Latest Developments in Low-Cost Integrated WDM Transceivers for Telecom Applications

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The need to support the ever-increasing data traffic demands has accelerated the development of the underlying network technology. Pluggable transceivers have now become a norm and industry has acknowledged that Photonic Integration, regardless of the material platform, is vital to the continuous scaling of optical networks. Indium phosphide (InP) based photonic integrated circuit (PIC) technology offers high performance and cost advantages when applied in Dense Wavelength Division Multiplexing–(DWDM) long haul communication systems [1] - both in highly parallel systems as well as in single wavelength, high bit-rate systems. However, for short and medium reach applications, the cost and integration challenges become increasingly stringent. In this paper, we review technology aspects and trade-offs for the application of InP-based PICs in mid-range (10-100 km) pluggable transceivers. Latest results on integrated high-speed modulators will be presented, together with the innovations that are required to cost-effectively apply PIC technology into commercial products.

The fact that the main optical system components (lasers, modulators, (de-)multiplexers, and photodetectors) can all be made in different alloys of InP makes this integration platform highly attractive. A whole system can be monolithically integrated on a chip, including wavelength locking, power monitoring and equalization; we therefore call this System-on-Chip (SoC) technology. The SoC technology enables several powerful, cost-cutting features. First, the whole circuit can be readily tested at the wafer level, helping design refinement and to identify defective samples early in the process, well before being packaged. And second, the monolithic integration reduces overall complexity at the packaging level, as there is no need for complex flip-chip bonding of different materials or cumbersome alignment of micro free-space components. This enables the co-packaging of electronics and optics in a non-hermetic form that eliminates the need for the traditional and expensive gold boxes. This way, low-cost, high-performance transceivers with increased functionality can be realised in standard form factors. For example, based on this technology, a 10x10 Gb/s NRZ DWDM transmitter optical sub-assembly (TOSA) designed for application into standard form factor transceivers has been developed. The multi-channel PIC comprises 10 distributed Bragg reflector (DBR) lasers (see spectrum in Fig. 1(a)) each modulated via a Mach-Zehnder modulator (MZM) and combined with an arrayed waveguide grating (AWG) for multiplexing, and several monitoring functions all in a chip occupying a small area of 4x6 mm. This is less than the amount of InP needed for 10 individual channels, and therefore the AWG and monitors come almost for free, on top of the reduced handling complexity in the packaging process.

In the 10-100 km transmission range the use of MZMs is appealing because, in contrast to electro-absorption modulators, they offer better chirp management and extinction ratio control over a wide wavelength range without incurring additional loss [2]. To meet the performance requirements within the power budget, high-efficiency MZMs are combined with cost-effective off-the-shelf electronics. The inset in Fig. 1(a) shows a representative eye diagram of the 10x10 Gb/s TOSA in which the MZMs were negatively pre-chirped. Pre-chirping is known to reduce the power penalty induced by fibre nonlinearity both in normal and anomalous dispersion fibres, enabling longer transmission distances [3]. RF extinction ratio higher than 12 dB with the peak to peak modulation voltage (Vpp) of 1.5V is obtained, using low-cost drivers.

The next generation transceivers will require higher bit rates per channel. In this context, up to 5-times channel throughput increase (i.e. 50 Gb/s/λ) of the 10x10G-class TOSA has been demonstrated when paired with simple digital signal processing techniques and using PAM-4 signals. Figure 1(b) illustrates how the MZM chirp is exploited to enable the PAM-4 WDM dispersion tolerant direct-detection based transmission up to 25 km without dispersion compensating fibre (DCF) and 75 km with DCF. Figure 1(c) shows the frequency response characteristics of the MZM used in this experiment. The traveling-wave InP modulator has a 3-dB bandwidth in excess of 25 GHz, with a modulation voltage of only 1.6 Vpp. Overall, this technology is a compelling candidate for the realisation of high-speed-high-efficiency pluggable transceivers.

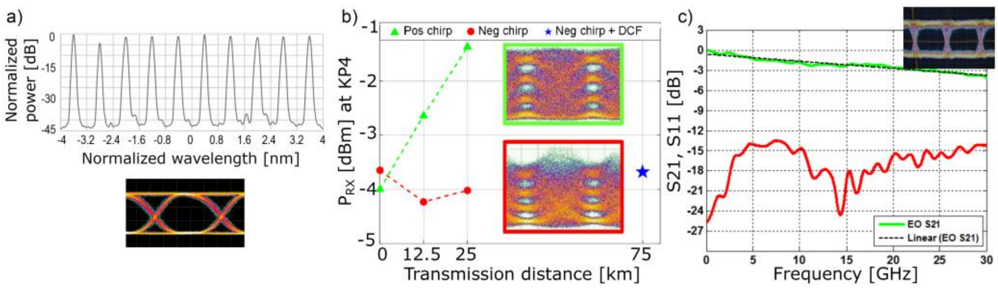

Fig. 1. a) Output spectrum and typical eye diagram of a 10x10 Gb/s NRZ DWDM TOSA based on the SoC technology. b) Chirp impact on PAM-4 WDM transmission at 25 Gb/s/λ using 10x10G-class TOSA. c) MZM frequency response.

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