Contributed paper

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# Novel burst mode laser driver with just-at-threshold bias

Ł. ŚLIWCZYŃSKI* and P. KREHLIK

Institute of Electronics, University of Mining and Metallurgy
30 Mickiewicza Ave., 30-059 Cracow, Poland

*In the paper, the novel idea of burst mode laser driver with high extinction ratio is presented. The concept is based on controlling the bias current very close to the laser threshold, what is obtained by stabilising the laser power between the data bursts in the range of a few μW. The at-threshold bias eliminates the laser turn on delay, making the driver suitable to transmit the bursts of data without any prebiasing procedure. The experimental driver design is described and measurement results are reported.*

**Keywords:** laser driver, burst mode transmission, optical TDMA.

## 1. Introduction

Emergence of multiaccess optical networks introduced the time division multiple access (TDMA) technique to the fibre optic multipoint-to-point transmission systems. In this scheme each transmitter is allowed to be active only during individually prescribed time slot. Therefore data is sent in the form of packets and such transmission technique is described as a burst-mode. TDMA is employed in passive optical networks (PON) [1,2,3] used as a mean for communication between a number of optical network units (ONU) and optical line termination (OLT) in the upstream direction.

## 2. Requirements for laser drivers for TDMA systems

In TDMA systems, special requirements arise for the laser driver circuitry. First, no significant optical power may be emitted from laser except during the time slot prescribed to the particular transmitter. If some residual power was emitted from all inactive ONU transmitters it would build up at the OLT receiver input causing an undesirable pedestal limiting the dynamic range of the receiver and difficult to deal with. Thus, the laser power extinction during the idle state must be high, i.e., the idle power should be at least from –20 to –30 dB below the power emitted during the data burst.

The simplest method for high extinction required by TDMA systems is to switch off the laser bias current when the transmitter is in its idle state (i.e., it does not transmit the burst of data). However, when the laser has been turned off, the beginning of the data burst may be corrupted, due to the laser turn on delay effect [4,5]. To prevent optical signal distortion the bias current should be turn on in proper advance to the data burst, and/or some dummy bits should be transmitted before the valid data to resume laser action [6]. For moderate data rate (as 155 Mb/s) the method based on predistorting of the modulating current was proposed to compensate the laser turn on delay [7,8].

Additionally, because of the burst nature of transmission, the standard mean power stabilising loop cannot be used for laser bias control, and some other method should be implemented. Usually, the bias control loop is closed only during the burst transmission, and is opened (inactive) during relatively much longer idle state. During this time the bias controlling signal is stored in some kind of memory (i.e., the capacitor or digital memory), to avoid serious delay caused by recovering the steady state when the loop is closed again. The schematic block diagram of typical burst mode driver is shown in Fig. 1.

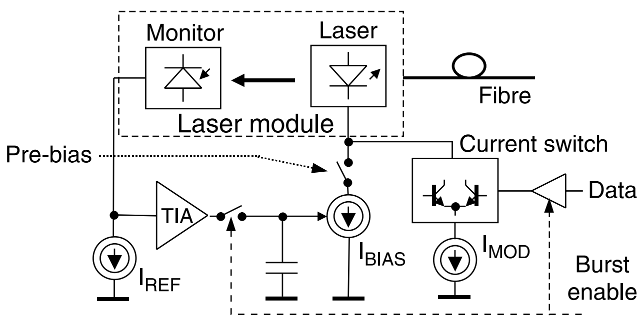


Fig. 1. Example of a typical burst-mode fibre optic transmitter.

The concept of the burst mode driver described above is not free from disadvantages, as it requires quite complicated control. In PONs duration of the data, burst is short (in the range of 360 ns for GigaPON to 2.8 μs for

*e-mail: sliwczyn@uci.agh.edu.pl

155 Mbit/s APON) [1,2]. Thus, the time available to measure and stabilise laser output power is quite short what is demanding for the transmitter electronics.

## 3. The novel concept of burst mode transmitter

In the contrast to the typical burst mode laser driver in the proposed solution, the bias current is not turned off during the idle state, but is permanently kept very close to the laser threshold current. This way high extinction ratio may be obtained and turn on delay may be avoided at the same time.

Measurements of some 1.3 μm and 1.55 μm MQW lasers from different vendors performed in various temperatures show that bias close to the threshold may be obtained by stabilising the idle optical power in the range of 2–10 μW. Higher power is undesirable because it reduces the extinction ratio. Lower may push the laser into spontaneous emission regime, what means substantial subthreshold biasing incurring optical signal distortion. Typical *P* versus *I* characteristics of MQW laser are shown in Fig. 2.

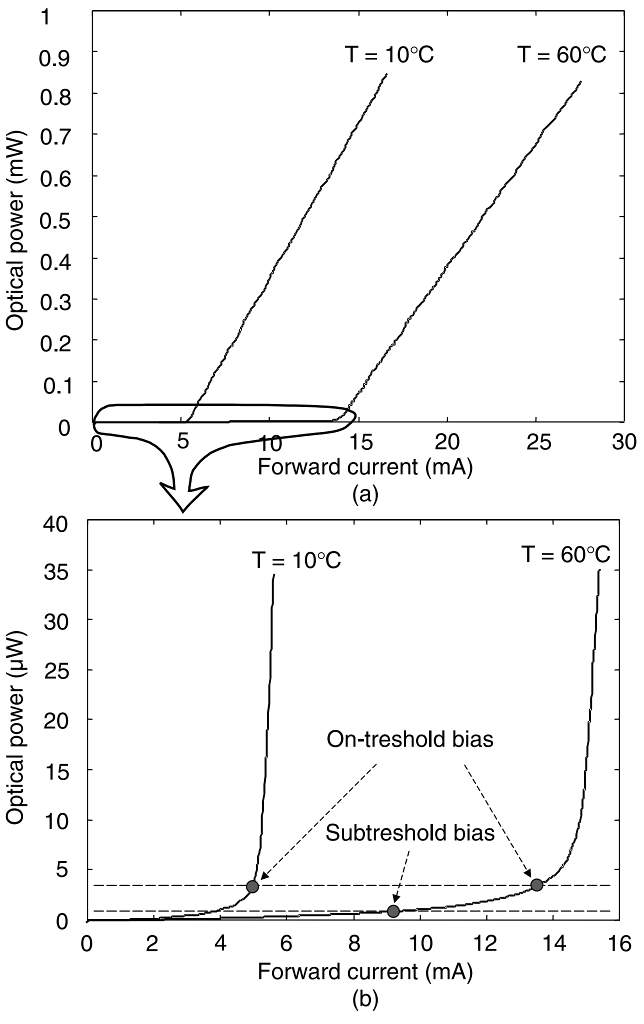


Fig. 2. Power versus forward current characteristics of MQW laser: in the full current range (a) and enlarged fragment close to the threshold (b).

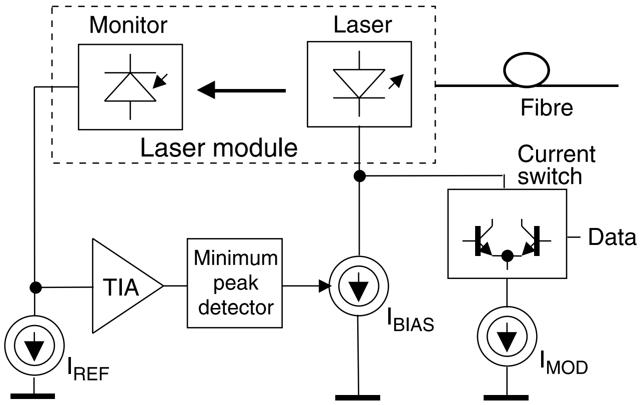


Fig. 3. Simplified block diagram of the proposed burst mode laser driver.

The block diagram of the proposed burst-mode transmitter is shown in Fig. 3. It comprises the laser module (including monitoring photodiode), reference current source, transimpedance amplifier (TIA), minimum-value peak detector, controlled biasing current source, and long tail current switch for laser modulation.

In the transmitter idle state (no data burst transmitted), the modulating current is switched off so the laser power and consequently the monitor current decrease to the value determined by the bias current. The minimum-value peak detector is active so its output signal is proportional to the difference between the monitor current and reference current. The peak detector drives the bias current source, what, via the optical coupling in the laser module, affects the monitor current, and this way the feedback loop is established. When the loop gain is high, the steady state is reached for monitor current equal (or very close) to the reference current $I_{REF}$. Thus, the reference current value and monitor photodiode sensitivity determine the idle state laser power regardless of ambient temperature variations and laser ageing.

During transmission of the data burst monitor current increases driving up the output of TIA. At the same time output of the minimum-peak detector stays fixed at the value determined in previous idle state. Thus, the feedback loop is opened and the bias current is not affected by the data pattern. In this transmitter state the laser current is switched between $I_{BIAS}$ (low optical power) and $I_{BIAS}$ + $I_{MOD}$ (high optical power) what represents logical "zeros" and "ones".

The solution takes advantage from the relatively long transmitter idle time, being at least a few s in fastest PON applications. Thus, the chain consisting of monitoring photodiode, TIA and peak detector need not to be very fast. This is important point because in the standard laser modules a monitoring photodiode is implemented as simple InGaAs PIN structure with relatively big area (300 μm diameter). The response of such photodiode is inherently slow because of its large capacitance (around 15 pF) and tailing effect, caused by the long time constant of diffusive component of photodiode current [9].

 

It should be noted that during the transmitter active state TIA is supplied with quite large current from the monitoring photodiode. Therefore, in order not to slow the circuit operation it is essential to equip TIA with clipping diode preventing it from strong overdrive.

In comparison to typical burst mode, the driver proposed solution presents some important advantages. Because the bias current is the same in idle and active states, there is no need for any control signals (like "burst enable" or "prebias"). In the idle state, the modulating signal should be simply set to logic "zero". Consequently, no dummy prebias bits are required to avoid turn on delay, and no light tail after burst appears (see Fig. 4). Additionally, there is no lower limit for data burst duration (what is essential for GigaPON applications), also there is no upper limit for idle time (what may be important in EPONs).

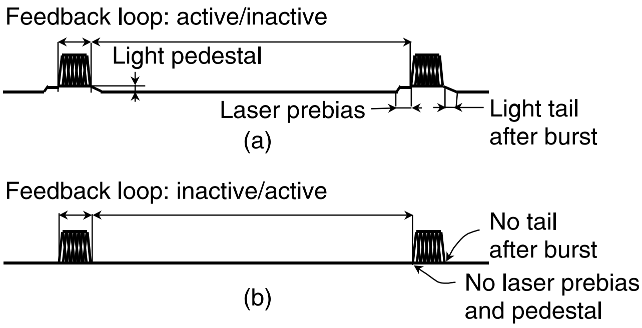


Fig. 4. Comparison of operation of burst-mode transmitter: typical (a) and described in the paper (b).

## 4. Experimental results

Using the concept described above, the experimental driver circuit was designed and examined. A simplified schematic diagram of the circuit is presented in Fig. 5. As the modulating current switch and the bias current source a part of IC continuos mode laser driver by Maxim is used. The monitoring photodiode is connected to IC transimpedance amplifier. The series resistor $R_S$ at the amplifier input separates it from relatively large photodiode capacitance what prevents the amplifier from instability. The second stage of amplification is realised using the PECL line receiver. Total transimpedance of the chain is $1.2\times10^6\ \Omega$. The second stage output emitter follower is not internally pulled down, thus it may be used as peak detector when loaded with the capacitor $C_D$. The resistor $R_D$ of large value assures slow discharge of the capacitor, what prevents the circuit from latch-up. A peak detector realised in this way measures the maximum value of its input signal, so the inverting output of amplifier is used to obtain minimum optical power detection. The signal from the peak detector is connected, via DC shift circuit, to the control input of the bias current source. This way the negative feedback loop stabilizing the idle optical power is established. The desired value of the

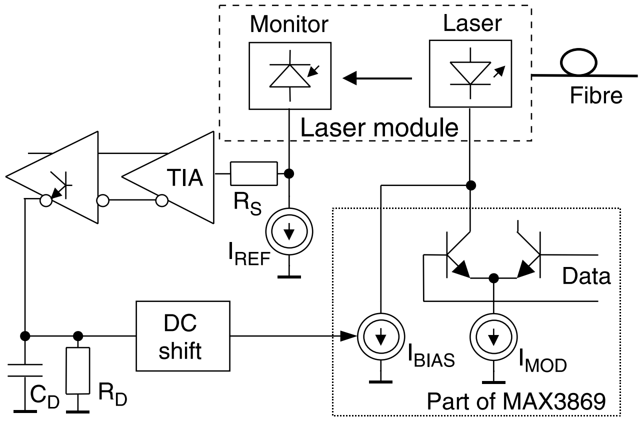


Fig. 5. Simplified schematic diagram of experimental driver circuit.

idle power is obtained by proper adjusting the reference current $I_{REF}$.

To asses performance of the proposed burst mode driver, the measurement set shown in Fig. 6 was built. The 1 Gb/s pseudo random bit sequence (PRBS) generator was gated by a pulse generator to obtain desired burst on/off duration. For eye pattern observations, the output of the photodiode module was terminated with 50 Ω to obtain full measurement bandwidth. To increase measurement sensitivity the load was changed to 1 kΩ when measuring weak optical power in idle state.

Four different lasers were used during the driver characterization. They were two FP MQW 1.3 µm devices: PT3343 by Photon and T13F by Lasermate, and two DFB MQW 1.55 µm devices: PT3563 by Photon and T15D by Lasermate.

As an example, the measurements performed for 380 ns long bursts with 10 µs repetition time are shown in Fig. 7. In the presented case, the idle state power was set to 2 µW, what is –28 dB below power transmitted in active state. It may be seen that the power in idle state was constant with no tailing after the burst [see Fig. 7(b)]. The beginning of

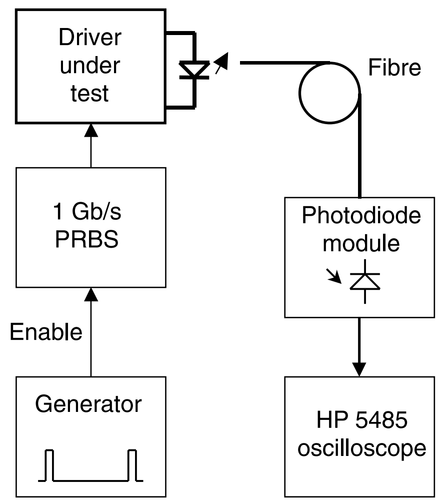


Fig. 6. Measuring set used for driver characterization.

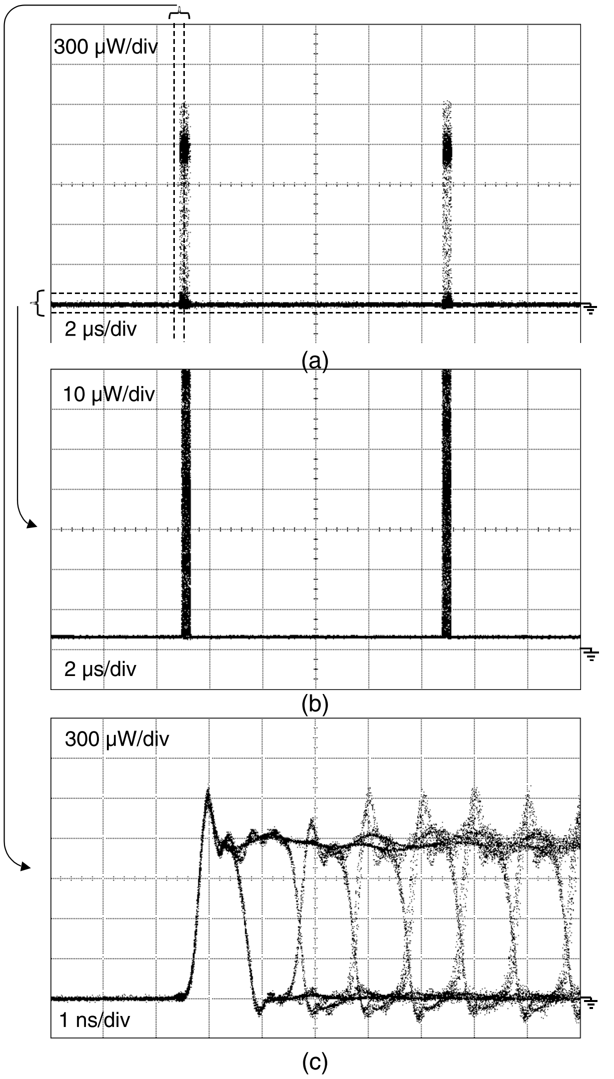


Fig. 7. Transmitter output for 380 ns/10 μs bursts, (a) general view, (b) low power region enlarged, and (c) beginning of the burst enlarged.

data burst was not affected by the turn on delay effect, and no significant jitter or duty cycle distortions were observed [see Fig. 7(c)].

In the measurements the burst duration was changed from 10 ns up to 100 ms. It was found that it had no observable influence on data eye pattern and idle state power. When varying the idle state duration (i.e., the interval between bursts) its lower limit was found. When the idle time was too short, the undesired reduction of bias current was observed. This resulted in optical power decrease and eye pattern distortions, caused by turn on delay. The origin of this effect is the monitoring photodiode current tailing, what disturbs the idle state power controlling. For lasers having InGaAs monitor, the minimum idle state duration (assuming 10% reduction of idle power) is about 10 μs. Much better results were obtained for lasers with heterostructure InGaAs/InP monitor displaying only minor tailing effect, like PT3343. In this case, the minimum idle state duration was about 1.3 μs.

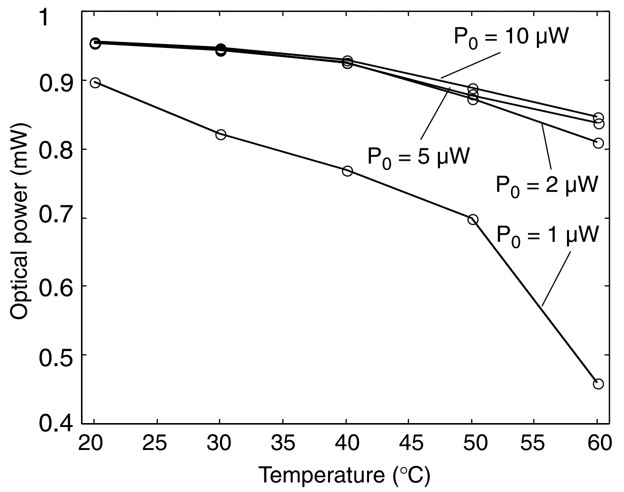


Fig. 8. Temperature dependence of logic "one" power for different idle state power values.

Next, the temperature behaviour of the driver was examined. The laser power and eye pattern distortion during the data burst was measured for various idle power values, for ambient temperatures in the range from 20°C to 60°C. The idle state laser power was set by the proper value of $I_{REF}$ and modulating current was left unchanged. The temperature dependence of laser power in active state, obtained with PT3343 laser is shown in Fig. 8. For the idle power equal to or greater than 2 μW, the active state power only slightly decreases with temperature. This is caused by the laser slope efficiency decrease, and eventually may be compensated by proper temperature dependence of modulating current. No pattern distortion was observed in the conditions mentioned above. However, when the idle power was reduced to 1 μW, the in-burst power becomes strongly temperature dependent, and significant duty cycle reduction and rising edge jitter was observed, especially for higher temperatures (see Fig. 9). This effect may be understood with help of Fig. 2. When driver stabilises the idle power at too small level (about 1 μW for the laser under test), the bias current is still close to the threshold for 20°C, but becomes significantly below the threshold for 60°C.

Similar results were obtained with three other lasers. The minimum idle state power need for robust operation was in range from 2 μW to 4 μW.

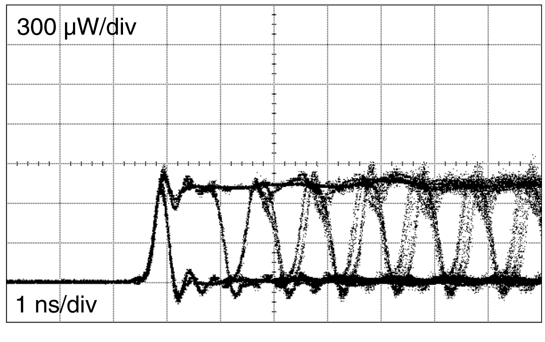


Fig. 9. Distorted eye pattern of burst beginning for $P_0$ = 1 μW, $T$ = 60°C.

## 5. Conclusions

The novel solution of burst mode laser driver with high optical power extinction was proposed and experimentally examined.

The concept is not to turn off the laser bias current during the transmitter idle state, but to control the bias in the way to hold the laser close to its threshold. Using nowadays MQW laser, the idle power as low as a few µW may be obtained using this method. The permanent at-threshold bias eliminates distortion of the beginning of the data burst, thus the circuit is suitable for high speed burst mode transmission, even in Gb/s range. In contrast to typical burst mode driver, the proposed circuit does not need any external control advancing the burst of data.

In difference to typical solutions, the presented driver has no any demands for minimum duration or duty cycle of data bursts. However, the requirement for minimum interval between consecutive bursts should be fulfilled for proper operation. For applications where the idle state is short, the lasers with heterostructure InGaAs/InP monitor are required.

## Acknowledgements

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## References

1. ITU-T Recommendation G.983.1, "Broadband optical access systems based on passive optical networks (PON)", ITU, 1998.
2. ITU-T Recommendation G.984.2, "Gigabit-capable passive optical networks (GPON). Physical media dependent (PMD) layer specification", ITU, 2003.
3. G. Kramer and G. Pesavento, "Ethernet passive optical network (EPON), building a next-generation optical access network", *IEEE Communications Magazine* **40**, 62–73 (2002).
4. L.A. Coldren and S.W. Corzine, *Diode Lasers and Photonic Integrated Circuits*, Wiley, New York, 1995.
5. P. Krehlik and Ł. Śliwczyński, "Modelling of dynamic performance of semiconductor lasers under subthreshold biasing", *Opto-Electron. Rev.* **12**, 187–192 (2004).
6. D. Verhulst, Y.C Yi, J. Bauwelinck, X.Z. Qiu, S. Verschuere, Z. Lou, and J. Vandewege: "Theoretical and experimental study of laser turn-on delay in a GigaPON systems with pre-biasing bits", *Proc. IEEE/LEOS Symposium*, Benelux Chapter, 290–293, Amsterdam, 2002.
7. M. Yano, K. Yamaguchi, and H. Yamashita, "Global optical access systems based on ATM-PON", *FUJITSU Sci. Tech. J.* **35**, 56–70 (1999).
8. E. Sackinger, Y. Ota, T.J. Gabara, and C. Fischer, "15 mW, 155 Mb/s CMOS burst-mode laser driver with automatic power control and end-of-life detection", *Proc. IEEE International Solid-State Circuits Conference*, (1999).
9. G.P. Agrawal, *Fiber Optic Communication Systems*, Willey, New York, 1997.

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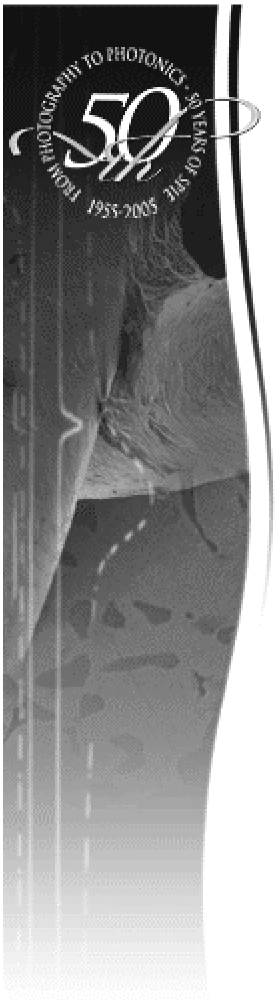


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