11.5-Gb/s OFDM Transmission over 640km SSMF using Directly Modulated Laser

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Abstract

We show 11.5-Gb/s optical OFDM transmission over 640km SSMF with directly modulated laser (DML) and direct-detection without dispersion compensation. DML can reduce the system complexity and cost.

Introduction

Orthogonal frequency division multiplexing (OFDM) technology has attracted lots of attention in last two years. It is believed that OFDM will become a strong candidate for modulation technologies in the next generation long-haul and access networks because of its high spectrum efficiency and the resistance to variety dispersions including chromatic dispersion. Single sideband modulation and coherent detection [1, 3] is usually employed to avoid the serious chromatic dispersion coming from the large signal bandwidth and long transmission distance, where optical phase lock loop and polarization scrambler are required to control the phase/polarization for the LO at the receiver and low line-width lasers are preferred at both the transmitter and receiver. Schmidt [2] has also demonstrated a direct-detection method for optical OFDM using the optical carrier. Compared with the traditional coherent detection, the direct-detection method can significantly simplify the system complexity and eliminate the phase noise and frequency offset so that the conventional DFB lasers can be used without severely degrading the performance (only 1dB worse).

To our best knowledge, only ECL or DFB lasers [6~12] were used for optical OFDM long-haul transmission experiment. In this paper, we showed the experiment of OFDM using DML and direct-detection to further reduce the system complexity and cost. Transmission of 11.5-Gb/s SSB-OFDM is achieved over 640km SSMF.

Experimental Setup

Fig. 1 depicts the experimental setup for the SSB-OFDM transmission over 640km SSMF using the DML and direct-detection. At the transmitter, an OFDM baseband signal was generated offline and uploaded into a Tektronix AWG 7102 arbitrary

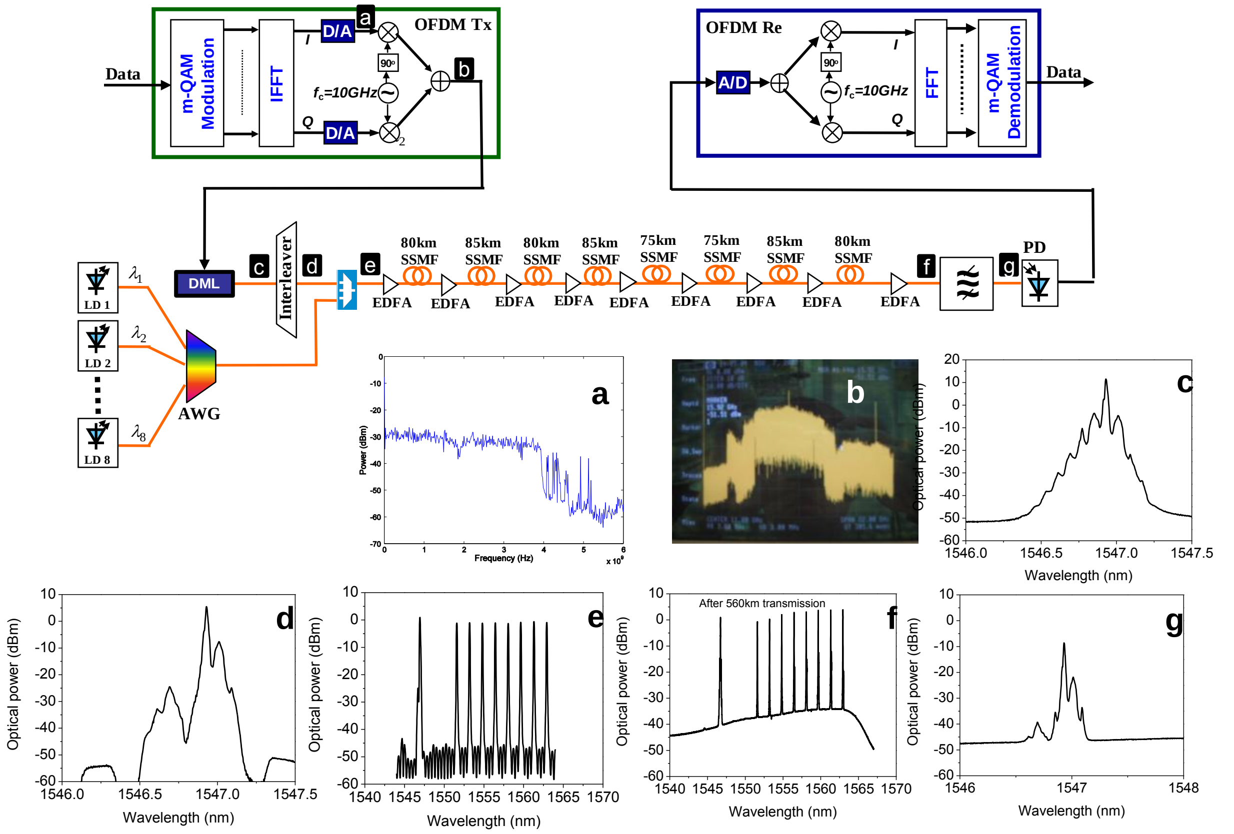

Figure 1. Experimental Setup for SSB-OFDM Transmission over SSMF with DML and Direct-Detection (a) Baseband OFDM signal; (b) RF OFDM signal at 10GHz carrier; (c) Optical DSB-OFDM signal; (d) Optical SSB-OFDM signal after optical interleaver; (e) WDM transmission; (f) Received WDM signal; (g) Received optical SSB-OFDM signal after filter.

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waveform generator (AWG). The waveforms produced by the AWG were continuously output at 10Gsample/s and 10-bits DAC and the output bandwidth was 5GHz based on the Nyquist law.

QPSK was used to map bit stream data to each OFDM sub-carrier. The FFT size used was 256 and 1/32 cyclic prefix (CP) was applied. The first 25 and last 24 sub-carriers were set to zero so that the operative baseband OFDM signal bandwidth was 4GHz. Training sequence was added every 256 OFDM data frames. An analog IQ-mixer up-converted the OFDM signal from the baseband to a 10GHz radio frequency (RF). The DML at 1546.95nm was modulated by the 14GHz RF OFDM signal with 8GHz bandwidth at 10GHz carrier frequency. The optical spectrum after the modulator is shown in Fig. 1(c). The second-order components can be suppressed to about 20 dB less than the first-order side bands by carefully adjusting the input RF OFDM signal power and the bias of the modulator. A 25/50GHz optical interleaver with 35dB channel isolation was used to separate one first-order sideband from the optical carrier and the other first-order sideband as shown in Fig. 2(d). The SSB-OFDM signal was then combined with another 8 CW laser array using an optical multiplexer and amplified/transmitted through fiber. All fiber is SMF-28 with dispersion of 17ps/nm/km and insertion loss of 0.2dB/km at 1550nm. The total input power into the SMF-28 is 8dBm. The fiber length is around 80km for each amplifier span, the detail information can be seen in Fig. 2.

At the receiver, SSB-OFDM signal was filtered by a tunable optical filter (TOF) with a bandwidth of 0.3nm. The direct-detector was a 45GHz IR photo-detector. The received RF OFDM signal was sampled first then down-converted by a Tektronix real-time oscilloscope (TDS6154C) at 40Gsample/s. The digital signal processing work was done off-line.

Experimental Results and Discussion

Figure 2 gives the OFDM baseband spectrum after 640km SSMF transmission. The 10-Gb/s OFDM BER performance after different transmission distance has been shown in Figure 3.

One preamble frame was added every 256 OFDM data frames for timing synchronization and channel equalization. The BER was measured only for 148 sub-carriers out of total 206 operative sub-carriers. Therefore, the bit rate of 640km transmission BER measurement was 11.5-Gb/s. For all BER reported in this paper 1 million bits have been evaluated. After 640km SSMF transmission, the bit rate before coding was 11.5-Gb/s. 7% was used for FEC coding, 3.13% for CP and 0.39% for preambles. As a result, the bit rate after coding is 10-Gb/s.

A BER below 2×10^{-3} which satisfied the EFEC limit can be obtained after 640 km SSMF transmission. This represents an excellent transmission performance where a BER of 1×10^{-9} or less is obtained with the help of FEC.

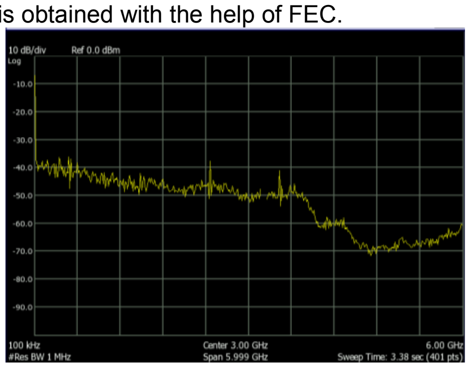

Figure 2. OFDM baseband spectrum after 640km SSMF transmission

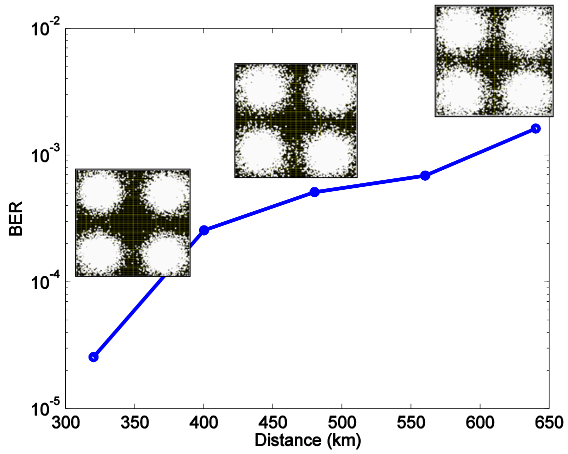

Figure 3. BER performance over 640km SSMF

Summary

For the first time, we have shown how to use DML for optical OFDM transmission with direct-detection in the optical metro and access networks. The architecture can eliminate the local oscillator, optical phase lock loop and polarization scrambler from the receiver. The low line-width lasers for the coherent detection has also been replaced by low cost DML, therefore, both cost and complexity can be reduced. We also experimentally demonstrated successful transmission of 11.5-Gb/s (10-Gb/s after coding) optical OFDM transmission over 640km SSMF with DML and direct-detection.

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