Effect of EDF position on the performance of Hybrid Dispersion-Compensating Raman/EDF Amplifier

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Abstract*-The effect of the location of the Erbium-doped fiber (EDF) on the performance of the hybrid dispersion compensation of Raman/EDF amplifier is discussed in this study. Two different configuration set-ups were determined according to the position of the EDF amplifier. The setup in which EDFA is positioned before is denoted by type A, while type B denotes the setup in which EDFA is positioned after. In these two amplifier configurations, the Raman gain saturation due to the Stimulated Brillouin scattering (SBS) effect is included. Type B shows a better hybrid fiber amplifier (HFA) performance in terms of overall gain, noise figure (NF), and flatness gain profile. A small signal gain of 33 and 35 dB with a flat gain bandwidth of 40 nm is achieved for types A and B, respectively. In addition, type B exhibits a high peak gain of 23 dB, with gain variation of 3 dB along 70 nm bandwidth for large input signal compared with the 17 dB peak gain of type A with gain variation of 4.4 dB along the same bandwidth.

Keywords—Hybrid fiber amplifier, Erbium doped fiber amplifier, Raman fiber amplifier, stimulated Brillouin scattering.

I. Introduction

Hybrid Raman/erbium-doped fiber amplifiers (HFAs) are enabling and promising technologies for future dense wavelength-division-multiplexing (DWDM) multi-terabit systems, as shown in experimental results during the past decade [1–7]. The significance of hybrid amplifiers is to extend the span length, to reduce fiber nonlinearities, and to expand the gain bandwidth and flatness. A signal wavelength bandwidth (conventional C-band) of 1530 nm to 1570 nm is considered as the optimal span for EDFA. After the C-band was fully utilized, it became one of the major limitations in EDFAs. The demand for the operation in the long L-band region emerged. Hence, longer EDF lengths and higher Erbium pump power are necessary to obtain EDF in the L-band region, resulting in a higher NF [8]. Besides, the Raman fiber amplifier (RFA) shows a flexible gain bandwidth that is related to different Raman pump power unit wavelengths allowing the operation of RFA in S, C, and L-band regions [9].

Dispersion compensation fiber (DCF) is one of the suitable fiber types that are used to exploit the Raman amplification because of the following two important reasons: (1) the ability to compensate for the losses in the transmission fiber length and (2) the ability to achieve high Raman gain of approximately 10 dB to 20 dB if the nonlinearity in the special fiber is 7 to 8 times higher than its value in a standard single-mode fiber (SMF) [10–12]. A combination of dispersion-compensating Raman/EDF amplifiers was presented [13] using a residual Raman pump power to enhance the efficiency of the amplifier. The simulation results presented in [13] in which the effects of single, double, and triple Raman pump units using the average power model (APM) as a Raman gain medium in RFA were considered. In APM, the Raman gain saturation attained from the effect of a large input signal power was disregarded. The Raman gain saturation was, however, included in our previous work [14] in which the bidirectional fiber was used as a Raman gain medium. A dispersion-compensating Raman/EDF hybrid amplifier that uses different double pump configurations in which the gain, NF, and nonlinear effect-induced penalty were considered in all proposed configurations was presented in [15]. A single pump Raman/EDF hybrid amplifier that had been the focus of static, dynamic, and all system performance comparison studies was reported in [16]. However, the effect of EDFA position on the performance of the hybrid fiber amplifier was not considered or presented. In this paper, the effect of EDFA position changes on performance parameters of the HFA-utilizing OptiSystem simulation is demonstrated. The performance parameters are discussed in terms of overall single channel gain, NF, and gain profile. The simulation setup is explained in section II, while in section III, the results and discussion are presented. The conclusion is discussed in section IV.

II. Simulation Set-up

Two hybrid Raman/EDF amplifiers are designed according to the position of EDFA, which are shown in Fig. 1 (a, b). In Fig. 1(a) EDF is positioned before and is denoted as type A, while in Fig. 1(b) EDF is positioned after and is denoted as type B. DCF of 7 km with 0.55 dB/km attenuation coefficient, -98 ps/nm.km dispersion coefficient, and 15.3 μm^2 effective area was used as the Raman gain medium. EDF of 10 m with normal concentration of 440 ppm, 2.2 μm core radius, and effective area of 15.2 μm^2 were used as EDFA. A total power of 300 mW at 1480 nm was used to pump the Raman gain medium during counter propagation. Meanwhile, 40 mW at 1480 nm pump power was used to pump EDFA. Both Raman and EDFA are pumped through the wavelength division multiplexer (WDM). The input signal was achieved using a tunable laser source with different input signal power that ranged from -40 dBm to 5 dBm. In the two amplifier set-ups, insertion losses and isolators were not considered.

Two optical spectrum analyzers, namely, OSA1 and OSA2, were used to measure the output signal power and to reflect the Brillouin Stokes signal power, respectively. For type A, the input signal was first amplified through EDFA. This amplified signal was then inserted into the RFA stage to obtain an additional gain. The Raman gain saturation occurred as a result of the large input signals in RFA, resulting in the appearance of Brillouin Stokes signals.

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