Multiplexing Systems Performance Enhancements With All-Optical Signal Processing

Ivan Glesk[1], Md Shakil Ahmed[1], Zifei Wang[2], and Lawrence R. Chen[2]
[1]Dept. of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, UK
[2]Dept. of Electrical and Computer Engineering, McGill University, Montreal, Canada
ivan.glesk@strath.ac.uk

***Abstract*—It is believed that an all-optical signal processing based on advanced integrated devices (passive, active or both) would play an important role in future multiplexing systems. In this paper we discuss approaches and techniques we have developed and demonstrated for improving the scalability and performance of Optical Code Division Multiplexing (OCDM).**

Keywords—data multiplexing; ultrafast all-optical signal processing; dispersion management, silicon photonics,

I. Introduction

Various advanced multiplexing techniques have been developed to improve network scalability. This way, OCDM systems have drawn a lot of attention because of their abilities to support bursty traffic and variable data rates. In particular, OCDM using Two-Dimensional Wavelength-Hopping Time-Spreading codes (2D-WH/TS OCDM) was found to be a highly flexible multiplexing scheme for highly scalable applications which can also offer increased physical layer privacy and on-demand bandwidth sharing. To further improve the scalability, a code's reuse approach was demonstrated in 'OCDM over OTDM' architecture. We have shown that the scalability measured by the total number of simultaneous users in this hybrid scheme is increased by a factor of $M \times N$, where N is the number of used OTDM channels and M is the number of OCDMA users per the OTDM channel. A further increase in scalability was demonstrated by adding a third dimension in the spectral domain. This allowed us to increase the OCDMA user groups operating in each OTDM time slot by assigning them into P different spectral sub-bands. We have shown that this scaled-up leads to a total number of simultaneous users, $k = P \times M \times N$. To achieve this, ultrafast all-optical signal processing devices are required.

II. Towards All-Optical Devices

Having in mind the high scalability for OCDM systems, first we need to start with the selection of coding scheme. Improperly selected codes will affect cardinality, network scalability, achievable BER, and will increase the Multi Access Interference (MAI). 2D-WH/TS coding scheme has often been selected to deliver the desired system performance and scalability. However, to build these high performance Multiplexing systems based on 2D-WH/TS OCDM require ultra-fast all-optical switching devices for clock recovery, data de-multiplexing, and dispersion management.

A. *All-optical Switching Devices*

We need to develop ultra-fast all-optical switching devices, where analogue or digital signal (data) being in optical domain can be controlled by the optical control signal. In OCDM applications, ultra-fast all-optical picosecond time gates based on Semiconductors Optical Amplifiers (SOA) were demonstrated as de-multiplexing gates. To overcome the slow recovery time of SOA based gates, SOA nonlinearity can be replaced by the ultra-fast nonlinearity seen in silicon nanowire waveguides. Switching devices such as Sagnac [1] and Mach-Zehnder [2] were successfully demonstrated producing the functionalities such as picosecond 'time gating', ultrafast all-optical 'thresholding' including all-optical 'clock recovery'. Moreover, integrated optical filters, AWGs and delay lines belong to a category of key passive components which have a wide range of applications in optical multiplexing schemes including OCDM.

B. *All-optical Devices for Tunable Dispesion Management*

All-optical tuneable dispersion management using the SOA control has been recently implemented on multi-wavelength OCDM system to overcome the dispersion related impairments [3,4] of data transmission. Realization of similar integrated tuneable devices on silicon will be an important stepping stone towards more complex sub-systems for use in optical signal processing. CMOS compatible approaches already led to the development of various SOI devices including sub-wavelength waveguide gratings (SWG) technology that helped with further device miniaturization and offered unique building block capabilities for future photonic devices. Since the effective index of the SWG waveguide is modifiable by selecting different 'block sizes and duty cycles', the properties of these devices could be greatly extended and controlled in order to deliver desired parameters. This introduces a flexible control of the waveguide itself including its refractive index, supported mode size and dispersion.

III. Conclusion

A need for ultrafast integrated all-optical devices supporting highly scalable multiplexing systems has been discussed. A hybrid solution involving incoherent OCDM based on 2D-WH/TS codes supported by ultra-fast all-optical signal processing has been already demonstrated as a feasible approach to meet those demands.

References

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