9:15am - 9:30am
WC4

A New Model for Optical Interconnection Systems Including LD Turn-on Delay Effects

Seung-Woo Lee, Eun-Chang Choi* and Woo-Young Choi
Dept. of Electronic Engineering, Yonsei University, Seoul, Korea
*Electronics and Telecommunication Research Institute, Taejon, Korea

With the increasing bandwidth required for board-to-board data communication systems, optical interconnection is finding wider applications. In designing optical interconnection systems for such applications, zero-bias modulation of the transmitter LD can minimize power consumption and simplify drive circuits. However, zero-bias modulation may degrade the overall system performance due to LD turn-on delays. Consequently, LD modulation scheme should be carefully determined in order to optimize the overall system performance such as power consumption and the bit error rate. In [1], a simple analytical model for estimating the power consumption in optical interconnection systems for a required BER was presented. The model, however, does not include LD turn-on delay effects and, consequently, cannot accurately model the performance degradation due to turn-on delays. In this paper, we propose a new analytical model that includes LD turn-on delay effects and, with it, investigate system performance dependence on various LD bias schemes. In addition, we confirm the accuracy of our model with the detailed numerical simulation results.

The optical interconnection system investigated in this paper is made up of LD, driver circuits, fiber, PD, and receiver circuits as shown in Fig. 1. For a desired BER in such system, the minimum modulation current can be calculated from the following formula [1]:

$$I_m - I_{th} + I_b \geq [f(\sigma) + V_{sen} + Q \times (\sigma_{n1} + \sigma_{n0})]/(\eta_t R) \quad (1)$$

Here, I_m is the modulation current, I_b the bias current (See Fig. 1), and I_{th} the LD threshold current. $f(\sigma)$ is a function determined by process variations for components used, V_{sen} is the decision sensitivity, and σ_{n1} and σ_{n0} are receiver noise variations. η_t is the total link efficiency and R is the load resistance. In order to include the LD turn-on delay effects, we model the maximum turn-on delay $t_{d.max}$ as $t_{d.max} = \tau \ln[I_m/(I_m + I_b - I_{th})]$[2], where τ is the carrier lifetime in LD. The receiver circuit can be modeled with a Gaussian filter, having time-domain response h(B,t) where B is the bit rate. Then, Eq. 1 becomes

$$I_m - I_{th} + I_b \geq [f(\sigma) + V_{sen} + Q \times (\sigma_{n1} + \sigma_{n0})]/[\eta_t R \times h(B, t = t_{d.max})] \quad (2)$$

Solving the above equation provides the dependence of the minimum power consumption on the bit rate for a given BER. Figure 2 shows the results calculated with and without considering turn-on delay effects. The parameters used are $\tau = 3$ ns, $I_{th} = 3.0$ mA, and BER = 10^{-15}. Values for other parameters are same as in [1]. It is clear from the figure that inclusion of turn-on delay effects is a must for accurate system performance modeling. In addition, the minimum power consumption can be achieved with zero-bias modulation only if the bit rate is not too high, below 300Mbps in this case. Figure 3 shows the dependence of the minimum power on I_{th}. From the figure, the required minimum threshold current with which zero-bias modulation saves power can be easily determined. For example, at 500Mbps I_{th} should be below about 0.3mA in order to take a full advantage of the zero-bias scheme.

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Figure 4 shows the relationship between BER and transmitter power determined from our model for various bias conditions and bit rates. From data like this, the optimal bias condition for the minimal power consumption can be easily determined.

In order to verify the accuracy of our model, we performed numerical simulation of the entire optical interconnection system. The LD power output was obtained by numerically solving LD rate equations. Fiber, PD, and the receiver were modeled with their characteristic system functions. The results from the numerical simulation agree well with those obtained from the analytical model. For example, the minimal transmitter power needed for BER of 10^{-15} at 500Mbps was 14.1dBm from the analytical model and 14.2dBm from the simulation. In short, we proposed a new analytical model for optical interconnection systems that is simple and accurate and can be very useful for analyzing and designing optical interconnection systems for board-to-board communication applications.

Reference

[1] M. Yoneyama, et al., J. Lightwave Technol., vol. 14, no. 1, pp. 13-21, Jan. 1996.

[2] L. P. Chen and K. Y. Lau, IEEE Photon. Technol. Lett., vol. 8, no. 2, pp. 185-187, Feb. 1996.

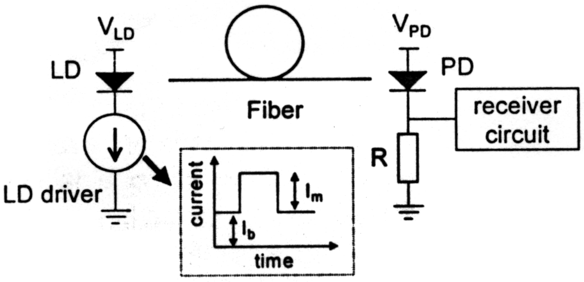

Figure 1. A schematic for optical interconnection system investigated in the paper.

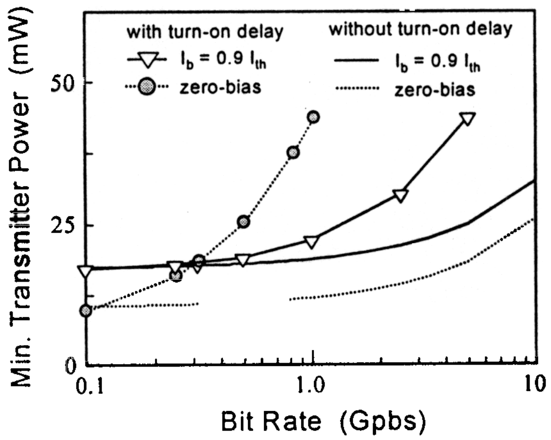

Figure 2. Dependence of min. transmitter power on bit rate for BER=10^{-15} with and without turn-on delay

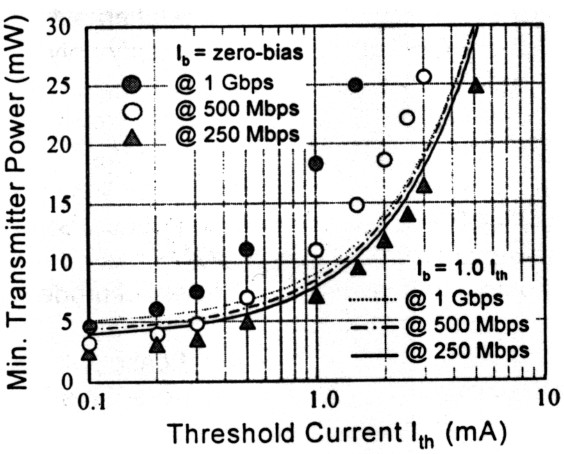

Figure 3. Dependence of min. transmitter power on threshold current I_{th} for BER=10^{-15}.

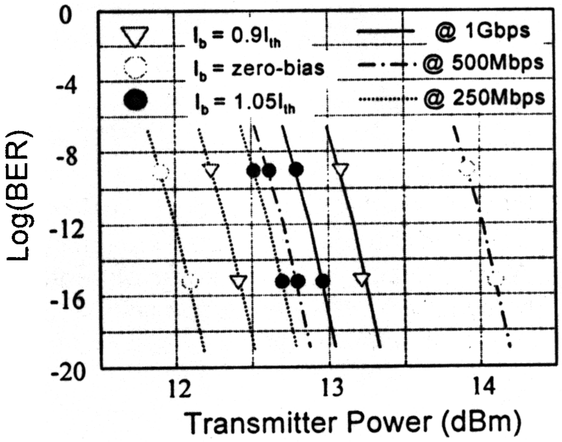

Figure 4. BER versus transmitter power for three different biases : I_b=$0.9I_{th}$, $1.05I_{th}$, and zero-bias