Demonstration of 128×100-Gb/s Real-Time Coherent UDWDM-PON with >35-dB Power Budget

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Abstract: We propose a coherent UDWDM-PON scheme and experimentally demonstrate a real-time 128×100-Gb/s downlink coherent UDWDM-PON at 37.5-GHz channel spacing. The power budget can achieve more than 35 dB after 48-km SSMF transmission.
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1. Introduction

With the increasing bandwidth demands for high-speed passive optical network (PON), traditional direct detection and time division multiplexing (TDM) technologies cannot cope with the target of higher receiver sensitivity, larger network capacity and more number of users [1]. Therefore, ultra-dense wavelength-division multiplexing (UDWDM) PON based on coherent detection technology become an effective solution for the future optical access network (F-OAN) [2]. In recent years, we have experimentally demonstrated several real-time coherent UDWDM-PON systems. A 40×10-Gb/s coherent UDWDM-PON over 40-km field-installed fiber is experimentally demonstrated at channel spacing of 5-GHz [3]. A real-time bidirectional UDWDM-PON supporting 1000 users at maximal data rate of 10-Gb/s with 5-GHz spacing for each user is also reported in [4]. Most recently, a real-time 4×25-Gb/s coherent UDWDM-PON at 12.5-GHz spacing over 50-km standard single-mode optical fiber (SSMF) is demonstrated in [5].

In this paper, a capacity of 12.8-Tb/s coherent UDWDM-PON scheme is proposed. We experimentally demonstrate a downlink 128×100-Gb/s coherent UDWDM-PON at 37.5-GHz channel spacing in C-band. The DP-QPSK coherent modules integrated with real-time digital signal processing (DSP) are used at optical line terminals (OLT) and optical network units (ONU) to generate/receive 100-Gb/s signals. After 48-km SSMF transmission, more than 35 dB power budget can be achieved considering the forward error correction (FEC) threshold of 1×10^{-2}.

2. Configuration of 128×100-Gb/s Coherent UDWDM -PON

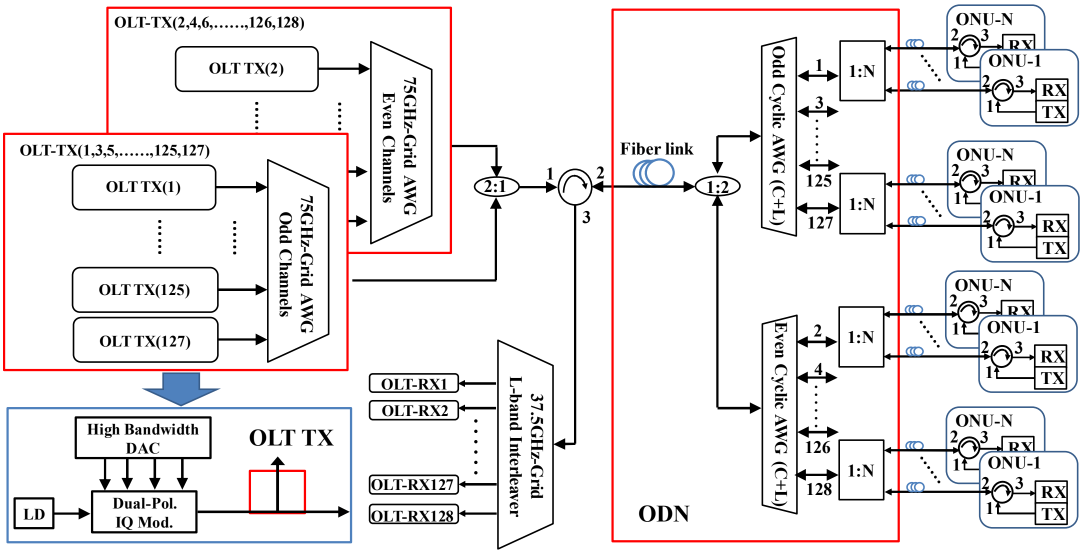

Fig. 1 Configuration of 128×100-Gb/s coherent UDWDM-PON with optical distribution network.

The configuration of the proposed coherent UDWDM-PON is described in Fig. 1 [6]. The system can support 128 optical signal channels and each channel carries 100-Gb/s signals within the bandwidth of 37.5-GHz. The channels are divided into odd and even groups with 64 channels in each group. The downlink signals are multiplexed by two 75-GHz grid arrayed waveguide gratings (AWGs) with their central wavelengths difference of 37.5-GHz. The 100-

Gb/s optical signals can be generated by one set of laser and IQ modulator based on high-bandwidth DAC [7], as shown in the inset of Fig. 1.

In the optical distribution network (ODN), the downlink optical signals are also divided into odd/even groups. Two cyclic AWGs with same characteristics as those at the OLT side are then used to de-multiplex 128-channel 100-Gb/s signals. Then, each channel optical signal is split into *N* parts by a 1:*N* power splitter and launched into the corresponding ONUs. Each ONU includes one optical circulator and coherent transceivers for coherent detection of downlink optical signals and generation of uplink optical signals. Therefore, the upstream data rate of each user is 100/N-Gb/s and the value of *N* can be determined according to the corresponding power budget in the practical system. In the uplink, the optical signals are firstly multiplexed in time domain from *N* ONUs and then combined by the two cyclic AWGs with 75-GHz grid the in same way as downlink. After transmission over ODN, a 37.5-GHz grid interleaver is used to de-multiplex the uplink optical signals, which are coherently recovered at the OLT side.

3. Experimental Setup and Results

The experimental setup of the 128×100-Gb/s coherent UDWDM-PON system is shown in Fig. 2. At the OLT side, two 75-GHz optical frequency comb generators are used to generate odd and even optical carrier groups with 64 channels in each group. Two groups of optical carriers are injected into two 100-Gb/s DP-QPSK integrated modules to produce 128-channel 100-Gb/s modulated signals. Another DP-QPSK integrated module to generate optical signal for test channel is driven by an external cavity lasers (ECL). The outputs of the DP-QPSK modules are then spectral shaped and combined by one C-band wavelength selective switch (WSS). The WSS is also used to select the test channel by programming the shape of spectrum and tuning the wavelength of ECL. It is noted that the decorrelation between the test channels are guaranteed by partitioning them into odd and even groups and adding optical delay line (ODL) on one group. In this way, the 128-channel modulated optical signals are generated and the optical spectrum in the downlink is shown in the inset (I). After transmitted over 48-km SSMF, a programmable WSS is used to filter one channel in the ODN. The optical power is controlled by a variable optical attenuator (VOA). A semiconductor optical amplifier (SOA) is used to amplify the received power in ONU side. Finally, the optical signals are coherently received by the DP-QPSK coherent module and the bit error rate are countered by a BER monitor. The recovered constellations of two polarizations at the receiver side are shown in the inset (II). The DP-QPSK integrated module is shown in the inset (III).

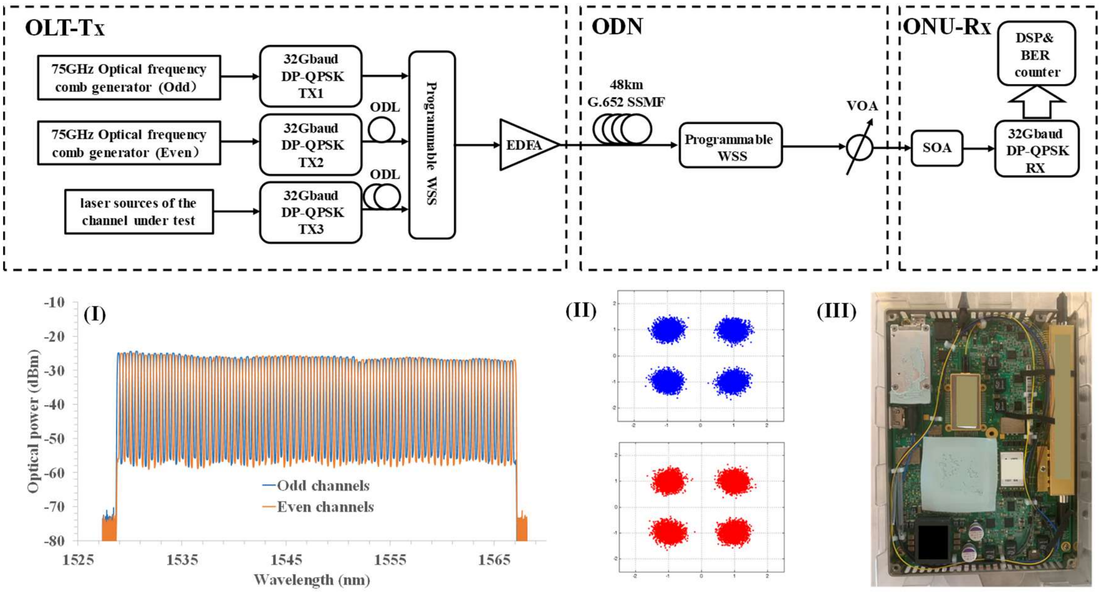

Fig. 2 experimental setup for 128×100-Gb/s coherent UDWDM-PON in downlink. (I) Optical spectrum downlink optical signal; (II) Constellation recovered at the ONU of two polarizations; (III) 100-Gb/s DP-QPSK coherent integrated modules.

We first investigate the BER performances of the selected 64th channel of downlink signal at back-to-back (BTB) case. The results are shown in Fig. 3(a). When SOA is used at the ONU side, the receiver sensitivity can achieve -35 dBm at the BER threshold of 1×10^{-2} with only one channel signal transmitted. But the receiver sensitivity without SOA is -29 dBm, which means the SOA can bring 6-dB power improvement at the ONU side. The transmission penalty is negligible when the 128 channels optical signals are all launched into the fiber link. It means the crosstalk and nonlinear effects have little effect on the downlink channels. We also measure the BER performances of other channels when the 128-channel optical signals are all transmitted over 48-km SSMF with SOA used in the receiver side. It can be seen from Fig. 3(b) that the BER performances are similar on the selected 6th, 35th, 64th, 93rd and 123rd downlink channels.

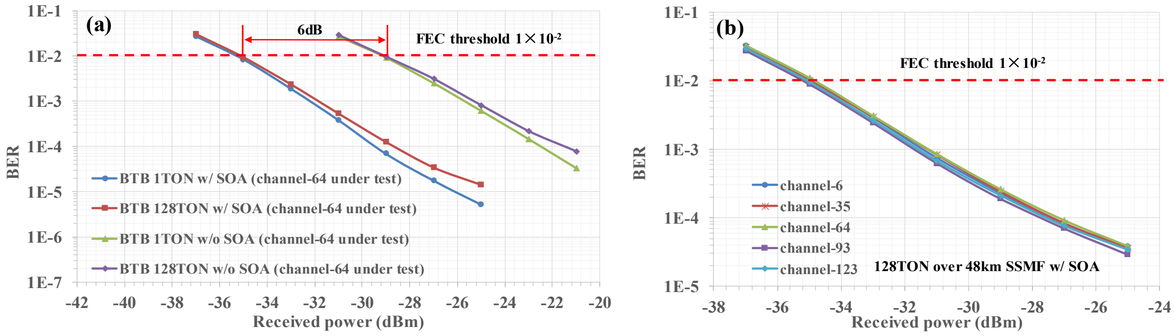

Fig. 3 (a) BER versus received power with/without SOA in B2B case, (b) BER of selected WDM channels after 48-km SSMF.

Then we identify the optimal launch power considering the 64th channel when all the 128-channel signals are transmitted after 48-km SSMF. The received power of the 64th channel is fixed at -33 dBm. As shown in Fig. 4(a), the optimal input power is 22 dBm (about 1 dBm for each channel). Further increase of input power will result in the performance degradation due to the nonlinear effects in the transmission system. The nonlinear effects are mainly caused by the four-wave mixing effect in the fiber link. The corresponding largest power budget is more than 35-dB according to the receiver sensitivity of -35 dBm. Finally we measure the BER performances of all the 128 downlink optical channels at the power budget of 35-dB. As shown in Fig. 4(b), all the optical signals can achieve BER threshold of 1×10^{-2}. The corresponding full optical spectrum in the C bands is also depicted in Fig. 4(b).

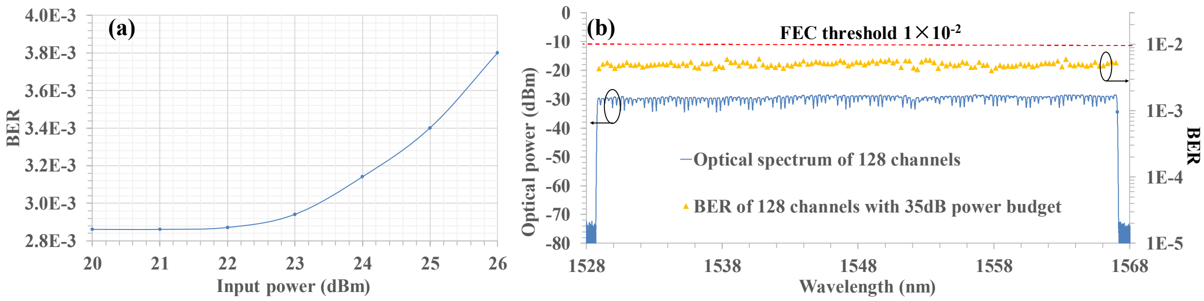

Fig. 4 (a) BER versus launch power after 48-km SSMF of select channel, (b) BER of all WDM channels and optical spectrum after 48-km SSMF in downlink.

4. Conclusions

We experimentally demonstrate a real-time coherent UDWDM-PON system in downlink over 48-km SSMF transmission with channel capacity of 128×100-Gb/s at 37.5-GHz spacing. The real-time DP-QPSK coherent integrated modules are used to generate and receive 100-Gb/s DP-QPSK signal at the OLT and ONU sides. The system performance is also evaluated for all the channels, which can achieve power budget more than 35 dB based on the proposed coherent UDWDM-PON scheme.

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5. References

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