Neuromorphic computing by means of recurrent spectrum slicing for next generation high baud rate transmission systems

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***Abstract*— In this paper we review our recent work in photonic neural networks based on recurrent optical spectrum slicing as potential accelerators for the mitigation of transmission impairments in short reach, high symbol rate (>100 Gbaud) transmission systems. Results will focus on self-coherent receiver architectures.**

Keywords—optical communications, photonic neuromorphic computing, self-coherent receivers

I. Introduction

Nowadays, the relentless need for bandwidth requires the constant adoption of new generation optical transceivers. 800G pluggables increase their shipments to cover mainly intra-data center (DC) communication scenarios, while 1.6T has already found the road for standardization with IEEE P802.3dj task force [1]. While coherent technology has penetrated the DC interconnects with 400ZR for 40-80 km, Intensity Modulation/ Direct Detection (IM/DD) modules remain more power efficient [2]. Solutions that either increase the transmission reach and dispersion tolerance of IM/DD transceivers or simplify the coherent ones (self-coherent, coherent-lite), are of paramount importance for a sustainable transition to the next generation optical networks. In this work, we review our propositions for recurrent optical spectral slicing (ROSS) accelerators in self-coherent 100 Gbaud transceivers.

II. Recurrent Optical Spectral Slicing Receiver

ROSS accelerators are based on recurrent optical filters that slice spectrally the input signal, separately processing its different sub-bands [3]. The basic unit of this system is a node consisting of a first-order bandpass or bandstop optical filter, two couplers and a feedback loop with delay T_d. The feedback loop is equipped with a phase shifter so as to adjust the feedback phase. In a multi-node receiver configuration like in Fig. 1, each of the ROSS nodes is focused on a specific spectral band of the input optical signal and has a feedback loop with delay adjusted as a portion of symbol period. Diversity in the time domain is provided to the different nodes which are separated by fixed delay lines $T_{1,2,3}$ in their inputs. The proposed self-coherent receiver acts twofold. Firstly, it

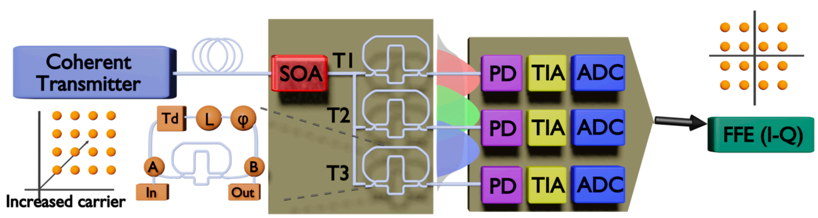

Fig. 1. The self-coherent architecture based on high-linewidth distributed feeddback lasers, with ROSS-NN as a neuromorphic receiver and processor. Coherent modulation formats can be extracted with direct detection while power fading and bandwidth limitations of the transceiver are combated in the optical domain.

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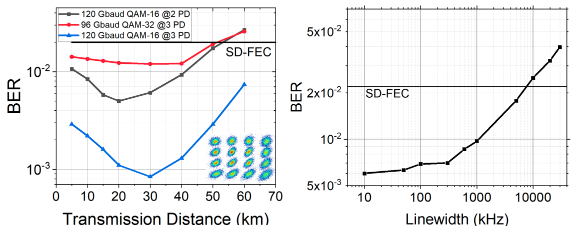

Fig. 2. a) The system performance in O-band transmission. The comparison is held between the schemes with two and three photodetectors, with FFE and RNN as post processing algorithms. b) The system tolerance to the transmitter linewidth.

translates phase information to the amplitude of the signal in order to retrieve the complex constellation in the intensity domain [4]. This process is assisted by the residual carrier of the incoming signal (>10 dB greater than the signal) as depicted in fig. 1a. Secondly, the recurrent spectral slicing with versatile filter transfer functions provides equalization capabilities through frequency diversity, that is, dedicated treatment for each spectral region. In this way, it can combat chromatic dispersion (CD) induced power fading and component bandwidth limitations by applying different weights to diverse frequency components. Lastly, by employing detuned nodes in the frequency domain, lower bandwidth (up to 50%) detectors and receiver electronics can be utilized. This is important from the power consumption perspective, as analog-to-digital conversion becomes prohibitively consuming beyond 100 Gs/s (70 GHz) due to higher order interleaving processes [5].

III. Results And Discussion

A. System Performance Analysis

In [4], an extensive optimization and evaluation of the self-coherent system has been carried out. Here, we focus on the performance of M-QAM high-baud rates systems as a function of reach in the O-band. In the simulations we consider dispersion coefficient D=2 ps/nm/km. We compare in terms of bit error rate (BER) the cases with two or three ROSS nodes and photodetectors at different cardinalities and baudrates considering a Feed-Forward Equalizer (FFE) as the digital back-end of the receiving system. These results reveal that the 40 km extended reach can be achieved even with the simplest two-node receiver. In Fig. 2b, we provide the system BER as a function of the linewidth of the transmitter's laser. It is shown that a good tolerance is provided up to 300-500 kHz while the BER remains below the 20% FEC limit for over 5 MHz. This is a promising result as a large portion of a coherent module's cost is due to the external cavity lasers (ECL) with linewidths below 50 kHz.

B. Discussion and Comparison with similar schemes

In this paragraph, we draw a comparison of our proposed 120 Gbaud self-coherent transceiver (QAM-16) with proposed solutions for 800G, namely the 4x106 Gbaud PAM-4 and the dual polarization 80-120 Gbaud QAM-(16-64). We think that the proposed system offers simplifications in all the major parts of the transceiver. In the transmitter part, employs two cheap DFB sources versus four in the IM/DD case and one ultra-narrow linewidth ECL of the coherent transmitter. In the receiver part, the proposed scheme reduces bandwidth requirements, employing even 30 GHz analog bandwidth components in its three-node configuration, half of that the other propositions require. This simplification results in significant power savings, even at the expense of two more receivers, when considering the power consumption of high-bandwidth ADCs [5]. Finally, the major simplification resides in the digital signal processing (DSP) part, where no pulse shaping, or demanding equalization algorithms are required. On the other hand, IM/DD solutions suffer from the power fading effect that restricts the transmission distance to a few km even when heavy algorithms like MLSE are mobilized. As for the coherent receiver, the DSP consumes the greater part of a pluggable's power envelope [2]. Taking into account all the aforementioned simplifications and the consumption of the first commercial 800G pluggables [6], we estimate 2-5 W power savings for the 10-40 km transceivers.

III. Conclusion

In this work, we reviewed ROSS hardware accelerator as a self-coherent receiver for short-reach low power consumption optical interconnects. We presented results showcasing how the proposed self-coherent architecture can simplify both the transmitter, the receiver and the DSP parts of the module, achieving at least 40 km of transmission in the O-band.

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