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1.5 Tbit/s (75 x 20 Gbit/s) DWDM TRANSMISSION USING Er^{3+}-DOPED TELLURITE FIBER AMPLIFIERS AND A SINGLE OTDM DEMULTIPLEXING SCHEME

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Abstract *1.5 Tbit/s (75 x 20 Gbit/s) DWDM transmission with 61 nm continuous bandwidth over 200 km was successfully demonstrated by employing Er^{3+}-doped tellurite fiber amplifiers and a single OTDM demultiplexing scheme using injection locking mode-locked laser diode for subharmonic optical clock recovery.*

Introduction

DWDM transmission systems allow us to realize large capacity optical communication at relatively low cost. The transmission capacity of DWDM systems depends on the bandwidth of optical amplifiers and spectral efficiency. Total signal bandwidth of 64 nm using C-band and L-band has been demonstrated [1]. However, optical amplifiers have to be separated for each band as long as silica-based EDFA's are used. Therefore, there have been several nm bandwidths that were not used for signal transmission between both bands. Continuous signal bandwidth transmission is much favorable in increasing transmission capacity and decreasing system complexity. Raman amplification is very attractive to realize continuous band transmission [2]. Another candidate is to use Er^{3+}-doped tellurite fiber amplifiers (EDTFA's) [3]. An EDTFA amplifies signals ranged over C- and L-bands continuously. So far, continuous signal transmission in both bands using EDTFA's has been demonstrated only in [4] and [5]. Meanwhile, injection locking mode-locked laser diode (MLLD) is an attractive device for subharmonic optical clock recovery [6] for ultra-high speed transmission systems. If the clock recovery scheme with MLLD is applied to a broadband DWDM system, it is desirable that the scheme covers the entire bandwidth.

In this paper, we demonstrate 1.5 Tbit/s (75 x 20 Gbit/s) DWDM transmission experiment with 61 nm continuous bandwidth over 200 km by employing EDTFA's. We use only a single OTDM demultiplexing scheme with an injection locking MLLD and an electro-absorption modulator (EAM) for the entire bandwidth.

Experimental setup

A schematic diagram of the experimental setup is shown in Fig. 1. The setup is identical with the previous experiment [5] except for the demultiplexing scheme. The seventy-five DFB lasers operating between 1536.61 nm and 1597.19 nm with a channel spacing of 100 GHz, were multiplexed with a polarization-maintaining arrayed-waveguide grating (PM-AWG) after equalizing optical signal powers with polarization-maintaining variable optical attenuators (PM-VOA's). 75 WDM x 20 Gbit/s return-to-zero (RZ) signals were generated by using an RZ modulator operated at 20 GHz, and a $LiNbO_3$ intensity modulator. The 20 Gbit/s data was multiplexed from two 10 Gbit/s data with an electronic time division multiplexer (ETDM). The data pattern was pseudorandom 2^{23}-1. The pulse width of the RZ signals was 28 ps. The transmission line consisted of two spans of large effective area standard single mode fiber (SMF) of 74 km, negative dispersion fiber (NDF) of 26 km, and EDTFA. The period of the dispersion management was 50 km. The span loss was about 21 dB. The zero-dispersion wavelength was 1538 nm. The dispersion slope of the entire transmission line including the EDTFA's was less than 0.015 ps/nm^2/km in the entire bandwidth. The launched power to the fiber spans was +18.5 dBm. After transmission, the desired signal was selected by WDM demultiplexer (DEMUX). In the OTDM DEMUX scheme for 20 Gbit/s-to-10 Gbit/s, the MLLD

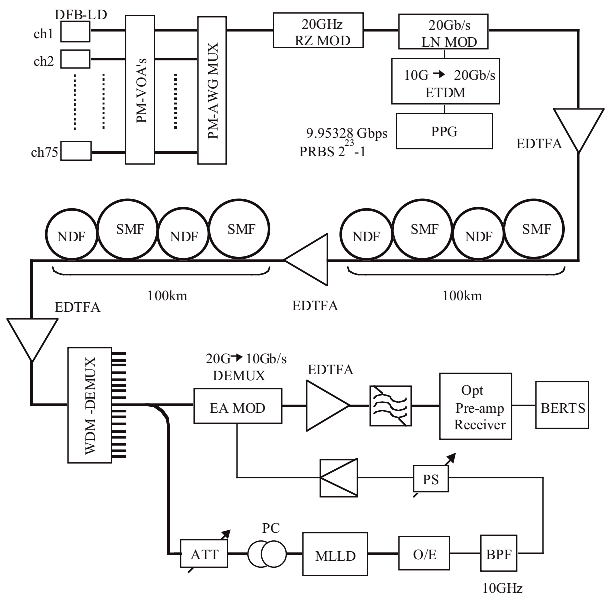

Fig. 1 Experimental setup.

generates 10 GHz optical clock pulses by injecting 20 Gbit/s optical RZ signal. Bit error rate (BER) of each channel was measured after the DEMUX.

Results and discussions

Fig. 2 (a) and (b) show the optical spectra of the signals (a) before and (b) after transmission, respectively. We slightly pre-emphasized the signal power of longer wavelength channels because of the wavelength dependence of the EAM absorption in the OTDM DEMUX.

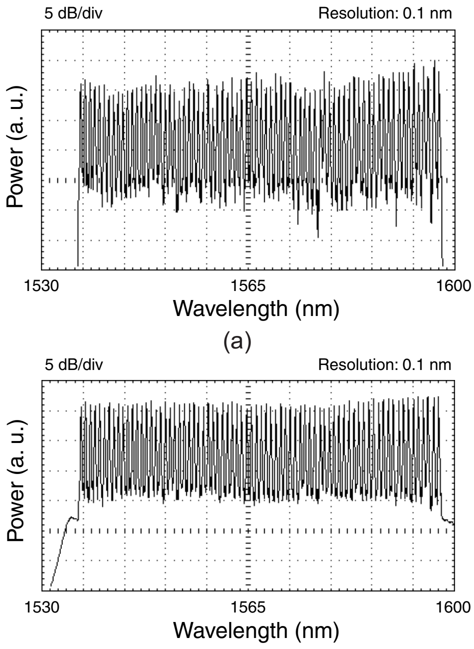

Fig. 2 Optical spectra of the signals (a) before and (b) after transmission.

In the OTDM DEMUX scheme, we tuned the free-running lasing wavelength of the MLLD to 1555 nm when the signal wavelength is < 1583 nm, and 1558 nm when the signal wavelength is > 1583 nm, respectively. The DC bias and the RF driving voltages for the EAM were fixed for the entire bandwidth. Fig. 3 shows eye diagrams of the transmitted signals after OTDM DEMUX. As seen from the figure, demultiplexing operation is successfully achieved with the single DEMUX scheme. We can also see however, small degradations of signal to noise ratio (SNR) and extinction ratio between mark and space for longer wavelength channel, which are mainly because of the wavelength dependences of the EAM absorption and the $LiNbO_3$ intensity modulator, respectively. The SNR degradation can be reduced if the DC and RF voltages to the EAM are optimized in accordance with the signal wavelength. Fig. 4 shows the measured BER for the 75 WDM channels after 200 km transmission. All the measured BER's were less than 1×10^{-9}.

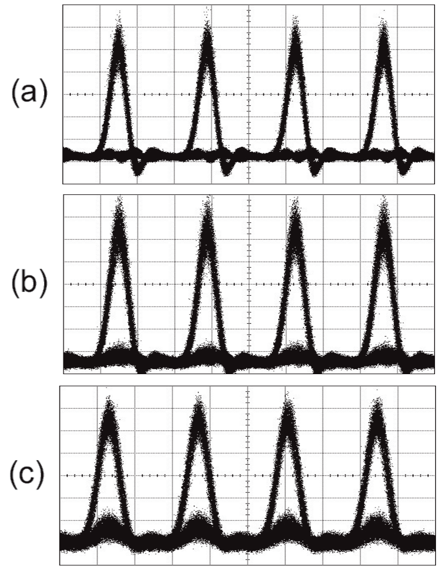

Fig. 3 Eye diagrams of the transmitted signals after 20 Gbit/s-to-10 Gbit/s OTDM DEMUX. (a) ch1 (1536.61 nm), (b) ch38 (1566.31 nm) and (c) ch75 (1597.19 nm).

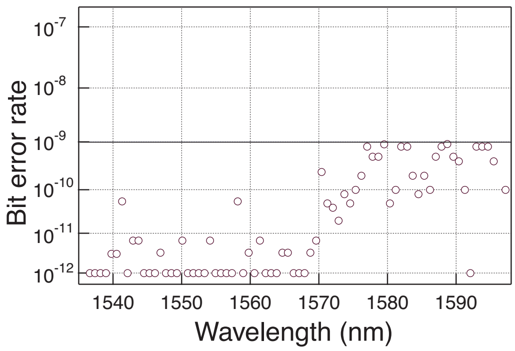

Fig. 4 Measured BER performances of 75 WDM channels.

Conclusions

We have successfully demonstrated 75 x 20 Gbit/s DWDM transmission over 200 km with continuous signal bandwidth of 61 nm using EDTFA's. We used only a single OTDM DEMUX scheme with an injection locking MLLD for subharmonic optical clock recovery. Further transmission capacity increases can be obtained by increasing spectrum efficiency and full utilization of amplifier bandwidth of EDTFA.

References

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