Bandwidth and Offset Launch Investigations on a 1.4 m Multimode Polymer Spiral Waveguide

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Abstract: Bandwidth measurements are conducted on a 1.4 m long spiral polymer multimode waveguide for a SMF and 50/125 μm MMF launch and for different input offsets. The waveguide exhibits a bandwidth of at least 30 GHz for all input types, while no impact is observed on the waveguide performance due to the different spatial input offsets. The results indicate that data transmission at data rates even higher than 25 Gb/s can be achieved over such structures demonstrating therefore the potential of multimode polymer waveguide technologies in short-reach datacommunication links.

Introduction: High bandwidth short-reach optical interconnects have been of particular interest in recent years in high-performance computing and data centre environments due to the inherent drawbacks of traditional electrical interconnects such as high frequency losses, poor immunity to electromagnetic interference and heat dissipation issues [1,2]. Multimode polymer waveguides are potential candidates for use in board-level optical interconnections owing to the large bandwidth, low crosstalk and high density that they can offer. In recent years polymer material which possess favourable optical, mechanical and thermal properties enabling cost-effective integration on printed circuits boards (PCBs) have been developed [3,4]. The use of large core size waveguides further offers relaxed alignment tolerances enabling therefore cost-effective board assembly [5]. As the demand of higher and higher data rates increases however for on-board interconnects, the bandwidth limitation of multimode waveguide due to modal dispersion needs to be examined. This paper presents therefore bandwidth studies and offset launch investigations on a 1.4 m long spiral waveguide, demonstrating a bandwidth-length product of at least 42 GHz·m for this long waveguide**.**

Experimental Results: The 1.4 m long spiral waveguide is fabricated on a 6-inch glass substrate from siloxane polymer materials (Core: Dow Corning® OE-4140 Cured Optical Elastomers; cladding: OE-4141 Cured Optical Elastomer) using standard photolithographic methods. The waveguide cross section is 50×20 μm^2 and the refractive index of the core and cladding material is 1.52 and 1.50 respectively. A vector network analyser (Agilent 8722ET) is used to measure the S_{21} parameters of the optical link with and without (back-to-back) the waveguide (Fig. 1a and 1b). The frequency response of the waveguide can be obtained from the difference between the recorded frequency responses of the waveguide link and the back-to-back link. The waveguide frequency response is investigated under different launch conditions as different mode power distributions at the waveguide input result in different levels of multimode dispersion in the guides. A single-mode fibre (SMF) is used to emulate a restricted launch while and a "typical" and a quasi-overfilled 50/125 um multimode fibre (MMF) are used to investigate the waveguide performance with a more uniform mode power distribution at the waveguide input. The "typical" 50/125 μm MMF launch is obtained by directly butt-coupling a cleaved MMF patchcord with the VCSEL source, while the quasi-overfilled MMF launch is achieved with the use of a mode mixer (Newport FM-1) before the waveguide.

An 850 nm vertical-cavity surface-emitting laser (VCSEL) (bandwidth of ~ 25 GHz) [7] is used as the transmitter, and a photodiode (VIS D30-850M) with bandwidth of 30 GHz is employed as the receiver. The VCSEL is butt-coupled to the input fibre patchcord (either SMF or 50/125 μm MMF), and a cleaved 50/125 μm MMF is used to couple the light output from the waveguide to the photodiode. Index-matching gel is used at the waveguide input and output facets to reduce the scattering losses due to surface roughness. An Agilent NA7766A variable optical attenuator (VOA) is employed to adjust the optical power received by the photodiode. Fig. 1c, 1d and 1e show the obtained frequency response of the waveguide for the SMF, the "typical" and quasi-overfilled 50/125 µm MMF input for the different input offsets respectively. The presented results are normalised with respect to that of the back-to-back link, showing that frequency response remains approximately constant up to the 30 GHz instrumentation limit for all launch conditions.

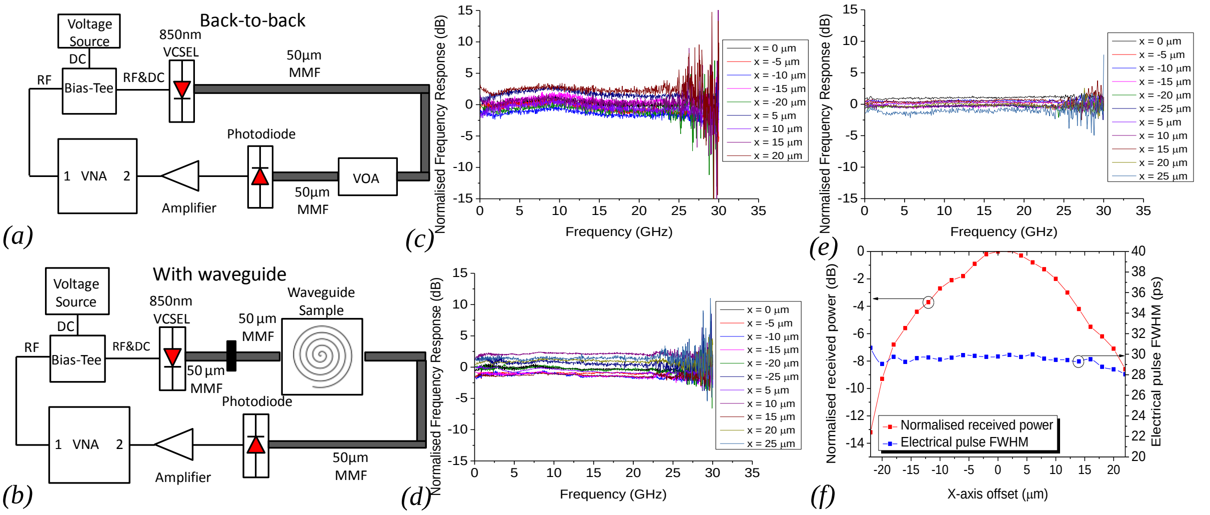

Fig. 1: Experiment set-up of S_{21} parameter measurement for (a) back-to-back link and (b) with waveguide when the 50 µm MMF is used as input; and normalised frequency response of the spiral waveguide for different horizontal offsets under (c) a SMF, (d) a typical and (e) a quasi-overfilled 50/125 µm MMF input; (f) normalized received optical power and FWHM of received signal as a function of the input position.

The dynamic performance of the waveguide is examined under the SMF input to further confirm the observations obtained from the S_{21} measurement. A single pulse with a FWHM of ~ 30 ps is generated by directly modulating the VCSEL using a 256-bit-long pattern at a 44 Gb/s data rate with bit pattern of a single "1" bit (i.e. 000...010...000). The optical pulse is launched into the spiral waveguide via a SMF and is collected with a 50/125 µm MMF (set-up similar to Fig. 1b). The received electrical signal is amplified by a 38 GHz amplifier (SHF 806E), and the FWHM of the received pulse is measured with a digital communication analyser (Agilent 86100A) for the different input positions. As expected from the S_{21} measurement, the FWHMs of the received pulses remain relatively constant and no significant pulse broadening is observed for the different input offsets (Fig. 1f). The power coupled at the waveguide is also measured for the different input positions (Fig. 1f). 3 dB points are found to be ± 10 µm. Increasing offsets result in larger power coupled into higher order modes which suffer from higher bending losses along the spiral waveguide. The repeatability of the observations is confirmed through multiple measurements. The results indicate that the link's performance does not degrade under different input offsets.

Conclusions: Bandwidth measurements have been carried out on a 1.4 m long spiral polymer multimode waveguide. The results indicate that the waveguide exhibits a bandwidth of at least 30 GHz different launch conditions for all input offsets, demonstrating the potential of transmitting data rates higher than 25 Gb/s over such structures.

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