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Remotely pumped hybrid double-pass L-band optical amplifier utilizing chirped fiber Bragg

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ABSTRACT

This paper reported an investigation of remotely pumped double pass L-band amplifier with dispersion compensation technique. The proposed design used chirped fiber Bragg grating (CFBG) to reflect the amplified signal back into the active medium, compensate the effect of fiber dispersion and block the recycled forward amplified spontaneous emission (ASE) and the residual 1480 nm pump power. The characterization of the design was done experimentally. The gain is 37.5 dB and noise figure is 4 dB with best BER of 10^{-52} is achieved when the EDF is placed 150 km away from the transmitter and 48 km before the receiver terminal.

1. Introduction

Due to the ever-increasing usage and demand for greater bandwidth in telecommunication system around the world leads to the need of long distance transmission in optical communication system. However, this would cause more fiber attenuation and dispersion through the transmission line. The discovery of optical amplifier helps to resolve this issue and allows for longer distance and higher bit rate [1]. Recently, the distance covered by a repeater-less submarine transmission system has increased significantly [2]. This increase has been made possible by the introduction of remotely pumped erbium-doped fiber amplifier (RP-EDFA) [3–5]. Optical transmission system utilizing remotely pump surmounted the geographical obstruction faced by the discrete EDFA and enabled utilization of longer span lengths [6]. The concept of the RP-EDFA was first implemented in 1985 [7]. In 1995, the first transmission system employing remotely pump amplification was commissioned [7]. Chaudhry et al. [8] demonstrated a 410 km link at 2.488 Gb/s optical transmission system by using pre R-EDFA and distributed Raman amplifier (DRA). The transmission fiber is used to send the optical signal and the power signal of 300 mW at 1480 nm laser diode at the same time. In 1996, Eskildsen et al. demonstrated the same design in a 490 km link at 2.488 Gb/s with total loss of about 87.4 dB [9]. Identical configuration was done by [10–13] in a 374 km, 340 km, 220 km and 202 km, optical transmission distance, respectively. Both forward- and backward-pumped DRA are used to produce a new configuration as proposed by Gautheron et al. [14]. By using this design, a 407 km at 2.5 Gb/s optical transmission distance was achieved.

Gabla et al. in 1992 used the R-EDFA as pre-amplifier to achieve a 357 km link at 2.488 Gb/s [15]. In this design the 1480 nm laser diode has been used to remotely pre-amplified the signal without any DRA through the transmission line. Abidin et al. designed an unrepeated transmission system employing a pre R-EDFA in 2005 [16]. In 2006, Naji et al. demonstrated a C-Band pre R-EDFA double pass design using CFBG as a reflector at 2.5 Gb/s [17]. Two 1480 nm of laser diode with total pump power of 700 mW has been demonstrated by Brandon et al. in 1998 [18].

A new configuration of dual 1480 nm laser diode as a post and pre-amplifier pumped by standard semiconductor pump laser is demonstrated to increase the total transmission distance in a 254 km at 4 × 10 Gb/s for the first time by Cremer et al. in 1996 [19]. In 2005, an identical design was studied over 250 km at 10 Gb/s [20]. Triple 1480 nm R-EDFA design is demonstrated by Gautheron over 481 km at 2.5 Gb/s [21]. In this design, the first 1480 nm laser diode is placed at the transmitter terminal to pump the post-amplifier, second and third 1480nm laser diode is placed at the receiver side to pump the pre-amplifier.

The design using 1480 nm laser diode and DRA at the receiver side demonstrated by Hansen et al. in a 442.5 km repeaterless transmission at 10 Gb/s system experiment with 80.6 dB loss [22]. In this design post R-EDFA using a dedicated fiber line when the pre

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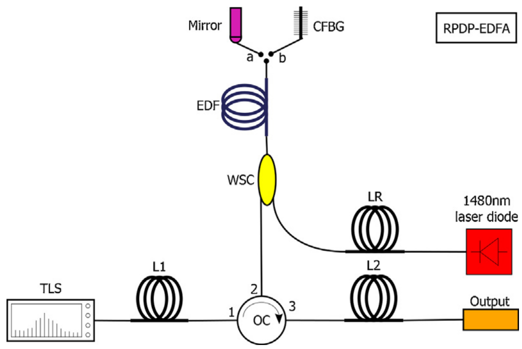

Fig. 1. Remotely pump double pass EDFA with dispersion compensation technique.

R-EDFA was pumped using the transmission line. A 529 km and 240 km have been achieved by [23,24] respectively.

Chirped fiber Bragg grating has been utilized as one of the dispersion compensation technique [25]. Both dispersion compensation fiber (DCF) and CFBG can be used for dispersion compensation. Prominent advantages of CFBG over DCF include being compact, low splicing loss, cheaper, no non-linear effects in the fiber besides CFBG could also be used to reflect back the amplified signal into the EDF as well as compensate the effect of fiber dispersion.

In this paper, we report for the first time an L-band remotely pump double pass compensating-EDFA (RPDPC-EDFA) with dispersion compensation technique which achieves 37.5 dB of gain at maximum transmission distance of 198 km with BER of 10^{-52}.

2. System configuration

The intended RPDPC-EDFA using CFBG as reflector is shown in Fig. 1 when **b** is connected. The main advantage to use the CFBG is to create the double pass amplifier through the reflection as well as its capability to compensate dispersion in the fiber. In this design the CFBG has 98% reflectivity at centre wavelength of 1590 nm as illustrated in Fig. 2. The CFBG will effectively block the residual pump power due to its small bandwidth (0.5 nm) while recycling the forward amplified spontaneous emission (ASE). The 150 km (L1) Single Mode Fiber (SMF) with 0.19 dB/km attenuation at 1590 nm is placed just before the input of amplifier. The 3 port circulator is used to isolate reflected ASE from input and ensure unidirectional propagation. The 30 m length of EDF is used has a 440 ppm Er^{3+}-ion concentration, cut-off wavelength at 950 nm and the absorption peek at 979 nm is 11 dB/m.

A 1480 nm pump laser is placed at the receiver side with varying distance of SMF (LR) from 40 to 60 km (we found that pump power level injected into the amplifier will be too high or too low for LR < 40 km and LR > 60 km, respectively) which has the same specification of L1 with power of 2 W used to pump the EDF in forward pump direction because of its higher conversion efficiency [19,20].

L2 is a distance between the RPDC-EDFA and the receiver side, which has the same condition of L1 & LR. L2 and LR were varied from 40 to 60 km with increment of 2 km at the same time. The input signal is fixed at −5 dBm. The output of the amplifier is collected at port 3 of the circulator and measured by an optical spectrum analyzer (OSA) with resolution of 0.065 nm. The performance of RPDC-EDFA is compared with the remotely pump double pass with Mirror-EDFA (RPDM-EDFA) as shown in Fig. 1 when **a** is connected. The same optical components were used in RPDM-EFDA with only the optical mirror was used as a reflector in place of CFBG. The optical mirror used is a broadband mirror with reflectivity of 97%.

The designed amplifier was characterised using simulation software (Optisystem) and verified experimentally. The gain and noise figure of the amplifier is illustrated in Fig. 3. The simulated result shows a good agreement with experimental since the parameters used in the simulation were taken to be as close as possible to the real devices. The designed amplifier was then simulated using a traffic data at bit rate of 2.5 Gbps to evaluate its performance.

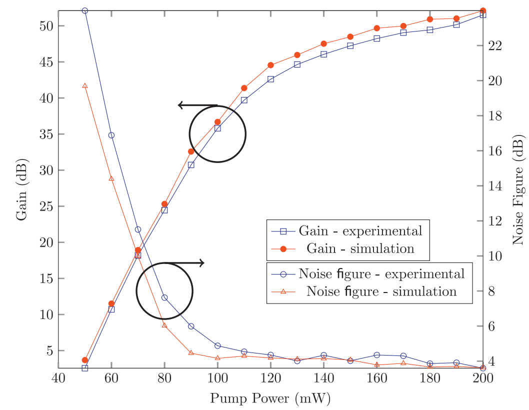

Fig. 3. Simulated and experimental result of gain and noise figure of RPDC-EDFA.

3. Result and discussion

The total distance for the repeaterless transmission system increases gradually as the RPDPC-EDFA is located further away from the transmitter side. This is true for pump power until it reaches a maximum distance that is dependent on the availability of the pump power at this specific location. The optimum distance for this design is between 44 and 52 km, as depicted in Fig. 4. Best BER

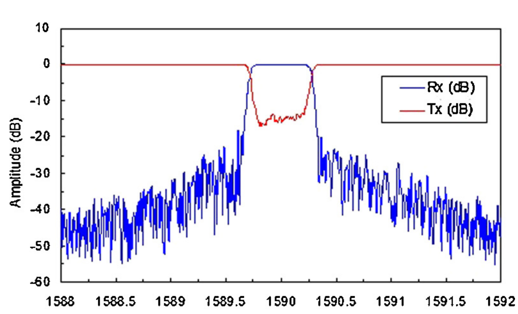

Fig. 2. The transmission and reflection characteristics of the CFBG.

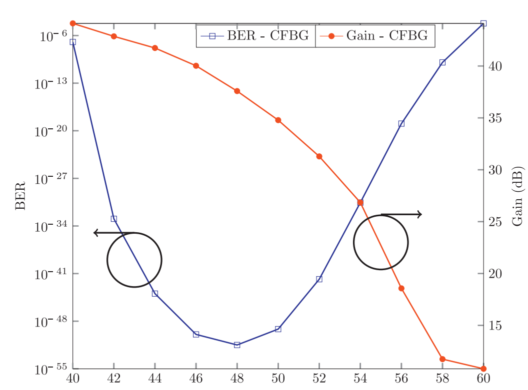

Fig. 4. BER and gain vs L2 and LR for RPDPC-EDFA.