24th European Conference on Optical Communication (ECOC'98), MoC05, pp. 91-92, Madrid (1998)

INFLUENCE OF NOISE IN OPTICAL PULSE SOURCE ON SOLITON TRANSMISSION

Hiroyuki Toda, Katsuyuki Mino, Yuji Kodama, Akira Hasegawa, and Peter A. Andrekson*

Graduate School of Engineering, Osaka University
2-1 Yamada-Oka, Suita, Osaka 565 Japan
phone: (06)879-7728 fax: (06)879-7774 e-mail: toda@comm.eng.osaka-u.ac.jp
*Department of Microelectronics ED, Photonics Laboratory, Chalmers University of Technology
S-412 96 Göteborg, Sweden

Abstract: We performed a 10 Gbit/s optical soliton transmission experiment in a sliding frequency loop and found that the noise in optical source decreased error free distance. The Gordon-Haus timing jitter is theoretically analyzed to verify experimental results.

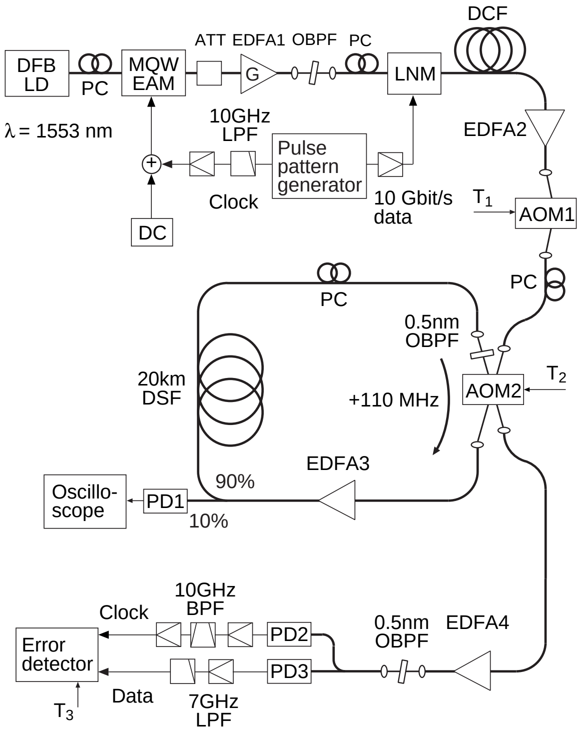
Introduction

Optical soliton transmission[1] is one of the most attractive techniques for future optical communication systems because of their potential of long-haul and/or high bit-rate communication. In a transoceanic optical soliton communication system using rare-earth-doped optical fiber amplifiers, sliding guiding filters to control the soliton amplitude and frequency may be effective in reducing the Gordon-Haus timing jitter and ASE noise accumulation. However, the amount of dispersive wave (non-soliton components) included in optical pulse source should be minimized since the radiative dispersive waves affect transmission quality[2-4]. In this paper, we show that noise in optical pulse source decreases error free distance even with sliding frequency soliton control in an experiment of 10 Gbit/s optical soliton transmission.

Experiment

Figure 1 shows the experimental setup. 10 Gbit/s optical pulses of 1553 nm are generated by a DFB laser diode, an MQW electro-absorption modulator (EAM) which is driven by a - 2.1 V dc and a 10 GHz RF signal of + 13 dBm, and a $LiNbO_3$ intensity modulator. The insertion loss of the EAM without applied voltages is 11 dB. In order to change the noise level of the pulse source, we inserted an optical variable attenuator (ATT) right after the EAM. The pulse width after the dispersion compensating fiber (DCF) with the group delay dispersion of - 50 ps/nm used for chirp compensation was 16 ps. The recirculating loop was constructed by a 20-km dispersion-shifted fiber (DSF), with propagation loss of 0.21 dB/km, and dispersion parameter D of 0.88 ps/nm/km at the signal wavelength. An acousto-optic modulator (AOM2) and an optical band pass filter (OBPF) with the 3-dB bandwidth of 0.5 nm were inserted in the loop as the frequency shifter and the guiding filter. The normalized filter strength is 0.58. The fiber collimators were aligned to pick up the +1-st order diffracted light of the AOM2 which was driven by a 110 MHz RF signal. Thus, the frequency of the transmitting light took + 110 MHz shift every round trip. The combined action of the frequency shift of AOM2 and the 0.5-nm OBPF acts as a sliding frequency soliton control[5, 6]. The noise figure (NF) of EDFA1 and EDFA3 was 10 and 6 dB, respectively. The ASE accumulation during transmission was suppressed due to the strong sliding frequency soliton control. The transmitted solitons were switched by the AOM2 and fed into fast photo diodes followed by an error detector to measure bit error rate (BER).

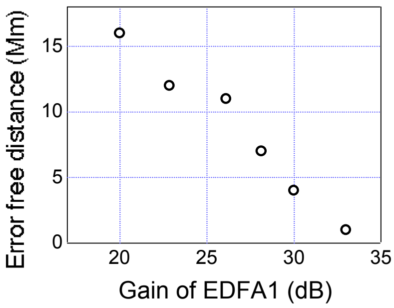
Figure 1: Setup for 10 Gbit/s soliton transmission experiment in a sliding frequency loop.



EAM : electroabsorption modulator, LNM : $LiNbO_3$ intensity modulator
AOM : acousto-optic modulator, OBPF : optical bandpass filter,

First, we measured BER versus transmission distance when the attenuation of the ATT is minimum. The gain of the EDFA1 G was 20 dB in this case. The obtained error free distance (EFD), where the BER of < 10^{-9}, was 16,000 km. Next, we increased the attenuation of the ATT and increased G in accordance with the attenuation in order to keep the output power constant. In this way, the noise included in the optical pulse at the transmitter can be increased. Figure 2 shows measured EFD versus G. As clearly seen, EFD is strongly affected by *G* and was only 1,000 km when *G* was 33 dB (ATT = 13 dB).

Figure 2: Obtained error free distance versus G, gain of EDFA1. The optical ATT was adjusted so that the output power of EDFA1 was constant.



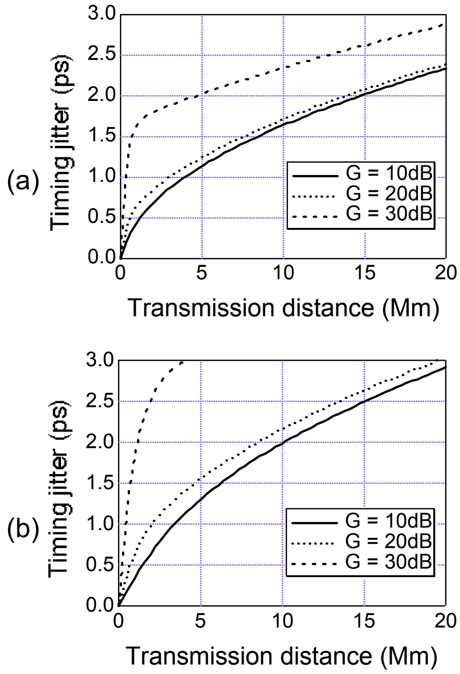
Theory and discussion

To investigate this phenomena, we derived an equation to obtain Gordon-Haus timing jitter(7). Figure 3 (a) shows the calculated jitter versus transmission distance with parameter *G*. The jitter is almost the same when $G < 20$ dB. However, when $G = 30$ dB, jitter is quickly increased with distance. This is because the mean frequency of soliton at the pulse source is modulated by the noise which results in the increase of timing jitter at the receiver even in the strong sliding frequency controlled soliton transmission line. To simulate a more realistic system, we calculated a timing jitter with a guiding-filter soliton system with pulse width of 20 ps, $D = 0.25$ ps/nm/km, EDFA spacing of 50 km, the NF of EDFA's in transmission line and the EDFA at transmitter is 5 dB and 7 dB, respectively. The bandwidth of the guiding filter placed at every EDFA is 1 nm. In this case, the normalized filter strength is 0.2. Figure 3 (b) shows the result. Since the effect of guiding filter is smaller, the jitter increases dramatically when $G = 30$ dB.

Conclusion

In conclusion, we investigated the influence of noise in optical pulse source on 10 Gbit/s soliton transmission. This influence should be taken care of in multi-channel WDM soliton systems using a single MQW EAM(8) since the input optical power level to the modulator is typically limited to several mW. The use of a low NF EDFA at the transmitter, several EAM's for pulse generation, or dispersion compensation scheme seems essential.

Figure 3: Calculated standard deviation of timing jitter of solitons at receiver versus transmission distance, (a) with sliding frequency control; (b) with guiding filter. For more detail, see text.



references

/1/ A. Hasegawa and Y. Kodama, "*Solitons in optical communications*," Oxford University Press, New York (1995).

/2/ L. F. Mollenauer, B. M. Nyman, M. J. Neubelt, G. Raybon, and S. G. Evangelides, *Electron. Lett.*, **27**, 178 (1991).

/3/ T. Widdowson, D. J. Malyon, X. Shan and P. J. Watkinson, *Electron. Lett.*, **30**, 661 (1994).

/4/ K. Iwatsuki, S. Kawai, S. Nishi, and M. Saruwatari, *IEEE/OSA J. Lightwave Technol.*, **13**, 639 (1995).

/5/ Y. Kodama, M. Romagnoli, and S. Wabnitz, *Electron. Lett.*, **30**, 261 (1994).

/6/ F. Fontana, L. Bossalini, P. Franco, M. Midrio, M. Romagnoli, and S. Wabnitz, *Electron. Lett.*, **30**, 321 (1994).

/7/ J. P. Gordon and H. A. Haus, *Opt. Lett.*, **11**, 665 (1986).

/8/ D. Le Guen, F. Favre, M. L. Moulinard, M. Henry, F. Devaux and T. Georges, D. Le Guen, F. Favre, M. L. Moulinard, M. Henry, F. Devaux, and T. Georges, *PDP of ECOC'97*, TH3A7 (1997).