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XXXVII Cycle

Modeling and Characterization of InP IQ Mach-Zehnder Modulators

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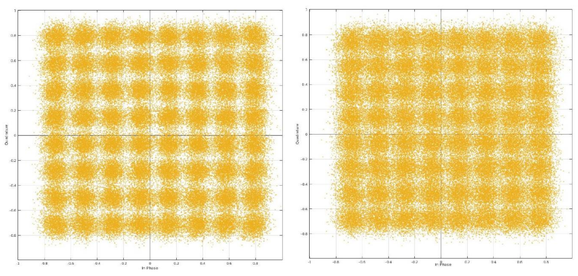
Research context and motivation

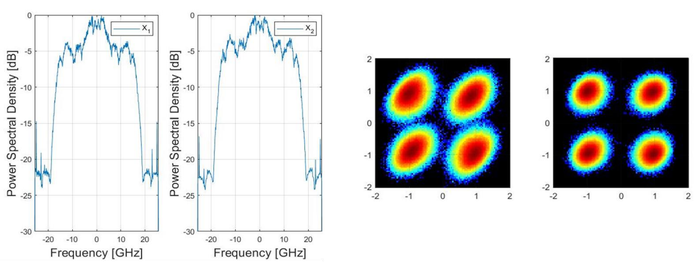
- The need for high bandwidth in optical fiber communications together with the optimization of traffic management on the network, are constantly evolving. To achieve an efficient transmission control, virtualization down to the physical layer of the devices involved in the whole communication system is necessary in order to accurately and realistically simulate the behavior of the network, in particular of a software defined network (SDN). For this to happen, it is necessary to model and appropriately characterize the devices involved in the optical fiber transmission, allowing a good management of the system and a correct interaction between the different components. This step is fundamental for the creation of an open optical network, allowing a cost reduction and a smarter management of the entire communication system. At the same time, a rapid growth of the application market for photonic integrated circuits (PICs) should be considered, which allows high bandwidth communications and good interaction with classic integrated electronic circuits. For this reason, nowadays more easily integrated technologies are now preferred to classic discrete optical components, usually in lithium niobate (LiNbO3), using silicon or indium phosphide (InP).
- Considering the need of an accurate simulation environment to emulate and control realistic physical layer effects in software-defined optical networks, the main goal of the research activity is to introduce a novel and scalable model of an InP Dual Polarization (DP) IQ-MZM within an accurate time-domain simulator for quality of transmission (QoT) estimation, integrating measurements performed on a real modulator sample to faithfully reproduce the component non-linear effects..

Addressed research questions/problems

- The usage of indium phosphide substrate for the realization of MZM improves the possibility to obtain photonic integrated circuits but introduces non-linearity and absorption effects.
- The complexity of the actual modulator sample under investigation kindly provided by Lumentum Company is also related to the introduction of other integrated components such as semiconductor optical amplifiers (SOAs) and their control.
- In order to investigate the novel InP DP-IQ-MZM model and to evaluate its performance, at first back-to-back simulation campaigns have been performed, considering a simplified model of the sample under investigation kindly provided by Lumentum Company.
- Simulations have been performed isolating the effects of the single components inside the modulator in order to evaluate for each step BER and OSNR estimations, considering different modulation formats and symbol rate.
- Measured band-cut given by the electrodes of the modulator have been inserted in order to obtain more realistic results.

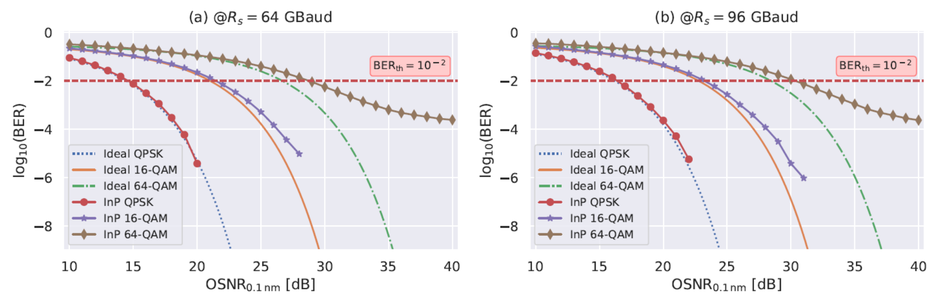


- On the other hand, the need to characterize the actual modulator InP sample components provided by Lumentum company is strictly related to the full control of the device, which has different bias points considering different input laser wavelengths, SOAs control currents and modulation format. The automation of the bias point control loop and for the research of the optimum working point related to SOAs input current, electrical driver gain and peaking is necessary for a full characterization of the device.



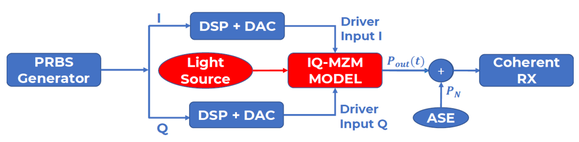
Novel contributions

- BER vs OSNR results obtained after simulation show a modification of the device performance increasing the complexity of the modulation format. Isolating the MZM impact from the other effects in transmission thanks to AWGN channel properties, the intrinsic SNR of the modulator has been evaluated, obtaining an almost constant value around 24 dB for all the configurations under test. The simulation instrument presents its potentialities in both accuracy and scalability of the framework.

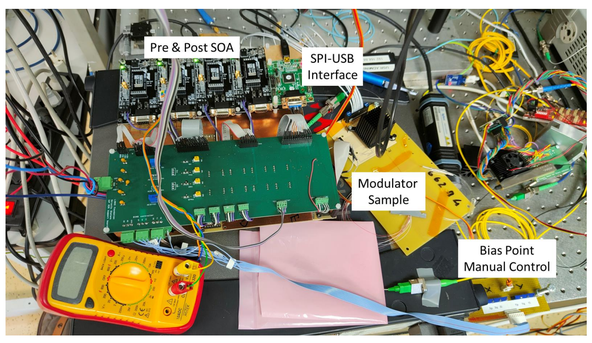


Adopted methodologies

- For the simulation environment, a Python model of the InP MZM has been developed, considering independently the effects of the single components under investigation in order to apply the principle of superimposition of effects and the AWGN channel properties.
  For back-to-back time-domain simulations the Python model has been inserted in a more complex split-step Fourier method (SSFM) modulator.

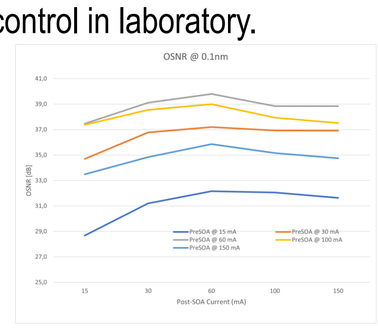


- For measurements and characterization of the device, laboratory activities in Links Foundation and Lumentum Laboratories have been performed, focusing on manual and automatic control of bias point and SOAs input current, exploiting Matlab, Python and LabView interfaces for instrument control.



Future work

- SOA characterization performing a measurement campaign on different input laser wavelengths in C-band, considering affordable input current ranges for SOA control.
- Research on the Noise Figure model of the modulator and on the maximization of the intrinsic SNR of the modulator.
- Expansion of the simulation framework considering SOA effect in transmission analysing back-to-back, single-span and multi-span transmission.
- Implementation of a multi-platform driver for the modulator control in laboratory.
- Measurements and simulations considering different modulator samples (64, 96, 128 Gbaud).
- Interaction of the modulator with other optical network elements (e.g. ROADMs) going towards the full transceiver model.



Submitted and published works

- Giacomo Borraccini, Stefano Straullu, Alessio Giorgetti, Rocco D'Ingillo, Davide Scano, Andrea D'Amico, Emanuele Virgillito, Antonino Nespola, Nicola Sambo, Filippo Cugini and Vittorio Curri., "*QoT-Driven Optical Control and Data Plane in Multi-Vendor Disaggregated Networks*", Optical Fiber Communication Conference (OFC), San Diego (USA), 2022, Technical Digest Series (Optica Publishing Group, 2022), paper M4F.5
- Rocco D'Ingillo, Giacomo Borraccini, Emanuele Virgillito, Stefano Straullu, Rocco Siano, Michele Belmonte and Vittorio Curri,"*Simulative Analysis of InP-based Dual Polarization IQ Mach-Zehnder Modulators*", Asia Communications and Photonics Conference (ACP) & International Conference on Information Photonics and Optical Communications (IPOC), Shenzhen (China), 2022 *(submitted)*

List of attended classes

- 02LWHRV – Communication (2022, 1 CFU)
- 01RISRV – Public Speaking (2022, 1 CFU)
- 01SHMRV – Entrepreneurial Finance (2022, 1 CFU)
- 01SWPRV – Time Management (2022, 1 CFU)
- 01SYBRV – Research Integrity (2022, 1 CFU)
- 01UNVRV – Navigating the hiring process: CV, tests, interview (2022, 1 CFU)
- 02RHORV – The new Internet Society: entering the black-box of digital innovations (2022, 1 CFU)
- 08IXTRV – Project Management (2022, 1 CFU)
- 01TRLRV – Optical Transport Networks (2022, 6 CFU)

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