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A novel flattened gain C-band cascaded hybrid optical Raman and thulium-doped fluoride fiber amplifier for super dense wavelength division multiplexing system

CHAKRESH KUMAR[1, 2*], RAKESH GOYAL[1]

[1]Department of Electronics and Communication Engineering,
Research Scholar, I.K. Gujral, Punjab Technical University, Kapurthala-144601, India

[2]University School of Information, Communication and Technology,
Guru Gobind Singh Indraprastha University, New Delhi-110078, India

[*]Corresponding author: chakreshk@gmail.com

In this paper, we have reported a very advanced hybrid optical amplifier (Raman-TDFF amplifier) for the 180 × 10 Gbps super dense wavelength division multiplexing system with the channel spacing of 100 GHz. The performances of the model have been evaluated in terms of gain and noise figures for the C-band (from 1525 to 1565 nm). Gain flatness (>21 dB) is recorded with the least variation of 2.5 dB without using any cost effective technique. Further, the effect of the proposed hybrid optical amplifier has also been analyzed with slightly shifting the wavelength spectrum for the same feature.

Keywords: gain, noise figure, Raman amplifier, thulium-doped fluoride fiber (TDFF) amplifier, super dense wavelength division multiplexing (SD-WDM), hybrid optical amplifier.

1. Introduction

The transmission of optical signals with high spectral efficiency now required the newly advanced optical amplifier for the super dense wavelength division multiplexing (SD-WDM) system. Thulium-doped fluoride fiber (TDFF) amplifier has been recently exposed as the right candidate for the next generation (SD-WDM) system. It has shown accepted rating for S^+-band (1450–1480 nm), S-band (1480–1530 nm) and L-band with the combinations of Raman, EDFA and SOA amplifiers [1–3]. Numbers of experiments have been evaluated with the TDFF amplifier [4, 5]. The capacity of the proposed amplifier can be increased with the help of pumping techniques, which are given as single wavelength conversion pumping [6, 7], dual wavelength pumping, and triple wavelength pumping [5, 8–12], respectively. The highest gain can be attained with the lowest pump power with the combination of suitable amplifiers at 800 and 1050 nm [11]. But the performance of the TDFF amplifier at 690 nm is better than 800 nm [13]. The different pumping of TDFF amplifier at 690 nm has been reported in [14]. In this paper, to the best of author's knowledge, for the very first time, the performances of Raman -TDFF hybrid amplifier for 180 × 10 Gbps system have been illustrated. This paper also declares the highest rating flattened gain that has ever been achieved with the proposed hybrid optical amplifier.

The layout of this paper is as follows. Section 1 shows the research metrology of the paper, Section 2 shows the description of a simulation setup, Section 3 explores the outcome from the proposed model, and Section 4 explores the final conclusion of this paper.

2. Description of simulation setup

The simulation setup for 180 × 10 Gbps SD-WDM with 100 GHz channel spacing is shown in Fig. 1. The modulation of 180 signals is carried out with the help of CW laser sources and Mach–Zehnder modulator. The data source and NRZ electrical drive are the supporting components of the transmitter section. The data source generates the

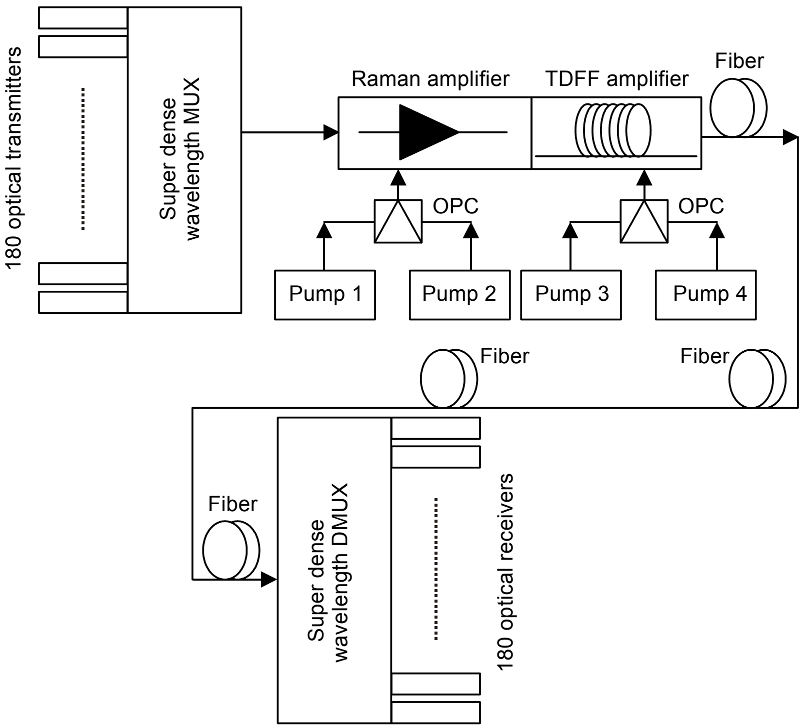

Fig. 1. Simulation setup of the 180 × 10 Gbps SD-WDM system.

10 Gbps pseudo-random sequence of 0 and 1. The electrical drive converts this binary sequence to the electrical domain for further signal processing. The power level of CW laser source is set to 0 dBm to mitigate the effect of nonlinearity at the higher power level. The different combinations of hybrid amplifiers are placed in the medium. Here, pumping to Raman is made with the help of two pumping sources, which are combined with the optical passive coupler. The power level of injected pumping is set to 1500 nm (510 mW) and 1510 nm (510 mW), respectively.

In the same way, dual pumping is injected to the TDFF amplifier with the passive optical coupler. The pumping power is set to 1515 nm (310 mW) and 1520 nm (510 mW), respectively. The PIN photodetector is placed on the receiver side to detect the optical signal with the rating of 0.875 for the responsivity and 0.1 nA for the dark current, respectively. The dual port SD-WDM analyzer is used to examine the characteristics of the proposed model in term of gain and noise figure.

3. Results and discussion

The performance of the proposed model for C-band in term of gain and noise figure is shown in Fig. 2. The simulation is established with the help of OptSIM 2016.12. The gains at 1525 nm are given as 21.55 dB for Raman-TDFF amplifier, 18.66 dB for EDFA, 15.66 dB for Raman amplifier, and 13.66 dB for SOA. In a similar manner, the recorded values for the noise figure at 1525 nm are given as 5.5 dB for Raman-TDFF amplifier, 6.9 dB for EDFA, 7.5 dB for Raman amplifier, and 8.1 dB for SOA. The maximum gains for the different set of amplifiers in the range of 1540 to 1545 nm are given as 15.22 dB for SOA, 16.25 dB for Raman amplifier, 21.55 dB for EDFA,

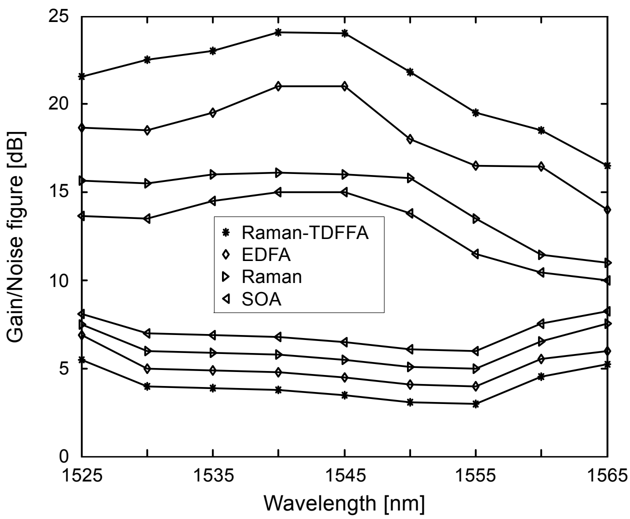

Fig. 2. Gain and noise figure with respect to channel wavelength.

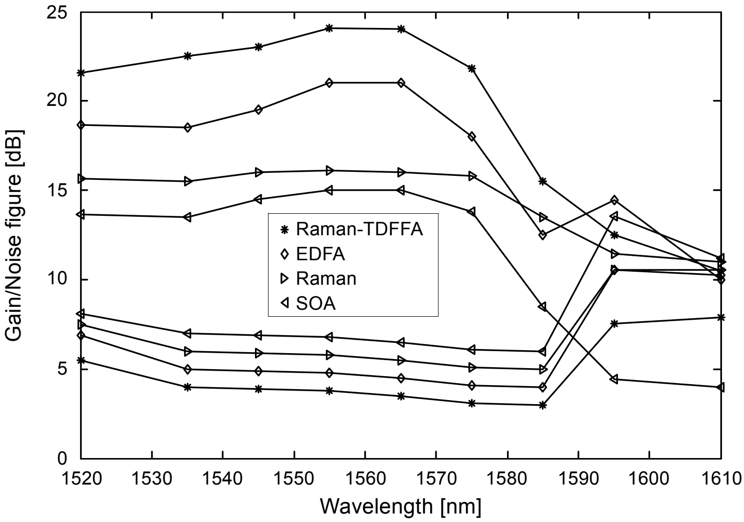

Fig. 3. Gain and noise figure with respect to varying channel wavelength.

and 24.05 dB for Raman-TDFF hybrid amplifier, respectively, with the least variation of 2.5 dB. It shows that the gain of all the amplifiers increases slightly linearly in the range of 1525 to 1548 nm and decreases onwards from the range of 1550 to 1565 nm. But, Raman-TDFF hybrid amplifier delivers the best rating flattened gain of 21.55 dB without any cost effective technique. Further, the effect of hybrid optical amplifier is also evaluated for a different range of the same characteristics (see Fig. 3). It is observed that the minor variations less than 2.5 dB are occurring in the range of 1590 to 1610 nm due to the dominant nature of optical amplifier nonlinearity and inter symbol interference (ISI). But it can be mitigated by adjusting the pump power and power of the CW laser source. It is also observed that the gain flatness of the Raman-TDFF hybrid amplifier is increasing in the same range and the smallest number of attributes of noise figure are recorded than the other amplifier.

4. Conclusion

The effect of Raman-TDFF hybrid optical amplifier has been evaluated for the C-band. The evaluated readings are also compared with the outcome of Raman, EDFA, and SOA amplifiers, respectively. The flattened gain of 24.05 dB is recorded by the proposed hybrid amplifier in the range of 1540 to 1545 nm. Maximum rating flattened gain of 21.55 dB is recorded for the proposed wavelength spectrum. Moreover, the lowest noise figure less than 5 dB is recorded in the same range with the variation of 2.5 dB. In this way, it can be recommended that Raman-TDFF hybrid amplifier is the right candidate for 180 × 10 Gbps SD-WDM in C-band spectrum for enhancing the super dense communication process.

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