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Optical fiber signal strength based on Raman optical amplifiers schemes in dense wavelength multiplexed communication systems

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Abstract: This study has clarified the optical fiber signal strength based on Raman fiber optic amplifiers schemes in dense wavelength multiplexed communication systems. The signal power with, without Amplification in various pumping configurations scheme is studied with propagation distance variations. The bidirectional pumping power configuration based various pump power is analyzed with propagation distance variations. Amplified forward signal power for various fiber types is investigated with propagation distance variations. These fibers are used such as single mode (SM)-28 fiber, non-zero dispersion shifted fiber (NZDSF), truewave reach fiber for the efficient employment in fiber systems. Amplified bidirectional signal power for various both pump power and fiber types are clarified with propagation distance variations. The pumping power configurations scheme variations are demonstrated with propagation distance variations. Forward/backward pumping power configuration direction variations are investigated and clarified with propagation distance variations for various pumping power values.

Keywords: backward pump; forward pump; Raman amplifiers; signal strength.

***Corresponding authors: Md. Amzad Hossain**, Institute of Theoretical Electrical Engineering, Faculty of Electrical Engineering and Information Technology, Ruhr University Bochum, 44801 Bochum, Germany; and Department of Electrical and Electronic Engineering, Jashore University of Science and Technology, Jashore, 7408, Bangladesh, E-mail: mahossain.eee@gmail.com; and **Ahmed Nabih Zaki Rashed**, Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Menouf 32951, Egypt, E-mail: ahmed_733@yahoo.com. https://orcid.org/0000-0002-5338-1623 (A.N.Z. Rashed)
Kausar Jahan, Department of ECE, Dadi Institute of Engineering and Technology, Anakapalle, Andhra Pradesh, India, E-mail: kjahan@diet.edu.in
Gade Harish Babu, Department of ECE, CVR College of Engineering, Hyderabad, India, E-mail: harish.sidhu12@gmail.com
Mahmoud M. A. Eid, Department of Electrical Engineering, College of Engineering, Taif University, Taif, Saudi Arabia, E-mail: m.elfateh@tu.edu.sa
Jyotsna Sharma, Department of Physics, Amity School of Applied Sciences, Amity University, Haryana, Manesar, Gurugram, 122051, India, E-mail: plasmajyoti@gmail.com
Shaik Hasane Ahammad, Department of ECE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, 522302, India, E-mail: ahammadklu@gmail.com
Pratap Kumar Dakua and Deepak Kumar Panda, School of Electronics, VIT-AP University, Andhra Pradesh, Amaravati 522237, India, E-mail: dakuapratapkumar@gmail.com (P.K. Dakua), deepakiitkgp04@gmail.com (D.K. Panda)

1 Introduction

Optical semiconductor light amplifiers are the speed improvement in the polarization cross gain with the optical amplification can be achieves [1–14]. The basic low facet of the reflectivity, the good coupling to light guided fibers, and the highest saturation output received power [15–22]. A single light optical amplifier can be replaced and upgraded with all the multiple required components for the achievements of the required for the electronic/electrical regeneration stations and can be used for the elimination the need for the conversion from electrical/light and per the conversion of the optical-electrical communication methods [23–35]. Semiconductor light optical guided amplifiers can be employed for the overcome of the distribution on the losses through the fiber optic systems and with light communication systems applications [36–49].

These optical light amplifiers can be employed for the purpose based on the applications in the metropolitan area networks and local area applications to be used as a low budget cost instead of light optic fiber light amplifiers [50–63]. Light fiber optic amplifiers are the key performance characteristics for the operation in the fiber optic systems in the presence of amplification systems in different configurations [64–75]. These light fiber optic amplifiers reconstitute the attenuated loss light signal, thus these fiber light amplifiers can be shared in to the expanding of the effective fiber reach between the input data electrical/light sources and the electrical/light destinations [76–85].

A semiconductor fiber light optical amplifiers are all light fiber optical amplifiers that are based on the operation mechanism in the gain medium systems [86–97]. These fiber optical light amplifiers like a fiber laser with the end of the mirrors should be employed by the replacement with an anti-reflection fiber light coatings [98–110]. Forward, backward and bidirectional amplification configuration are the most important amplification techniques that are used to strength the weak light input signal and played on to amplify the light intensity and modulated it [111–122]. Several studies are still working on the suitable pumping power and pumping wavelengths with the suitable amplification systems [123–135].

2 Proposed simulation setup

Figure 1a, b show the dense wavelength division multiplexing systems and the system with all forward, backward and bidirectional amplification system. The transmitter consists of multi sources with different wavelengths varying from λ_{s1} to λ_{Sn} and these sources are responsible for the generation of the light signals from the electrical signal forms. All the generated light signals are combined through multiplexing system and pushed into the fiber optic channel directly with the assistance of post amplification to strength the signal at the start of traveling through the fiber systems.

Optical add drop multiplexers have the basic function to add or drop for adding or drop any communication

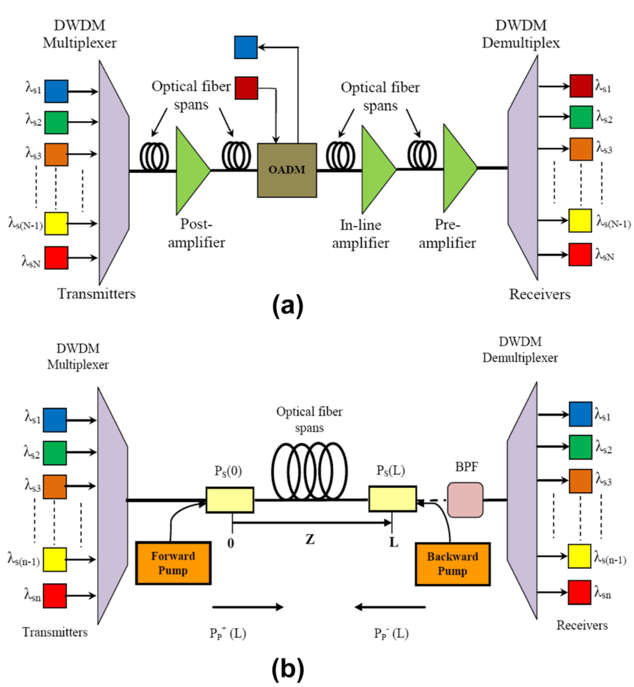

Figure 1: WDM amplified optical fiber system: (a) DWDM communication system model; (b) proposed simulation model description.

channels. The amplified signal is directed from OADMs devices to the fiber optic channel with the suitable wavelengths for the best communications between the *T*x. And *R*x. through inline amplification system. The output signal waveform is amplified again through preamplifiers system amplification. All the multiplexed are then demultiplexed at different suitable wavelengths and then routed to the destination side. Figure 1b clarifies the proposed system with all amplification methods in different configuration based on forward, backward and bidirectional amplification systems. Signal wavelength (λ_S) changes from 1.45 to 1.65 μm, pump wavelength (λ_P) changes from 1.40 to 1.44 μm, signal power (P_{SO}) changes from 2 to 20 mW, the pump power (P_{PO}) changes from 0.165 to 0.365 W, power percentage (r_f) is 0.5, the signal attenuation is 0.25 dB/km, and the pump attenuation is 0.3 dB/km.

3 Mathematical model analysis

The signal power without amplification (WoA) along the fiber cable of *Z* distance can be given by [1, 4]:

$$P_{S(WoA)}(Z) = P_{SO}\ \exp\ (-\alpha_{Ls} Z) \tag{1}$$

Where the P_{SO} is the initial signal power at the starting distance (at $Z = 0$). The pump, signal powers variations with respect to the fiber distance *Z* is formulated by [6, 8]:

$$\frac{dP_P}{dZ} = -\alpha_{LP} P_P(Z) - \frac{\lambda_S}{\lambda_P} g_{\text{eff}} P_S(Z) P_P(Z) \tag{2}$$

$$\frac{dP_S}{dZ} = -\alpha_S P_S(Z) + \frac{\lambda_S}{\lambda_P} g_{\text{eff}} P_S(Z) P_P(Z) \tag{3}$$

where α_S is the signal attenuation, α_P is the pump attenuation, g_{eff} is the Raman gain in $W^{-1}km^{-1}$, λ_S, λ_P are the signal wavelength and pump wavelength, respectively. The linear signal attenuation, Raman gain efficiency is estimated by:

$$\alpha_L = \alpha / 4.343 \tag{4}$$

$$g_{\text{eff}} = \frac{g_R}{A_{\text{eff}} \times 10^{-18}} \tag{5}$$

With A_{eff} is the section fiber effective area of the fiber within the amplification unit in μm^2. Eqs. (2) and (3) can be solved with the integration of both sides, then the pump power in the forward/backward/bidirectional schemes are given by:

$$P_{PF}(Z) = P_{POF}\ \exp\ (-\alpha_{LP} Z) \tag{6}$$

$$P_{PB}(Z) = P_{POB}\ \exp\ [-\alpha_{LP}(L - Z)] \tag{7}$$

$$P_{PFB}(Z) = (r_f) P_{POF} \exp\ (-\alpha_{LP} Z) + (1 - r_f) P_{POB}\ \exp\ [-\alpha_{LP}(L - Z)] \tag{8}$$

Where r_f is the pump power percentage launched in the forward direction. The signal power after amplification mechanism and the effective fiber length to avoid the nonlinearity effects (stimulated Raman scattering) can be calculated by [9, 13]:

$$P_S(z) = P_{SO}\ \exp\left[\left(\frac{g_R}{A_{\text{eff}}}\right) P_{PO} L_{\text{eff}} - \alpha_{LS} Z\right] \tag{9}$$

$$L_{\text{eff}} = \frac{1 - \exp(-\alpha_{LP} z)}{\alpha_{LP}} \tag{10}$$

Where P_{SO}, P_{PO} are the initial signal/pumping power at distance $z = 0$.

4 Results and discussions

We analyzed and clarified the optical fiber signal strength based on fiber Raman optic amplifiers schemes in dense multiplexed communication systems. The present methods have been investigated to find the signal power with, without Amplification in various pumping configurations scheme with propagation distance variations. As well as the bidirectional the pumping power configuration based various pump power is demonstrated with propagation distance variations. Besides amplified forward signal power for various fiber types is illustrated with propagation distance variations. Amplified bidirectional signal power for various both pump power and fiber types are clarified with propagation distance variations. The pumping power configurations variations are demonstrated with propagation distance variations. In the same way, forward, backward pumping power configuration direction variations are investigated and clarified with propagation distance variations for various pumping power values.

Figure 2 clarifies the signal power with, without amplification in various pumping configurations scheme with propagation distance variations for single mode fiber. The signal is degraded continuously with the increase of fiber length or the propagation distance. The signal in the bidirectional configuration scheme is degraded until reached 50 km distance. But after the distance of 50 km the signal is upgraded to reach amplitude of 50 mW. The signal in the backward configuration scheme is degraded but the signal in this case is better than without amplification. The signal can be upgraded in the forward configuration scheme and the signal power amplitude level can be enhanced. The signal wavelength, pump wavelength, initial signal power, initial pump power are 1.55 µm, 1.40 µm, 20 mW, and 0.165 W, respectively, in Figure 2.

Figure 3 illustrates the bidirectional pumping power configuration based various pump power with propagation distance variations for single mode fiber-28 (NDSF). The bidirectional pump power decreases with the increase of fiber length up to 50 km and after this distance the bidirectional pump power increases exponentially with the distance. The higher initial pump power the high the bidirectional pump power which its value is reached to 180 mW at pump power of 0.365 W, 130 mW at pump power of 0.265 W, 80 mW at pump power of 0.165 W. The signal wavelength, pump wavelength, and initial signal power are 1.55 µm, 1.40 µm, and 2 mW, respectively, in Figure 3.

Figure 4 illustrates the amplified forward signal power for various fiber types with propagation distance variations. The forward signal can be enhanced through the truewave reach fiber in compared to other proposed fibers. At the starting point the forward signal power is 2 mW. The forward signal is upgraded with truewave reach fiber up to 2.4 mW then the signal is degraded with the increase of distance. All the forward signal power are acceptable up to 50 km but after this distance the signal is weak through the increase of distance. The signal wavelength, pump wavelength, initial signal power, and forward pumping power are 1.55 µm, 1.40 µm, 2 mW, and 0.165 W, respectively, in Figure 4.

Figure 5 demonstrates the amplified bidirectional signal power for various pump power with propagation distance variations for single mode fiber-28 (NDSF). The higher pumping power the higher bidirectional signal power. The bidirectional signal power is reached to 15 mW at 0.365 W pumping power, 9 mW at 0.265 W pumping power, and 5 mW at 0.165 W pumping power. The bidirectional signal power slightly changes in decrease and increase by using various pump power levels. The signal wavelength, pump wavelength, initial signal power are 1.55 µm, 1.40 µm, and 2 mW, respectively, in Figure 5.

Figure 6 illustrates the amplified bidirectional signal power for various fiber types with propagation distance variations. The bidirectional signal power can be enhanced with truewave reach fiber in compared to other proposed fibers. The bidirectional signal power is 8 mW through truewave reach fiber, 6 mW through the NZDSF optic fiber, 5 mW through SMF optic fibers. The bidirectional signal power slightly change positive and negative exponentially with distance. The signal wavelength, pump wavelength, initial signal power, and forward pumping power are 1.55 µm, 1.40 µm, 2 mW, and 0.165 W, respectively, in Figure 6.

Figure 7 shows the pumping power configurations scheme variations with propagation distance variations for single mode fiber-28 (NDSF). The bidirectional pump power decreases exponentially with distance up to 50 km and the pump power increases exponentially after 50 km distance.

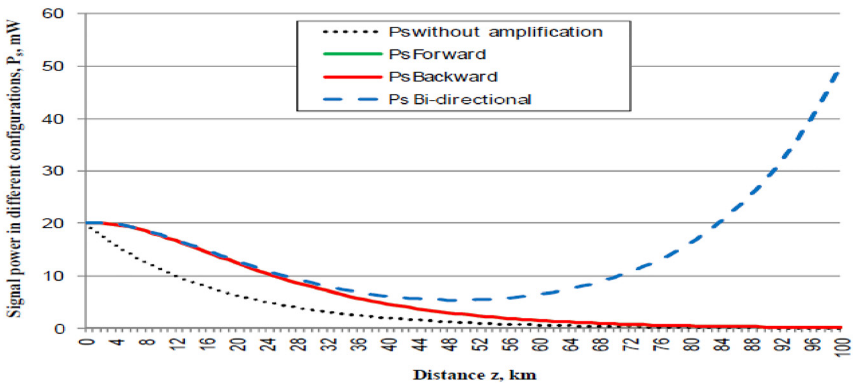

Figure 2: Signal power with/without amplification in various pumping configurations scheme with propagation distance variations for single mode fiber-28 (NDSF).

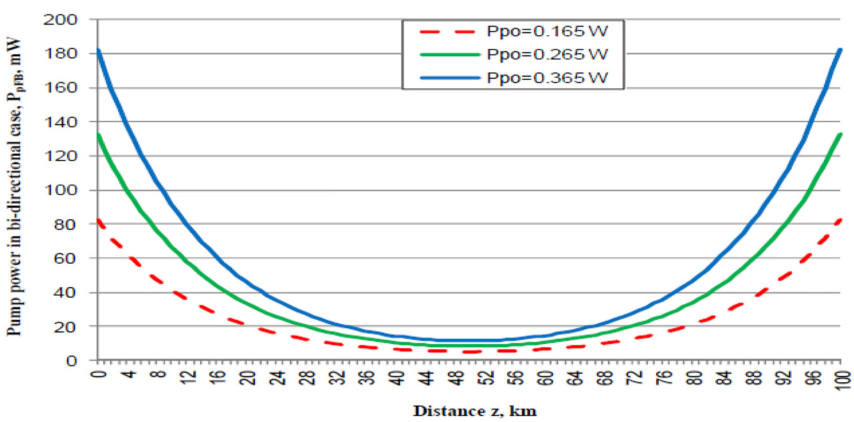

Figure 3: Bidirectional pumping power configuration based various pump power with propagation distance variations for single mode fiber-28 (NDSF).

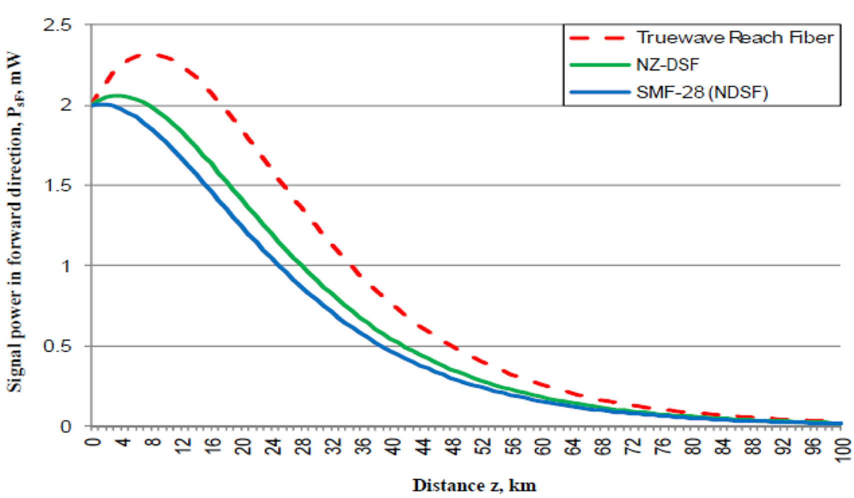

Figure 4: Amplified forward signal power for various fiber types with propagation distance variations.

The forward pump power is 160 mW at the starting distance, but the forward pump power decreases with the increase of distance in order to strength the weak signal power. The backward pump power is approximation 2 mW at the starting distance, but the backward pump power increases with the increase of distance to reach to a value of 160 mW in

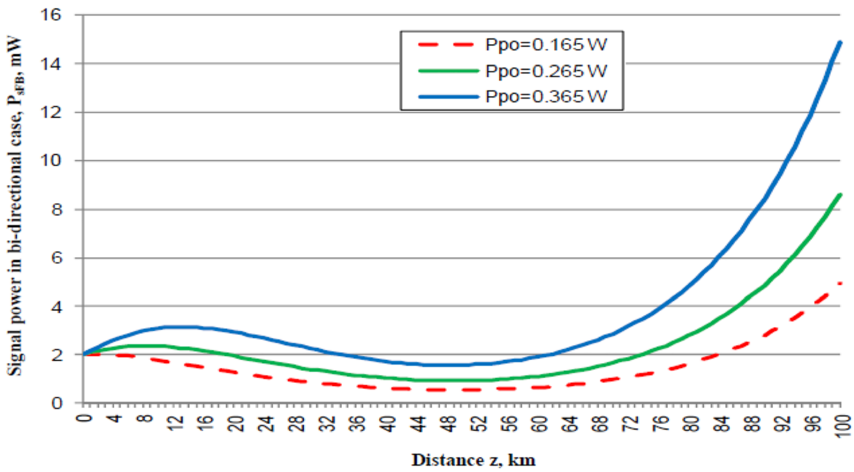

Figure 5: Amplified bidirectional signal power for various pump power with propagation distance variations for single mode fiber-28 (NDSF).

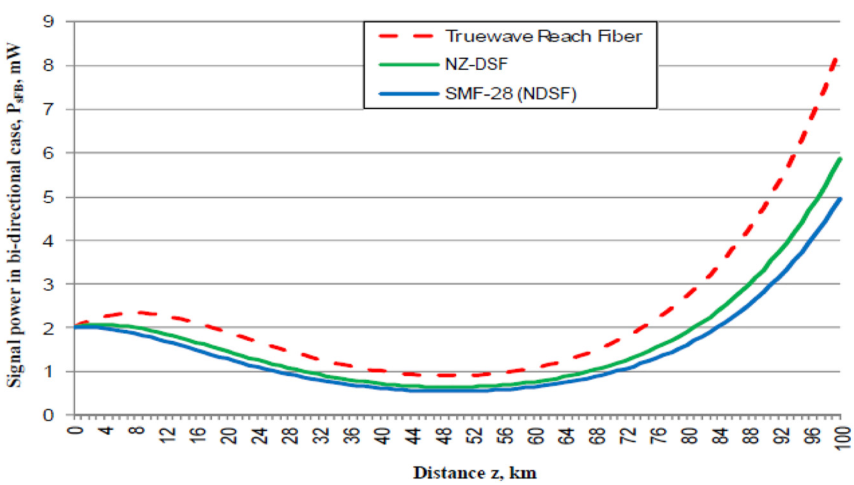

Figure 6: Amplified bidirectional signal power for various fiber types with propagation distance variations.

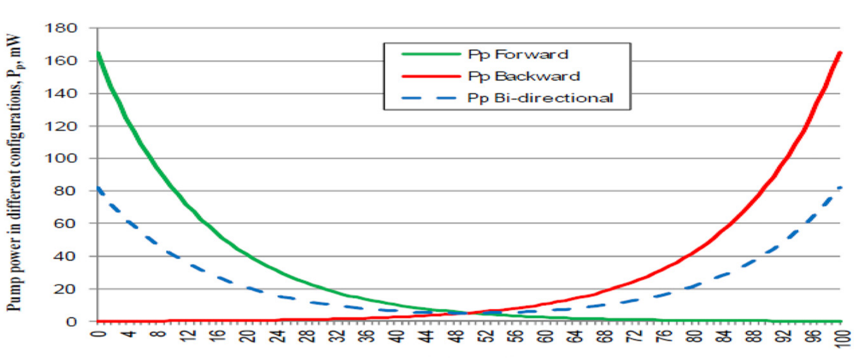

Figure 7: Pumping power configurations scheme variations with propagation distance variations for single mode fiber-28 (NDSF).

order to strength the weak signal power in the backward direction. The signal wavelength, pump wavelength, initial signal power, and forward pumping power are 1.55 μm, 1.40 μm, 2 mW, and 0.165 W, respectively, in Figure 7.

Figure 8 demonstrates the forward pumping power configuration direction variations with propagation distance variations for various pumping power values for single mode fiber-28 (NDSF). The forward pump power can be enhanced with the increase of pumping power value up to 0.365 W. The forward pump power decreases exponentially with distance. The forward pump power is 350 mW at 0.365 W pumping power, 260 mW at 0.265 W pumping power, and 160 mW at 0.165 W pumping power. The signal wavelength, pump wavelength, initial signal power are 1.55 μm, 1.40 μm, and 2 mW, respectively, in Figure 8.

Figure 9 indicates the backward pumping power configuration direction variations with propagation distance variations for various pumping power values for single mode fiber-28 (NDSF). The backward pump power increases exponentially with both pumping power values and distance. The backward pump power is 380 mW at 0.365 W pumping power, 260 mW at 0.265 W pumping power, and 150 mW at 0.165 W pumping power. The signal wavelength, pump wavelength, initial signal power are 1.55 μm, 1.40 μm, and 2 mW, respectively, in Figure 8. The backward pump power can be enhanced the weak signal power than the forward pump power.

5 Conclusions

We have investigated the optical fiber signal strength based on fiber Raman optics amplifiers schemes in dense multiplexed communication system. The higher the pumping

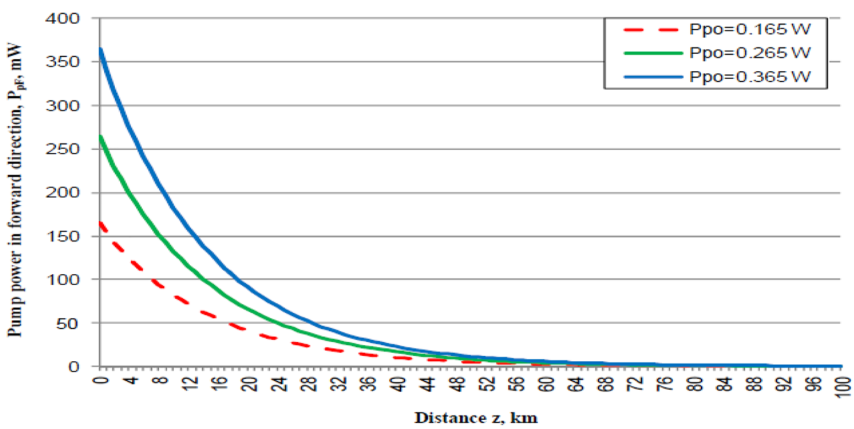

Figure 8: Forward pumping power configuration direction variations with propagation distance variations for various pumping power values for single mode fiber-28 (NDSF).

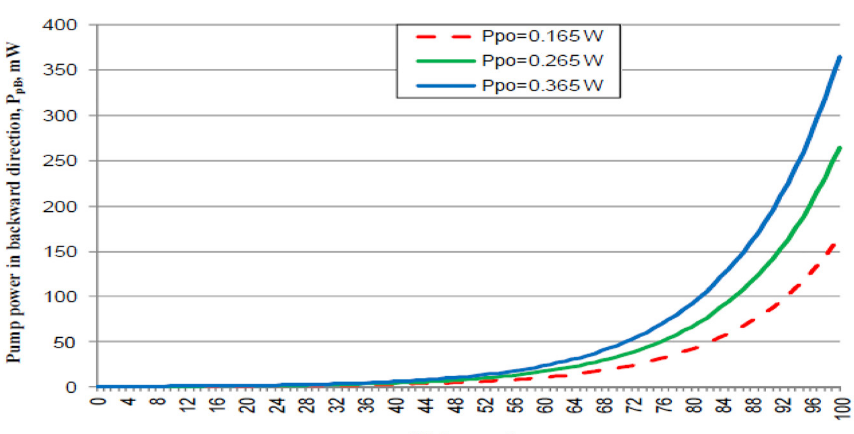

Figure 9: Backward pumping power configuration direction variations with propagation distance variations for various pumping power values for single mode fiber-28 (NDSF).

power value the higher forward, backward and bidirectional pump power. The signal power can be enhanced with true-wave reach fiber in compared to other proposed fibers. The backward pump power can be enhanced the weak signal power than the forward pump power at the same pumping power value. In the bidirectional pump power increases, decreases exponentially with the distance. Raman amplifiers are very efficient in both backward and bidirectional pumping configuration to strength the weak signal power through the fiber medium.

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