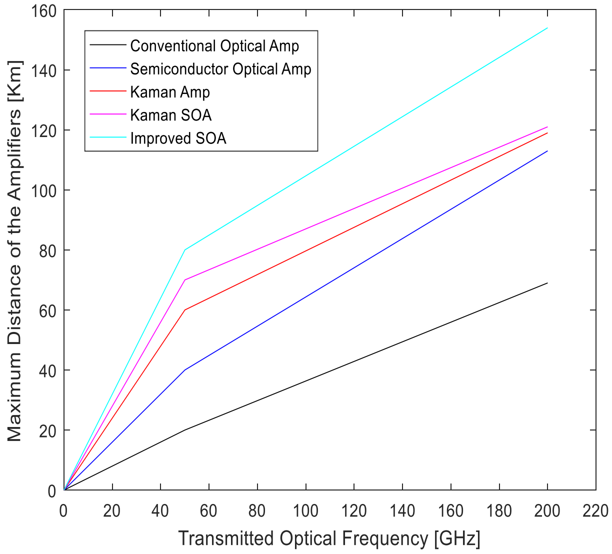

Fig 4. comparative results of optical amplifiers[21]

V. Conclusion

The fiber optic communication system stands as the most efficient mode of wireless communication, revolutionizing communication speed and enhancing data transfer rates significantly. This study scrutinized prior research by other scholars in the second segment of this paper. Additionally, it assessed the optical source (LASER), the dispersion of optical signals, and the potency of transmitted optical signals. Furthermore, the document delved into the principles governing optical amplifiers and explored the hurdles faced in optical network infrastructure.

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