Analysis of concentration quenching on Erbium Doped Fibers using 8-Channel WDM /TDM PON Optical Communication System

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***Abstract*— Erbium doped fiber amplifier (EDFA) has greatly helped in overcoming the propagation loses which are of biggest concern for next generation wavelength division multiplexing (WDM)/time division multiplexing (TDM) passive optical network (PON). This study is To characterize the performance of high-concentration EDFAs and the effect of the concentration quenching (homogeneous up-conversion and clustered erbium ions) to optimize the gain G and the performance in terms of BER and quality factor Q of the hybrid (WDM/TDM) passive optical network (PON) with 64x8 ONUs (optical network units) .**

Key words: erbium doped fiber amplifier, ions-ions interaction, up-conversion, hybrid PON.

I. Introduction

In today's increasing competitive and technologically advanced telecom environment, broadband networks offer telecom operators both new business opportunities and new challenges. The Internet today creates a great demand for very high bandwidth among people. Bringing optical fiber to everywhere is the definitive response to such demands for greater bandwidth. An emerging way to provide fast and smooth Internet to customers through fiber is Passive Optical Network.

A PON is a point-to-multipoint optical network, where an Optical Line Terminal (OLT) at the Central Office (CO) is connected to many Optical Network Units (ONUs) at remote nodes through one or multiple I:N optical splitters. The network between the OLT and the ONU is passive i.e., no requirement of power supply [1].

Hybrid WDM/TDM-PON architecture is the next generation passive optical network which has enhanced capability to increase PON-system scalability. This can be elegantly accomplished through the Time division multiplexing (TDM) and the wavelength-division multiplexing (WDM) PON schemes in the access fiber [2].

The EDFA is capable to amplify light in the 1550nm wavelength region (where the attenuation of silica fiber is minimum) and has greatly helped in overcoming the propagation loses which are of biggest concern for next generation (hybrids WDM/TDM PON) [3]. Many studies reported the Erbium-doped fiber amplifier (EDFA) performance degradation with Erbium concentration increase. In general, these additional losses are attributed to energy transfers between neighboring ions. When the erbium concentration is increased the average distance between two Er ions decreases and the probability they interact increases.

Therefore, the quantity of energy exchanged between neighboring erbium ions increases at the expense of degraded power conversion efficiency since part of the energy brought by the pump is lost in this process. In this paper, we address our most recent work on concentration quenching encountered in Erbium doped fibers.

II. Erbium Doped Fiber:

The optical amplifier EDFA is constituted of doped amplified fiber and laser pump coupled by an optical multiplexer. The fiber is doped with erbium, a rare earth element that has the appropriate energy levels in their atomic structures for amplifying light. EDFAs are designed to amplify light at 1550 nm. The device utilizes a 980 nm or 1480nm pump laser to inject energy into the doped fiber. The input signal (1550nm) and pump laser signal pass through fiber doped with erbium ions. Here the 1550nm signal is amplified through interaction with doped erbium ions [4]

The Erbium Doped Fiber Amplifier component allows the user to consider interactions between neighboring ions, most important ion-ion interactions for EDFA are: homogeneous up conversion effect (HUC) ,inhomogeneous pair-induced quenching (PIQ) and are schematically represented in Fig 1 .

The Homogeneous Up-Conversion (HUC) effect is an interaction effect and its impact on the EDFA performance is linked to the concentration of erbium ions in the fiber [5] [6]. On the other hand, the Pair-Induced Quenching (PIQ) effect means that the energy transfer rate between two or more ions is on a time scale significantly faster than that of the pump rate, so that at the pump powers considered the pump is unable to keep both ions excited [7].

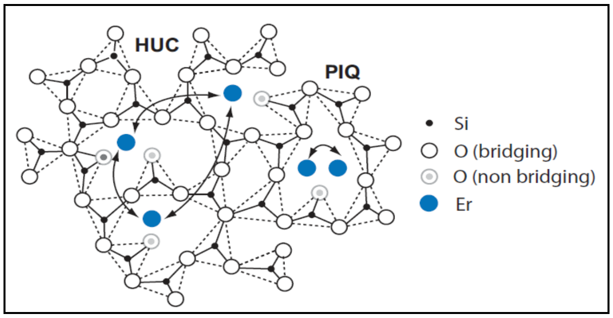

Fig1. Scheme of Pair-induced quenching (PIQ) and homogeneous up-conversion (HUC) processes in Erbium-doped silica glass.

III. SYSTEM DESCRIPTION

The simulation model for shows the schematic of the hybrid PON (WDM/TDM PON) downstream transmission is proposed using modulation formats system no return to zero (NRZ) to evaluate system performance .Figure 2 depicts the block diagram for simulation setup which can be implemented with a splitting ratio of 64 with 18 dB of loss.

The Continuous Wave (CW) laser array with 8 ports operates at wavelength region of 8 nm (1550 nm-1558nm) with frequency spacing is 0.8nm are which inputs light signal to Optical Line Terminal (OLT) unit with input power (5 dBm).

All channels modulated with modulation rate to achieve data transfer rate of 2.5 Gbit/s, NRZ (Non-Return to Zero) format was used for signal coding. For multiplexing eight channels into a single fiber (SMF) with an attenuation coefficient of 0.2 dB/km and length of 20 km , the optical multiplexer with 10GHz channel bandwidth and 100GHz channel frequency spacing is used to reduce the crosstalk between adjacent channels.

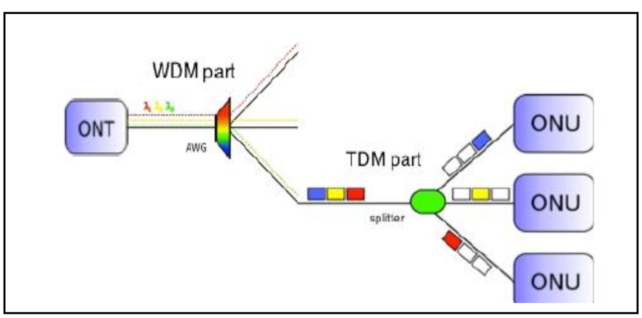

Fig.2. The system setup for 2.5 Gb/s over 20 km of SMF of WDM/TDMA-PON system with 8x64 users.

Optical amplifiers EDFA work to amplifying the optical pulses signal. The demultiplexer has the same parameters as the multiplexer in terms of channel bandwidth and channel spacing. On the receiver side of the system, the eight avalanche photodiodes (APDs) to detect signals and eight low pass Bessel, 3R regenerator, Bit Error Rate (BER) meters and eye diagram analyzers to evaluate performance of each channel.

To increase the BER we need to introduce an EDFA of length 6 m and doping concentration of 1.5e+025/m^{-3}. We have used bidirectional pumping scheme with pumping wavelengths of 980nm both and having pumping powers of 200 mw.

IV. RESULTS AND DISCUSSIONS

"Fig.3.a" and "Fig.3.b", shows respectably the gain and quality factor as a function of erbium ion density with include different cases ion-ion interaction (homogeneous HUC, inhomogeneous PIQ and combined the combination of the cooperative (HUC + PIQ)) . So it is cleared from graphs for threes cases, that the gain and Q factor increases with increasing of erbium ion concentration for the lower concentrations of 1.2e+025/m^{-3}, however up of this values, the effects of homogeneous and the combination of the cooperative provides a similar allure and relate to the issue of energy transfer between rare earth ions. This can have a negative impact on amplifiers gain and tends to cause more degradation in the performance.

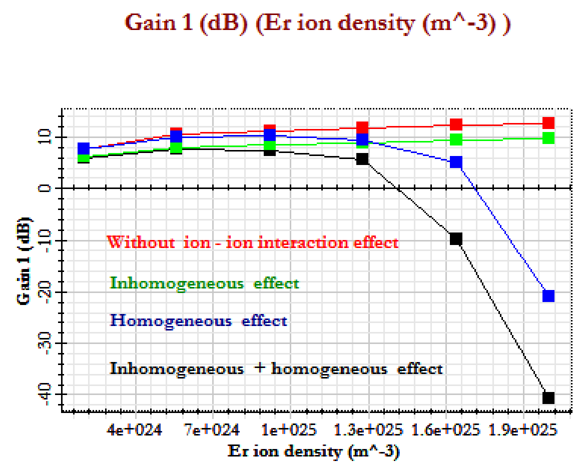

Fig. 3. a) Gain as a function of erbium ions density showing the first channel for ions-ions interactions.,

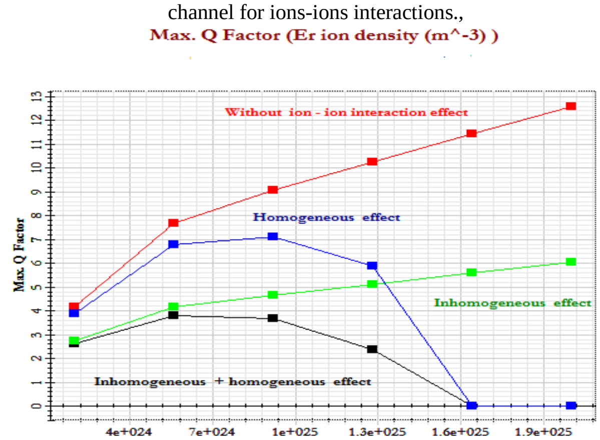

Fig. 3. b) Q factor as a function of erbium ions density showing the first channel for ions-ions interactions

The effect of ion-ion interaction on the system is investigated by relationship between the BER , Q factor and optical fiber length “fig.4.a” and “fig.4.b”. The hybrid system without ion-ion interaction is performed with lowest BER (of -25) and Q factor (9,90) at short distances (20km), however performance reduces when we increase the fiber length.

Also at 1.5e+025/m^{-3} of erbium concentration and fiber length of 20 km, in the term of Min of BER, the homogeneous broadening case (HUC) has the acceptable performance (Min of BER=-16) and quality factor of 7.6 flowed by inhomogeneous broadening (PIQ) with Min BER= -7,5 and lower Q factor of 5,2 .

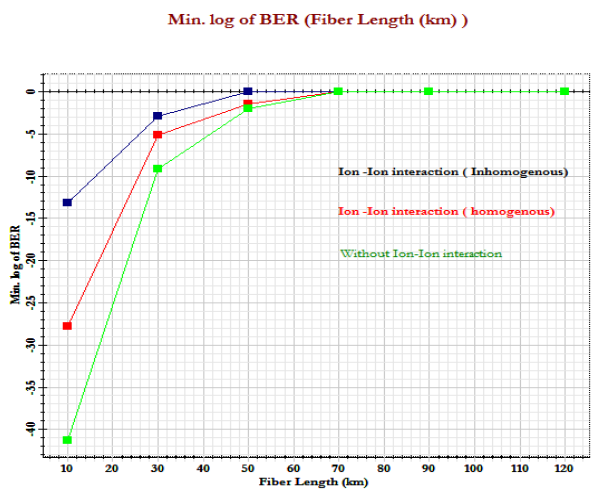

Fig. 4. a) Min of BER as a function of fiber length showing the first channel for ions-ions interactions.

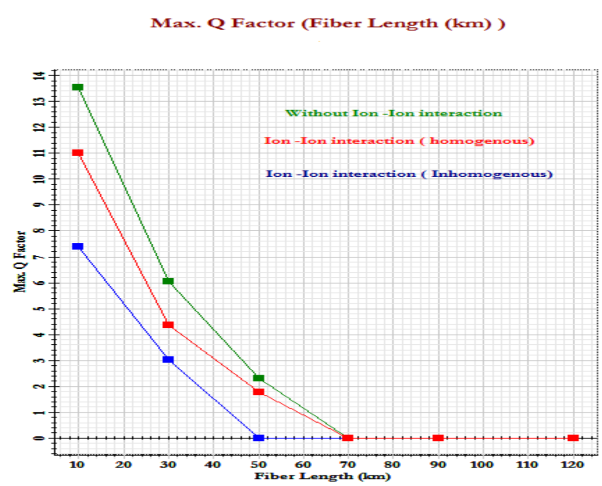

Fig. 4 b) Q factor as a function of fiber length showing the first channel for ions-ions interactions.

To demonstrate the impact of homogeneous up conversion HUC in the EDFA, the coefficient of homogeneous up conversion is varied for four values (UPC = 5e-021, 1e-022, 1e-023 and 1e-024 m3/s), The result is shown in figure 5, the better performance of the EDFA with Min value of BER (around of -25) is found when UPC = 1e-024 m^3/s for 20 km of fiber length.

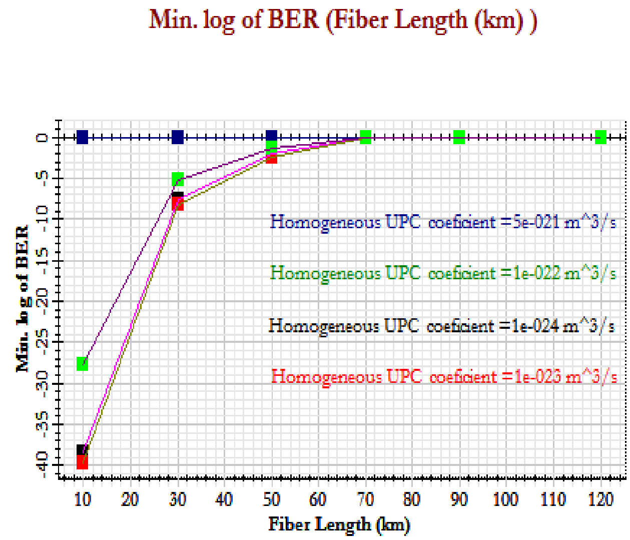

Fig. 5. Min of BER as a function of fiber length showing the first channel for different homogeneous up conversion coefficients.

In order to demonstrate the influences of inhomogeneous pair-induced quenching PIQ and to quantify the degree of clustering in the performance of an EDFA , different type of experiment must be made, all fiber parameters are kept constant except for the relative number of ion per clusters.

The simulations results (“fig.6.a” and “fig.6.b”) shows a high degradation in the performance of an EDFA due the effect of pair-induced quenching specially for high values of relative number of ions per clusters (K= 24%) ,whoever K = 1% provide the best result with Min value of BER around of -22 and Q factor of 9 .

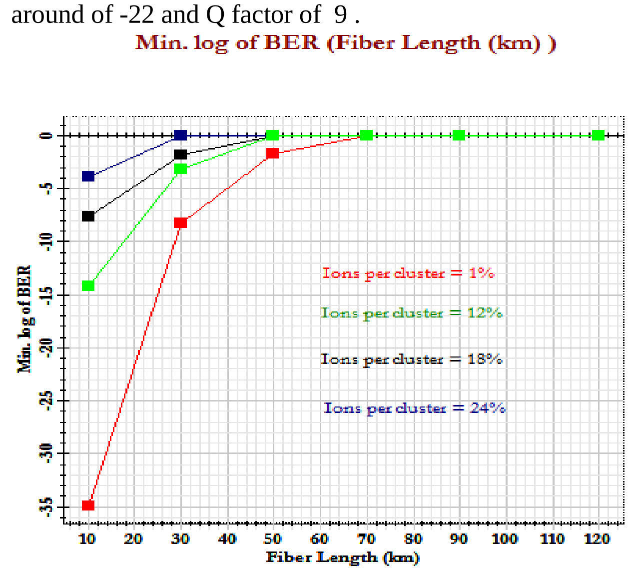

Fig.6. a) Min of BER as a function of fiber length showing the first channel for different inhomogeneous coefficients K (number of ions per clusters)

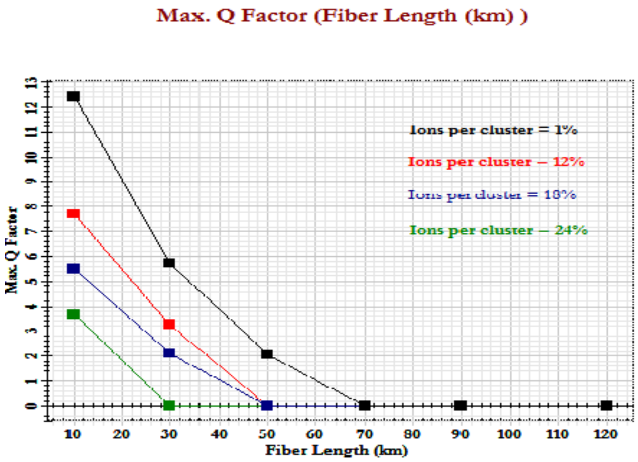

Fig.6. b) Q factor as a function of fiber length showing the first channel for different inhomogeneous coefficients K (number of ions per clusters).

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V. Conclusion:

This paper has simulated the hybrid Passive Optical Network (WDM/TDM PON) access network architecture which provides a reliable long reach last mile connection with high bandwidth to provide fast broadband internet access to residential and business customer., the simulative analysis has shown that the Erbium Doped Fiber Amplifier (EDFA) maximizes the transmission number of users up to 512 km at power 5 dBm and bit rate 2.5 Gbps. In the present work, we have investigated the performance of the optical amplifier. It has been observed that performance of the system is affected by some parameters of EDFA such as temperature, ions-ions interaction (homogeneous and inhomogeneous effect).

So this simulation shows that the gain and performance degradation of erbium-doped fiber amplifiers with high erbium ion concentration is modeled by introducing homogeneous effect (up conversion) and the effect of pair-induced quenching specially for high values of relative number of ions per clusters , whereas it has been concluded that best result (lowest BER around -25) is obtained at 20 km without these later .

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