Improvement of Gain with Figure of Merit in Discrete Raman Amplifier

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Abstract - Fiber Raman amplifiers are important component of wavelength division multiplexing fiber optic communication systems. The optimum initial values of pump powers for a system are calculated and analysed, so that a better gain results are obtained. This paper investigates the effect of counter propagating pumping in fiber Raman amplifiers as a function of figure of merit. It is shown that gain increases from 35 db to 39.5 db in the range of 0 (1/W) to 5 (1/W) figure of merit. The variation of gain is taken in consideration with the figure of merit.

Keywords - Counter Pumping, Fiber Raman Amplifier, Distributed Raman Amplifier, Wavelength Division Multiplexing and Gain of Raman Amplifier, Figure of Merit.

I. INTRODUCTION

Modern lightwave communication systems have used full gain bandwidth of erbium doped fiber amplifiers (EDFAs), and increasing capacity has resulted into the need of broader bandwidth optical amplifiers in the system [1]. Fiber Raman amplifiers are used now a days as all Raman or hybrid FRAs/EDFAs in all long haul and ultra long haul wavelength division multiplexed optical communication systems [2]. It supports high bit rate data transmission over long fiber spans, due to its benefits such as proper gain and Optical signal-to-noise ratio [3]. This paper considers the gain characteristic of distributed Raman amplifier as a function of pump power at counter pumping configurations. The amount of noise transferred will depend on the gain and length of fiber used. As noise figure is inversely proportional to gain so, if gain is improved, noise in the system is reduced. The paper is planned as follows: section II is devoted to the description of discrete Raman amplifier configuration. The theoretical model is discussed in section III. In section IV the results of the analysed model is discussed and in V section the conclusion and future scope of the paper is discussed.

II. DISCRETE RAMAN CONFIGURATION

In LRA highly nonlinear fiber with a small core is utilized to increase the interaction between signals and pump wavelengths and thereby reduce the length of fiber required. Because of small scattering cross section Raman amplification may better fit in a DRA rather than a discrete one. Therefore, in designing LRAs, several challenges such as increasing efficiency and solving fundamental trade offs are required. The important parameters representing LRAs are: the wavelength and input power level of signal, the wavelength and input power level of pump and the type and length of the gain fiber. The length of the fiber in LRA is between 5 km to 40 km. the following properties in signal and pump wavelengths bands are required to design the amplifier in detail: the attenuation coefficient, the Raman gain coefficient for the given pump wavelengths, the Rayleigh backscattering coefficient and the nonlinear coefficient. The targeted optical characteristics of a LRA usually gain, noise figure, output signal power level, optical signal to noise ratio, double Rayleigh backscattering noise power, nonlinear phase shift, and pump to signal power conversion efficiency. In this thesis report the work is done on the gain of the Raman amplifier. However, discrete Raman amplifiers have many attractive aspects over rare-earth-doped fiber amplifiers such as an erbium-doped fiber amplifier (EDFA) including arbitrary gain band, better adjustability of gain shape, and better linearity. The principal advantage of Raman amplification is its ability to provide distributed amplification within the transmission fiber, thereby increasing the length of spans between amplifier and regeneration sites.

Fig.1 shows the basic configuration of discrete Raman amplifier. It generally comprises a gain fiber, a directional coupler for combining the pump and the signal wavelength, and isolators at the input and output ends. The orientation of the pump can be either forward or backward with respect to the signal propagation, whereas the counter propagating one is called counter pumping; the copropagating pumping scheme is called copumping. There is also an option of bidirectional pumping, in which the gain fiber is pumped in both directions [4].

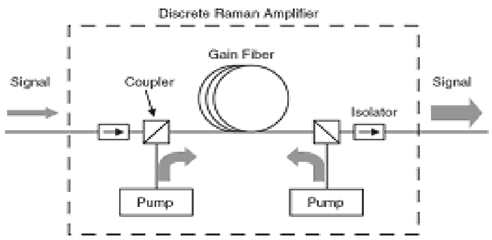

Fig 1: Discrete Raman amplifier in counter propagation configuration

III. THEORATICAL MODEL

Under such conditions the saturated gain of the amplifier is given by:

$$G_s = \frac{G_A}{1+r_0G_A}$$

where r_0 is related to the signal to pump power ratio at the fiber input as and G_A is unsaturated gain or we can say that G_A is the total amplifier gain or on-off Raman gain. If we use the typical values [4] as g_R= $3W^{-1}$/km for a DCF, L_{eff}=1km, P_0~1.5W then the signal can be amplified by 20 db. Once the gain fiber and pump power are given, the net gain G(z) can be written explicitly as a function of the fiber length z.

$$G(z)=\exp(g_RP_0L_{eff}-a_sz) \quad (1)$$

The first term indicates the on off Raman gain and other is the fiber attenuation. After taking the derivative of (1) with respect to z, seeking the condition for z in which the derivative becomes zero. The net gain is maximal when

$$z = -\frac{1}{\alpha_p}\ln\left(\frac{\alpha_s}{g_R P_0}\right)$$

where P_0 is the input pump power at z=0, ap is the attenuation constant for pump and g_R is Raman gain coefficient.
Now, the final proposed model is as follows:

$$\text{Gain} = \frac{w_sP_p(0)G_s/w_sP_p(0)-w_pP_s(0)G_s}{\exp[-a_s/a_p(\ln(a_s/g_rP_0))]}$$

From my work, we can see the improved gain of Raman amplifier. According to the equations given above we can obtain better results of gain.
where w_s = angular frequency of signal
P_p = pump power
w_p = angular frequency of pump
P_s = signal power
Equations are taken from [5].
Also we can conclude the figure of merit as the ratio of Raman gain coefficient to the pump attenuation constant. By knowing figure of merit, the efficiency of the fiber for LRAs can be estimated and compared. Mathematically,

$$FOM= g_r/\alpha_p$$

IV. SIMULATION MODEL AND RESULTS

In this two cases are considered: when the pump has different value and all other are kept fixed or constant and when only the Raman gain coefficient is fixed and other may or may not vary.

TABLE 1
COMMON SET UPS of SIMULATION CASES

Signal power	200 mW
Optical frequency/ angular frequency of pump	980 nm
Optical frequency/ angular frequency of signal	1350 nm
Saturated gain	19 dB

Case I: When the pump has different value and all other are kept fixed. In this case the attenuation constant of pump and signal are taken as 0.3 and 0.17 respectively.

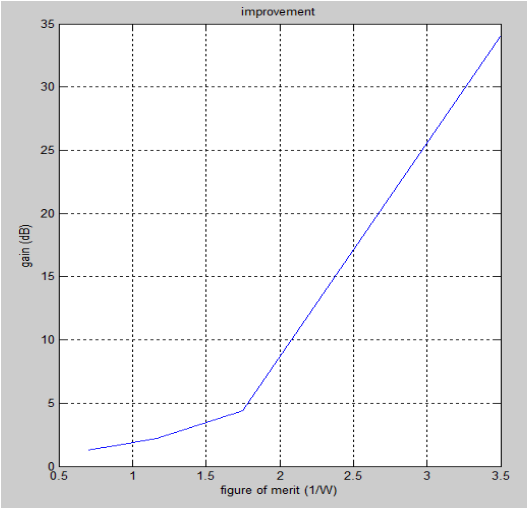

Fig 2: Raman gain at case I

Case II When only the Raman gain coefficient is fixed and other may or may not vary

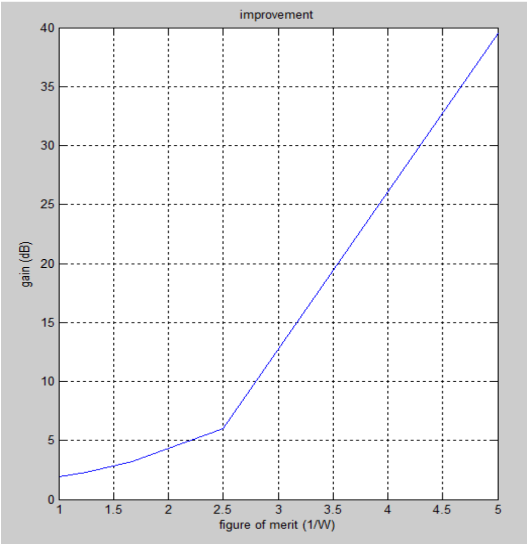

Fig 3: Raman gain at case II

In this case the attenuation constant of pump and signal are taken as 0.52 and 0.17 respectively.
So as we increase the attenuation constant for pump the Raman gain increases. Raman gain coefficient is also increased. As figure of merit totally depends on Raman gain coefficient and attenuation constant for pump. By changing these two parameters the value of Raman gain is improved. So from the previous such results [6] the value of Raman gain obtained is 35 dB and in this paper value exceeds to 39.5 dB.

V. CONCLUSION AND FUTURE SCOPE

With the use of lumped Raman amplifier in the counter propagation configuration we are successful to achieve a better gain performance which can increase the efficiency of system and the overall performance of the system is improved. With the increase or decrease of such values in our model we can further increase the value of Raman gain. As in this paper our motive is to increase the Raman gain from the previous one, so it is accomplished with a factor of 4.5 dB.

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