Estimation of EDFA Performance in 40 Gbit/s 8 Channel DWDM Transmission System

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Abstract— In this research, we demonstrate 8 channels wavelength division multiplexing (WDM) transmission system with in-line Erbium Doped Fiber Amplifier (EDFA) using both co-propagation (980 nm) and counter propagation (1480 nm) EDFA configuration. The performance of an EDFA in a 40 Gbit/s 8 channel dense wavelength division multiplexing (DWDM) transmission system with NRZ-OOK modulation format and 100 GHz channel spacing was investigated with an aim of finding optimal configuration. Results show that the pumping wavelength of 980 nm the usage of 15 m long doped fibers gain value is around 27 dB, thus the usage of 30 m long fiber already drives gain indicators close to 30 dB. With the increase of pump power and fiber length co-propagation EDFA configuration at pumping wavelength of 1480 nm provides noticeably high and stable gain values of more than 40 dB.

1. INTRODUCTION

Erbium Doped Fiber Amplifier (EDFA) has been considered as an attractive solution for the simultaneous amplification of all dense wavelength division multiplexing (DWDM) channels because of several major advantages — immunity to cross talk among wavelength multiplexed channels, insensitivity to light polarization state, high energy efficiency (> 50%) and time constant enough to cover modulation noises. The working principle of EDFA is based on transient processes at 3-three level erbium atomic structure. Population inversion can be achieved using laser pumping at 980 nm or 1480 nm to excite electrons to the upper erbium atomic state. When excited to the upper state, electrons rapidly decay nonradioactively to the meta-stable state by emitting light within the 1525–1565 nm band. Stimulated photons are in coherence with the input signal, and that results in signal amplification [1].

If electrons in the meta-stable state are not stimulated within the electron lifetime in that state, electron transition to the lower states results in spontaneous emission (ASE). In this case, photons are emitted spontaneously in all directions, but a proportion of those will be emitted in a direction that falls within the numerical aperture of the fiber and are thus captured and guided by the fiber. Those photons captured may then interact with other dopant ions, and are thus amplified by stimulated emission [2].

Simplified transition process is shown at Fig. 1.

2. METHOD ANALYSIS

The experimental part was focused on optimization of EDFA parameters. Optimal length depends on doping level and pump power, therefore different doped fiber lengths (10 m, 15 m, 20 m, 25 m,

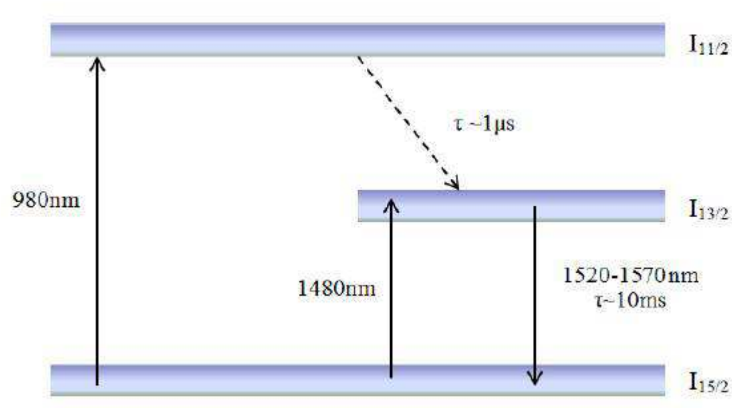

Figure 1: Simplied scheme of Er^{3+} energy levels in silica fiber [3].

and 30 m) and excitation source power (200 mW, 300 mW, 400 mW, 500 mW) were used in order to reach the highest amplification value. Simulation of an amplifier was done with the help of RSoft Design Group OptSim 5.2 software using *Sample mode* simulation core and physical model of EDFA. Physical EDFA OptSim model is based on the solution of the EDFA rate equations under the so-called "effective overlap approximation" therefore implementing a detailed model for the EDFA saturation and wavelength dependence of the gain. EDFA rate equations are used to describe absorption and emission rates. For example, in pumping at 980 nm, it is required to form a system model with three energy levels. When the excited state absorption (ESA) is considered, a forth level should also be included. If the pumping is performed at 1480 nm, a simple system model with two energy levels can be used.

This model assumes that, for each wavelength, the emission and absorption coefficients [dB/m]) can be obtained by multiplying the emission and absorption cross sections [m^2] by a coefficient which depends on fiber dopant density and effective area, but does not depends on wavelength nor incident optical power. Experimental measurement scheme is shown in the Fig. 2. Simulations were done using both co-propagating (980 nm) and counter propagating (1480 nm) EDFA configuration accordingly. Gain values were measured on every WDM channel at the certain combination of doped fiber length and pump power.

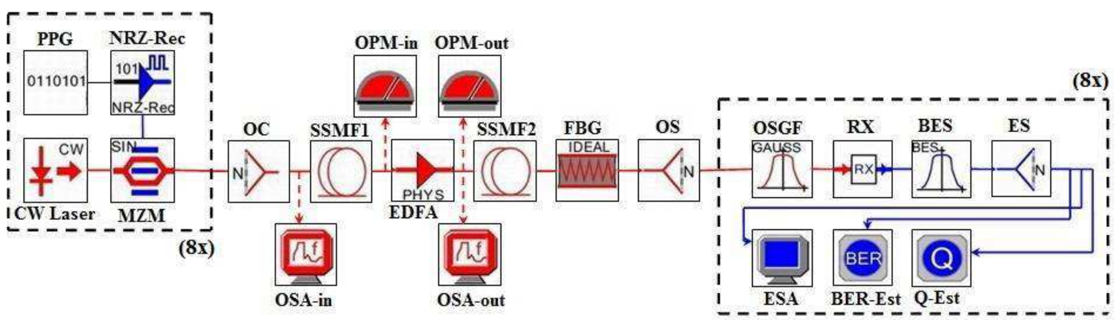

Figure 2: The experimental setup used for investigating the DWDM transmission.

3. RESULTS AND DISCUSSION

After the analysis of EDFA performance with co-propagating pumping at 980 nm wavelength the most notable results were achieved using 15 m and 30 m long fibers as it is displayed at Fig. 3. For 15 m long fiber at the pump power of 200 mW gain value is around 24 dB for all the channels and it does not change much with the increase of pump power until 300 mW — the improvement is only

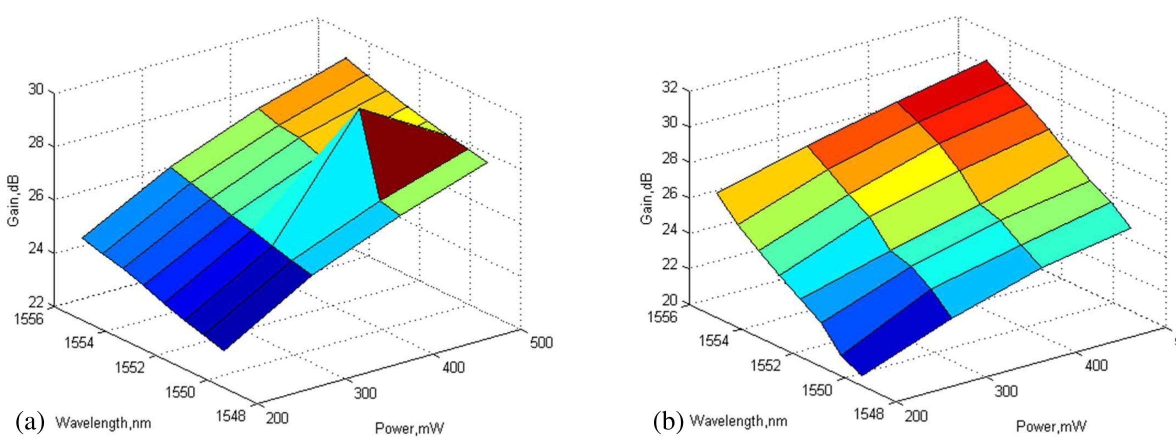

Figure 3: EDFA gain depending on the pump power for (a) 15 m and (b) 30 m long doped fibers at 980 nm pumping wavelength.

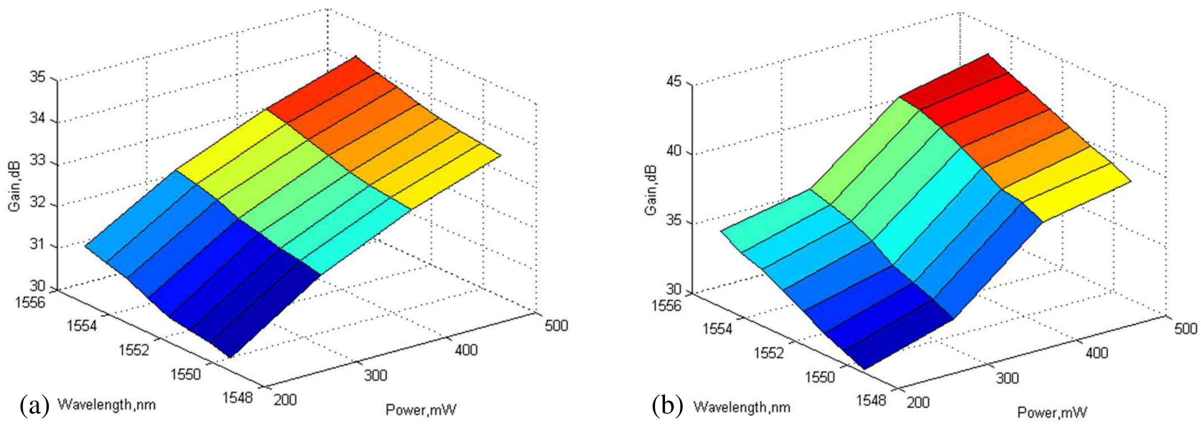

Figure 4: EDFA gain depending on the pump power for (a) 15 m and (b) 30 m doped fibers at 1480 nm pumping wavelength.

for 2 dB. The significant change is clearly visible at 400 and 500 mW where gain is already around 27–28 dB. These leaps are clearly visible at Fig. 3. In addition, the usage of higher powers gives almost constant gain at every WDM channel.

For 30 m long fiber with pump power of 200 mW notable gain value of 27 dB is observed for the first channel of WDM system and keeps slightly decreasing until 20 dB at eighth channel. With the increase of pump power to 300–400 mW gain picture is uneven — it varies around 27–29 dB for the first channels and drops to 23–24 dB in the end of WDM system. High gain values of around 29–30 dB are reached with the increase of pump power to 500 mW.

The usage of co-propagation EDFA configuration at 1480 nm (Fig. 4) gives a stable gain level on each channel, which means that with this configuration it is easier to reach EDFA saturation regime. For 15m long fiber pump power increase does not affect gain significantly — it is about 30–33 dB even if the pump power was increased for 100 mW in each case. Gain is stable throughout the whole WDM system. The situation changes dramatically in case of 30m long fiber. Gain value keeps growing with the increase of pump power: at 200 mW it is about 34–35 dB while at 400–500 mW gain value already reaches 40–43 dB.

4. CONCLUSION

In this paper 8 channels WDM transmission system with in-line EDFA was investigated using both co-propagation (980 nm) and counter propagation (1480 nm) EDFA configuration. There is always an optimum EDFA length depending on the pumping laser power. If the fiber is too short then the whole potential of the amplifier will not be realized. Some laser energy will remain unused. Whereas if the EDFA fiber is longer than the optimal value then erbium inversion level at the end of the EDF will be less than 50% and fiber will start to absorb the signal. The obtained results have shown that at the pumping wavelength of 980 nm the usage of 15 m long doped fibers gain value is around 27 dB, thus the usage of 30 m long fiber already drives gain indicators close to 30 dB. Respectively, it is more efficient to use longer fibers. With the increase of pump power and fiber length co-propagation EDFA configuration at pumping wavelength of 1480 nm provides noticeably high and stable gain values of more than 40 dB. However, in this case a large amount of ASE noise is produced as well.

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