OPTICAL COMMUNICATIONS ON PHYSICAL ENGINEERING TEACHING

P. S. ANDRÉ, J. L. PINTO
Department of Physics, University of Aveiro, 3810 - 193 Aveiro, Portugal
Email: pandre@fis.ua.pt, jlp@fis.ua.pt

A. N. PINTO
Institute of Telecommunications, University of Aveiro, 3810 - 193 Aveiro, Portugal
Email: anp@av.it.pt

Abstract

In the last few years various techniques have been suggested to improve the performance of high capacity optical communication systems. In particular, the generation of optical solitons, the resolution of the limitations imposed by the chromatic dispersion and the performance of WDM systems and networks have been thoroughly discussed and investigated. In this paper it will be summarised some of the work carried out on the simulation and implementation of optical systems for high bit rate optical communication systems working at 1550 nm and its use on physical engineering teaching.

KEYWORDS: Optoelectronics, communications, physical engineering

Introduction

In high capacity optical communication systems, soliton transmission and electro-optical modulation have been key technologies to improve the performance of optical networks. Various techniques have been used for the generation of optical solitons, mainly fiber lasers, externally modulated DFB lasers and direct modulated lasers and to overcome the limitations imposed by the chromatic dispersion using negative chirp devices, mainly electro-optical Mach-Zhender modulators [1].

The integration of these topics in the undergraduate physical engineering course aims to focus on innovative and practical engineering applications and to establish effective links to national and international institutions, laboratories and enterprises. The experimental part of this work was carried out in a research telecommunications institute.

Optical soliton source

A soliton source based on a DFB laser with a bandwidth greater than 10 GHz emitting on the 1550 nm window has typically being used. By operating the laser on a non-linear regime of gain switching, it is possible to obtain very short optical pulses, suitable for high-speed lightwave telecommunication systems, from a quasi-sinusoidal modulation current. In this case the laser which have a threshold current of 11.55 mA was polarized with a current of 15 mA and modulated with a 2.5 GHz sinusoidal current with 20 mA of amplitude. In these conditions a 20 ps pulse with a bit rate of 2.5 Gb/s was obtained. The diagram of the soliton source can be found on Figure 1.

A Mach-Zhender modulator with a bandwidth greater than 10 GHz codes the pulses generated at the laser. A EDFA is used to achieve the correct peak power for a soliton pulse and his spontaneous emission noise is filtered by a band pass optical filter.

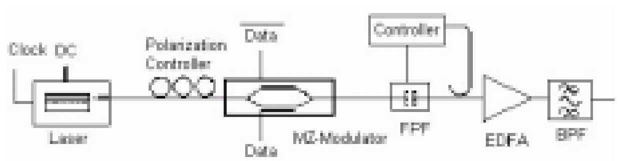
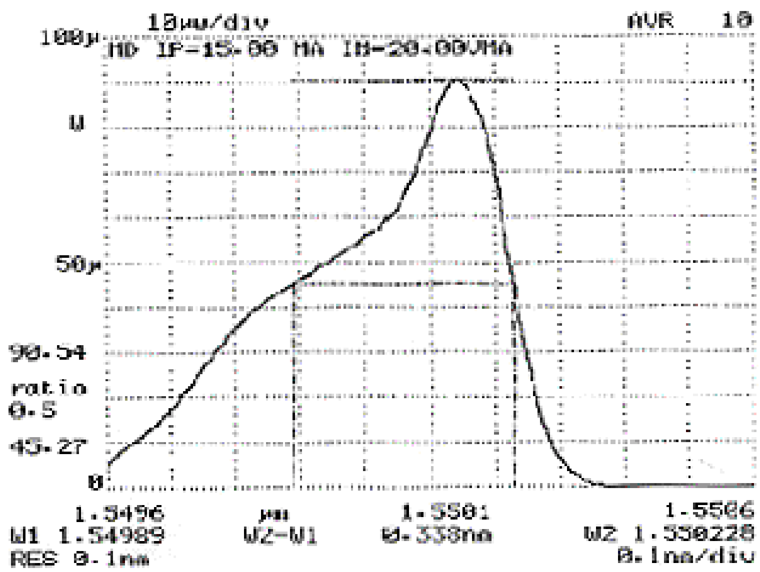
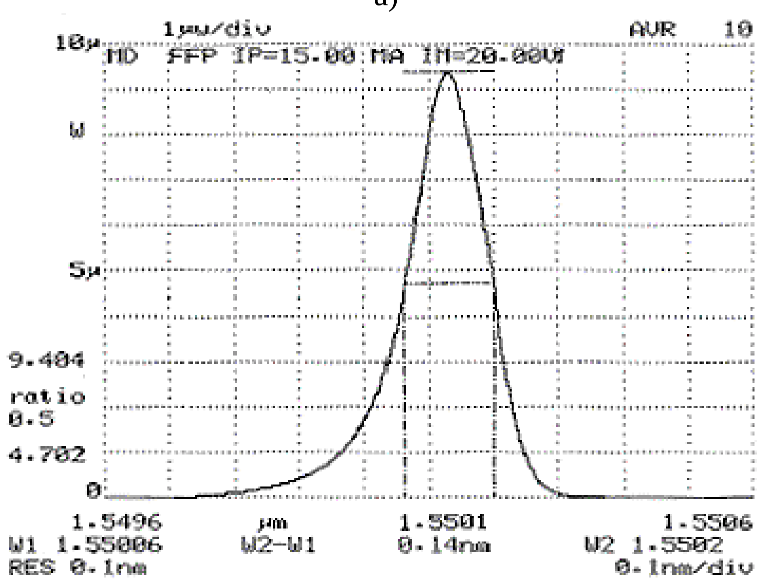


Figure 1 – Diagram of the soliton source.

A shortcoming of the gain switching method is that optical pulses are considerably chirped. In order to reduce the frequency chirp, the pulse width is filtered with a narrow optical filter. A Fabry-Perot filter with a bandwidth of 0.16 nm is typically used and, as it can be seen in Figure 2, the filter reduces considerably the pulse spectrum.



a)



b)

Figure 2 - Optical spectrum for a 20 ps generated pulse: a) without optical filter, b) with optical filter.

The generated sequence, at the output of the source, is shown on Figure 3. The apparent diference between the power of the pulses is due to a low sampling rate of the acquisition software.

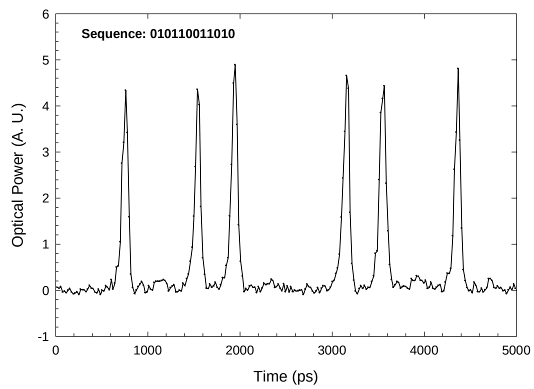


Figure 3: A bit sequence at the output of the source.

Optimisation of Mach-Zhender modulation characteristics

The static transfer function for the optical field of a dual drive Mach-Zhender Ti:LiNbO$_3$ modulator is given by the following equation.

$$H(t) = L \times \cos\left(\frac{\phi_2(t) - \phi_1(t)}{2}\right) \times e^{\left(j \times \frac{\phi_2(t)+\phi_1(t)}{2}\right)} + X$$

where ϕ_1 and ϕ_2 are the phase change in each arm and are a function of the applied voltage, the geometry of electrodes and the physical parameters of the Ti:LiNbO$_3$ waveguide. L is a constant, function of the total loss on the device and *X* is a constant which is a function of the crosstalk between the input and the output port and places a constrain in the maximum extinction ratio of the device [2].

A dual drive commercial Mach-Zhender modulator with a bandwidth of 12.5 GHz was characterised and a mathematical model which implements the transfer function was build in *Matlab©* and implemented in a photonic transmission simulation program, *PTDS©*. The modulation characteristics of the modulator were simulated as a function of the bias and modulation voltages.

Figure 4 shows the simulated transmitter output pulses and chirping produced by a 10 Gb/s NRZ modulation, with an extinction ratio of 16.5 dB and α parameter of 0.68.

The extinction ratio and the α parameter where optimised for the 10 Gb/s system, at the values of 15 dB and – 0.538 respectively, and were setting by adjusting the modulation and bias voltages applied to the two electrode of the Mach-Zhender modulator.

The dispersion power penalty for a BER of 10^{-9} was 2.2 dB for the compensated system and 15.5 dB for the uncompensated system.

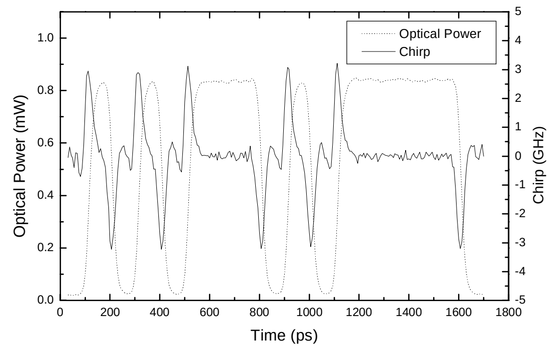


Figure 4: Optical output pulses and chirping

Discussion and conclusions

The study and test of a stable and viable optical soliton source for 1550 nm working at bit rates up to 10 Gb/s has been integrated into the undergraduate course of physical engineering. The effect of extinction ratio and chirping of the modulator on the transmission performance has been exploited in order to increase the transmission distance at multigigabit applications. Students seemed to have no difficulties in carrying out theoretical and practical work on this topic at the facilities of the Telecommunications Institute of the University of Aveiro and Portugal Telecom.

Among so many other innovative and practical applications, the implementation and development of optical communications systems seems to a good topic for project work on physical engineering courses, stimulating the interaction with enterprises.

Finally, the wide range of skills developed will also have impact on the student's mobility and on the cooperation between institutions and laboratories, at national and international level. In the future it is also expected to stimulate the employment throughout the European community.

Acknowledgements

The financial support of FCT and Portugal Telecom are gratefully acknowledged. The authors also wish to thank the Telecommunications Institute and the Aveiro University.

References

1. Sung Kee Kim, O. Mizuhara, Y. K. Park, L. D. Tzeng, Y. S. Kim, Jichai Jeong, „Theoretical and experimental study of a 10 Gb/s transmission performance using 1.55 μm $LiNbO_3$ – based transmitters with adjustable extinction ratio and chirp", *J. Lightwave Technology*, **17**, pp 1320-1325, (1999).

2. Dennis Derickson ed., *Fiber optic test and measurement*, Prentice Hall PTR, New Jersey, (1998).

3. F. Koyama , K. Iga , „Frequency chirping in external modulator" *J. Lightwave Technology*, **6,** pp 87-92, (1988).