25 Gb/s Data Transmission over a 1.4 m Long Multimode Polymer Spiral Waveguide

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Abstract: Data transmission studies of a 1.4m long multimode polymer spiral waveguide using an 850nm VCSEL are presented. Error-free 25 Gb/s data transmission is demonstrated over that waveguide length, achieving a record bandwidth-length product of 21GHz×m.
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1. Introduction

Short-reach optical interconnects have attracted significant interest in recent years for use within high-performance electronic systems, such as data servers, supercomputers and data storage systems, in order to overcome the inherent limitations and high cost of electrical interconnects when operating at high data rates [1]. In particular, multimode polymer waveguides constitute a promising candidate for use in board-level interconnections as they show excellent optical transmission properties, exhibiting low loss at datacommunications wavelengths and low crosstalk [2]. Moreover, the polymer materials possess suitable thermal properties and environmental stability for direct integration onto standard printed circuit boards (PCBs), while the large dimensions of the waveguides (typically ~30-70 μm) offer relaxed alignment tolerances, enabling system assembly with conventional pick-and-place tools. Various optical backplane systems have been demonstrated in recent years featuring large arrays of on-board polymer multimode waveguides which enable high aggregate interconnection data rates. The typical length of the waveguides employed in such demonstrators is on the order of a few tenths of centimeters (10-20 cm) [3].

The continuous improvement in the high-speed performance of vertical-cavity surface-emitting lasers (VCSELs) can enable a further increase in the achievable data rate on each on-board waveguide channel [4, 5]. However, as the data rate increases, the bandwidth limitation of the waveguides due to their highly-multimoded nature needs to be considered, while stringent loss requirements are applied in the link due to the available power budget. In this work, we report on data transmission studies of a 1.4 m long multimode polymer spiral waveguide and demonstrate error-free (BER<10^{-12}) 25 Gb/s data transmission over that waveguide length. The results which, we believe constitute record performance over that waveguide length achieving a bandwidth-length product of at least 21 GHz×m, demonstrate the potential of the use of multimode polymer waveguides in high speed board-level interconnects.

2. Multimode polymer spiral waveguide and link setup

The 1.4 m long multimode spiral waveguide used in this work is fabricated with standard photolithographic methods on a 6-inch glass substrate from siloxane polymer materials (core: Dow Corning® OE-4140 Cured Optical Elastomer and cladding: Dow Corning® OE-4141 Cured Optical Elastomer). These polymer materials are appropriately engineered to meet the application requirements: they can withstand temperatures in excess of 300°C required for solder reflow processes, exhibit low loss (~0.04 dB/cm) at 850 nm wavelength and possess high environmental stability [6]. The waveguide cross section is 50×20 μm^2 while the index difference Δn between the core and cladding materials is approximately 0.2 at 850 nm. The waveguide input and output facets are exposed with a dicing saw and no post-processing steps are undertaken to improve the facet quality.

The experimental setup used in the data transmission experiments is shown in Fig. 1. An 850 nm VCSEL with an oxide aperture of 9.5 μm is employed as the light source [4] while a 50/125 μm MMF pigtailed photodiode with a bandwidth of 30 GHz (VIS D30-850M) is used as the receiver. A pair of 16× microscope objectives is employed to couple the light into the spiral waveguide while a 50/125 μm MMF patchcord is used at the waveguide output to collect the transmitted light. Index-matching gel is used at the waveguide output to minimise any scattering losses due to facet surface roughness. A 2^7-1 pseudorandom binary sequence (PRBS), similar in length to the short run length codes typically used in datacommunications standards, is generated using an Anritsu pattern generator and fed to the VCSEL via a bias tee and a 40 GHz RF probe. The operating conditions of the VCSEL are optimised to obtain best link performance (I_{bias}=13.25 mA, V_{RF}=1.03 V pp). The received electrical signals at the photodiode are amplified using a 26.5 GHz SHF RF amplifier and connected via a 20 GHz RF filter to an Agilent (Infiniium 86100A) digital communication analyzer to record the waveforms and to a bit-error-rate (BER) test set (Anritsu

MP1800A) to measure the BER. For the BER measurements, an Agilent NA7766A multimode variable optical attenuator (MM VOA) is inserted in the optical link in order to adjust the optical power received at the photodiode. In order to compare the link performance with and without the 1.4 m long spiral waveguide, the optical back-to-back link is also set up (Fig. 1) and tested for the same VCSEL operating conditions. A cleaved 50/125 µm MMF is used to collect the light emitted from the VCSEL while the MM VOA is used to adjust the received power level at the photodiode. The received eye diagrams are recorded for the link with and without the spiral waveguide and BER measurements are carried out. The data transmission experiments are carried out for both 20 Gb/s and 25 Gb/s data rates. The total insertion loss of the spiral waveguide in the link (difference in optical power between points *A* and *B* in Fig. 1(b)) is measured to be 13.2 dB. Fig. 1(c) and 1(d) show images of the waveguide input and output facets.

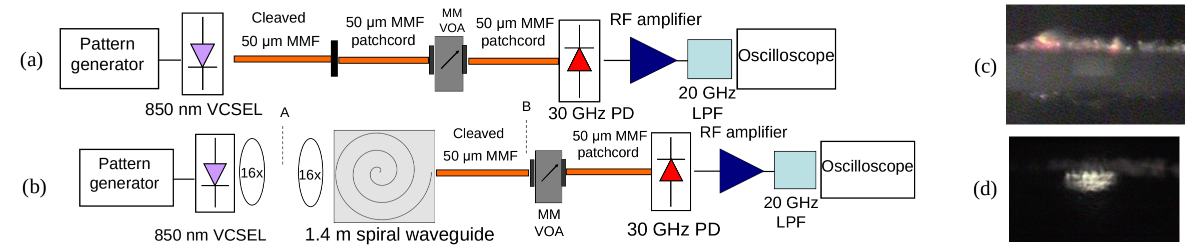

Fig. 1. Setup for the (a) back-to-back and (b) waveguide link, and images of the waveguide (c) input and (d) output illuminated with 850nm light.

3. Results

Fig. 2(a) shows the received eye diagrams for the optical back-to-back link (b2b) and the link with the spiral waveguide (WG) for a similar average received optical power level of -4.6 dBm. Open eye diagrams are recorded for the waveguide link while minimal additional noise and dispersion can be observed. Fig. 2(b) shows the recorded BER curves. The gap in the data points in the BER plot corresponding to the 25 Gb/s waveguide link is due to the insertion loss of the MM VOA which is ~1.5 dB. Error-free (BER<10^{-12}) data transmission is achieved for the link over the 1.4 m long waveguide for both 20 Gb/s and 25 Gb/s. The BER measurements indicate small power penalties of 0.2 dB and 0.5 dB at 20 Gb/s and 25 Gb/s respectively, due to the insertion of the waveguide in the link.

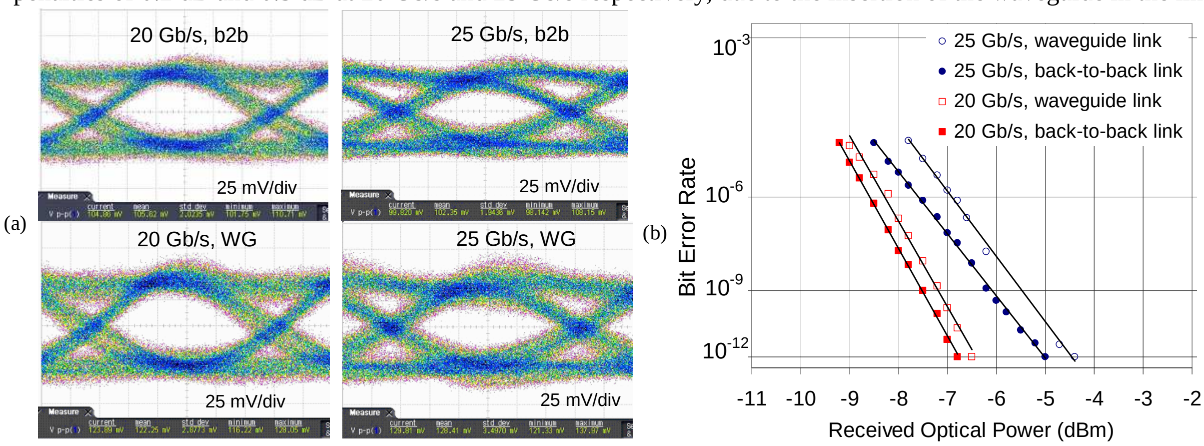

Fig. 2. (a) Received eye diagrams for the back-to-back (b2b) and waveguide link (WG) at 20 Gb/s and 25 Gb/s and (b) measured BER curves.

4. Conclusions

Multimode polymer waveguides are increasingly considered for use in high-speed board-level optical interconnects. Increasing data rates that can be achieved with VCSELs raise considerations about the bandwidth limitations of multimode waveguides in such on-board links. In this work, error-free 25 Gb/s data transmission over a 1.4 m long multimode polymer spiral waveguide is reported, demonstrating the potential of this technology.

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4. References

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