Longest-ever unrepeatered transmission over 713.2km of 2.5 Gb/s with a span loss in excess of 111dB

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Abstract: Longest-ever unrepeatered transmission over 713.2km for 2.5G and 665.7km for 10G is achieved by employing 2.5G PM-BPSK,10G PM-QPSK, optimized ROPAs structure and ultra low loss & large effective area fiber link.

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1. Introduction

The goal of unrepeatered transmission systems is to bridge long distances without any in-line active elements.So far, several articles have reported unrepeatered transmission distance [1-5]. At 2.5Gb/s, forward and backward Remote Optically Pumped Amplifiers (ROPA) were used to achieve 570km transmission reach [1]. At 10Gb/s, transmission distance record is 645km by using enhanced ROPAs[3].Large effective area G.654 fiber has been applied in terrestrial system [6,7], and it is proven that the key parameters of ultra low loss and large effective area can provide higher launch power, lower link attenuation and longer transmission distance.

Here we report an unrepeatered transmission reach of 713.2km(111.9dB) for 2.5G and 665.7km(105.1dB) for 10G system, with the first application of 2.5Gb/s PM-BPSK format and 10Gb/s PM-QPSK format, which improve OSNR sensitivity and power tolerance of the system. Such ultra-long haul is enabled by the use of enhanced ROPAs configuration, coherent transceiver and ultra low loss & large effective area fiber. To the best of our knowledge, it is the newest record to date.

2. Experiment setup

The experimental setup is shown in Fig.1,and it is configured to transmit 2.5G or 10G at 1550.12 nm. The 2.5Gb/s signal is PM-BPSK modulated at 2.67Gb/s which accounts for the 7% overhead of the Hard-Decision Forward Error Correction (HD-FEC) code. The 10Gb/s signal is PM-QPSK modulated at 11.5Gb/s which accounts for the 15% overhead of the HD-FEC code. A Tunable Dispersion Compensation Module (DCM) is used to reduce the nonlinear effect. Two 100GHz pass-band filters are used to eliminate the ASE at the transmitter side and receiver side.

The span is assembled with a large effective area optical fiber which has an average chromatic dispersion of 19.8ps/nm/km and effective area of 130 μm^2.The transmission fiber link consists of three parts divided by the two RGUs. For the 2.5G transmission, the forward and backward ROPAs are located at 118.5 km and 170.3 km from the terminals. The middle span is adjusted to 424.4 km for a total link length of 713.2km and loss of 111.9dB (losses of the ROPAs are not included), resulting in an average fiber loss (including splices) of 0.157dB/km. For the 10G transmission, the forward and backward ROPAs are located at 128.9 km and 170.3 km from the terminals. The middle span is adjusted to 366.5 km for a total link length of 665.7km and loss of 105.1dB. The dedicated pump paths use the same fiber length of the signal paths. As shown in Fig.1, all the fiber lengths are verified by OTDR, and the loss is carefully measured by optical spectrum analyzer (OSA).

3. Transmission results and discussion

Fig.2 illustrates the simulated optical power of 2.5G channel over 713.2km and 10G channel over 665.7km. The best performance requires collective optimization of the signal launch power, forward and backward pump powers. The signal power launched in the fiber is -10.8dBm for 2.5G and -4.5dBm for 10G transmission. The forward signal path pump power launched at the transmitter side is 2780mW for 2.5G and 2330mW for 10G transmission. The same backward signal path pump power of 2670mW is used for 2.5G and 10G. For the dedicated pump path 1 and 2, the same pump power of 2820mW is used for both 2.5G and 10G. The forward ROPA is located at 118.5 km or 128.9km from the terminals. The residual pump powers reaching the forward ROPA are 12.2mW from signal path and 17.5mW, 18.2mW from pump paths for 2.5G, and 5.5 mW from signal path and 11.4mW, 11.2mW from pump paths for 10G.The forward gain is 11.9dB for 2.5G, and 15.4dB for 10G. The signal power after forward ROPA is 14.7dBm for 2.5G transmission, which is too high for 10G transmission. So in the 10G system, the first section is extended by 10.4km to 128.9km. The signal power after forward ROPA reduces to 11.7dBm for 10G transmission. As for the backward ROPA, the residual pump powers are 1.4mW from signal path and 1.99mW, 2.07mW from pump paths. The backward gain is 24.1dB for 2.5G, and 23.8dB for10G.

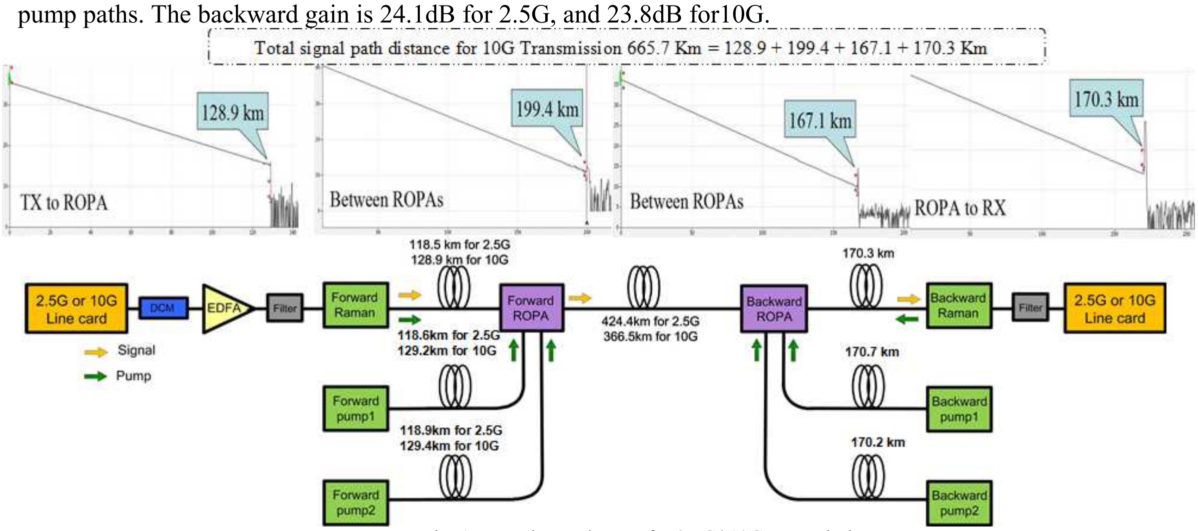

Fig. 1. Experimental setup for 2.5G/ 10G transmission

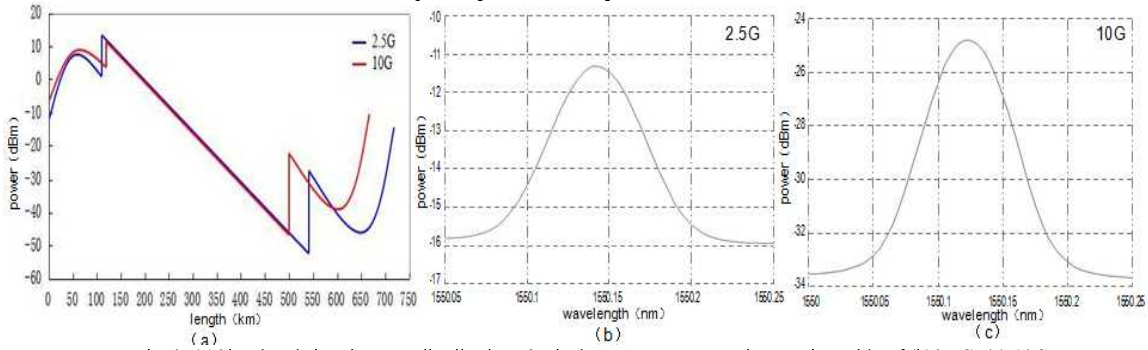

Fig. 2. (a)Simulated signal power distribution, Optical spectrum measured at receiver side of (b)2.5G, (c) 10G

The spectrum at the receiver side is shown in Fig.2. The OSNR of the signal channel is 0.36dB/0.1nm for 2.5G, and 6.47dB/0.1nm for 10G. The average pre-FEC BER over the duration of the test is 1.1E-03 for 2.5G and 2.5E-03 for 10G. Also the 24-hour BER stability test is good enough. Additionally, the absence of post-FEC errors on the client side was monitored using a BER-analyzer.

4. Conclusion

In this paper, we presented a new world record transmission of 713.2km(111.9dB) for 2.5G and 665.7(105.1dB) for 10G unrepeatered ultra long distance system with the first application of 2.5Gb/s PM-BPSK format and 10Gb/s PM-QPSK format. Such recording results are achieved by using enhanced ROPAs configuration, coherent transceiver, ultra low loss & large effective area fiber and commercial Raman pump modules.

5. References

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