

Development of a Variable Launch System used to Measure the Attenuation and Isolation of Planar Optical Waveguides

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Abstract- Polymer planar optical waveguides fabricated onto electrical printed circuit boards are a promising technology to provide high-speed communications on computer backplanes. The attenuation and isolation of these waveguides is critical to their operation. In this paper we describe a system to measure the attenuation and isolation of these optical waveguides with the ability to launch a variety of spot sizes and numerical apertures. Initial assessment of the measurement system's performance and initial measurements of optical waveguides will be described.

I. Introduction

Polymer planar optical waveguides fabricated onto electrical printed circuit boards are a promising technology to provide high-speed communications on computer backplanes. The integrated manufacture of these optical printed circuit boards, OPCB, is currently under investigation^[1] and the optical performance of the waveguides is an important aspect to refining the manufacturing process. Currently these waveguides are multimoded, operating at 850 nm and intended for data rates of 10 Gbit/s. The attenuation and isolation of the waveguides is the most fundamental measure of performance and is a requirement for their successful operation. The system developed measures the attenuation and isolation from the transmitted power and has the ability to vary the launch spot size and numerical aperture to fully explore the capability of these multimode waveguides.

II. The Measurement System

The variable launch attenuation and isolation system is shown in Figure 1 and builds on previous work for polymer optical fibres^[2]. Light from an 850 nm VCSEL laser is launched into a step index fibre with 365 μm core and 0.22 NA. The fibre is shaken at a few Hz with a few mm amplitude to slowly scramble any speckle. The fibre provides the input illumination to the variable launch board. This allows the variation of the launch spot size, which is defined by a range of interchangeable pin-holes ranging from 5 to 100 μm , and the numerical aperture, which is controlled by a variable aperture giving NA in the range 0.05 to 0.35. The launch board also includes a reference detector to monitor the launch power and a CCD with imaging optics to allow the alignment of the launch spot with the waveguide under test. The OPCB under test and the receive optics were mounted on movable stages. The output from the waveguide under test is imaged onto a CCD array to measure the total transmitted power.

III. System Assessment

An important aspect to the accurate measurement of attenuation and isolation is for the receive detection system to have a linear response to optical power. The linearity of the CCD arrays was measured by comparison with a calibrated fibre power meter and found to be linear within 0.05 dB/dB over the main part of its range, with a total dynamic range of ~ 35 dB. The linearity of the pick-off detector (DET1) is less important as the laser power is nearly constant.

An assessment of the launch beam was carried out to determine the near field and far field profiles of the actual launch spot. The magnification of the near field CCD imaging system was calibrated against a chrome on glass dimensional standard. This was repeated for both the launch and the receive imaging systems. The near field profile of the launch spot was measured using the receive

imaging system (L8, L9 and CCD2) while there was no OPCB present. The radial near field profile of a launch spot is shown in Figure 2, and this shows a good top hat profile. The lens L10 was inserted before the CCD array such that the far field profile was imaged. The radial far field profile is shown in Figure 3, and this also shows a good top hat profile.

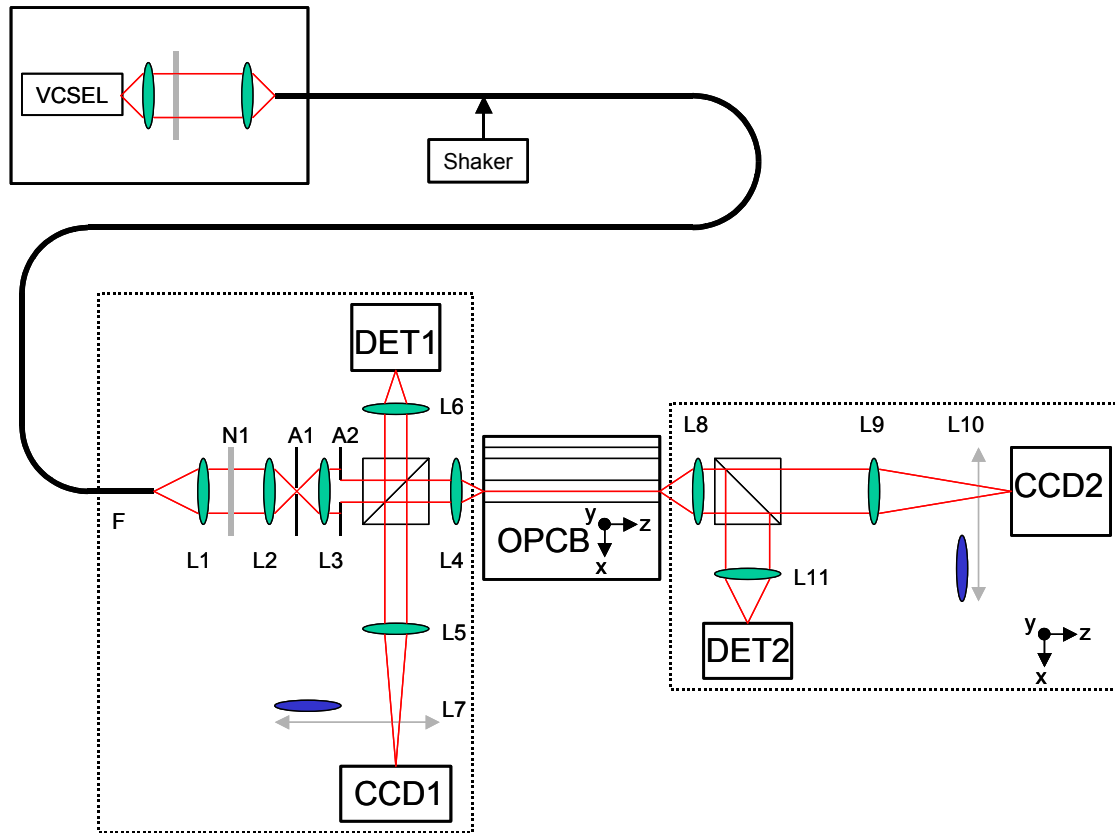


Figure 1. Measurement system optical layout. F = 365 μm 0.22 NA step index fibre; L1 = 50 mm focal length lens; L2, L3, L4 & L8 = 16 mm focal length 0.4NA objective; L5 & L9 = 150 mm focal length lens; L6 & L11 = 30 mm focal length lens; L7 & L10 = 60 mm focal length lens; N1 = neutral density filter; A1 = interchangeable pin-hole to set the launch spot size, A2 = variable aperture to control the launch spot NA. The CCD arrays image the near field, surface of the waveguide, and with the addition of L7 or L10 can image the far field distribution.

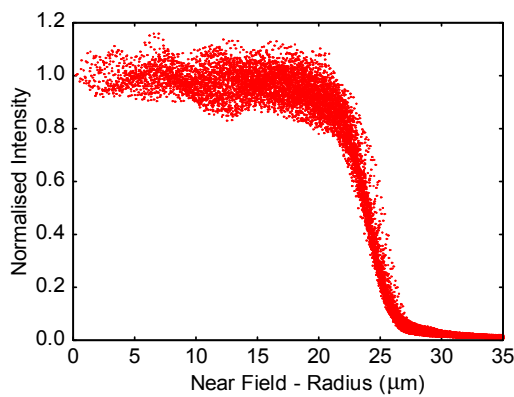


Figure 2. Near field profile of launch spot.

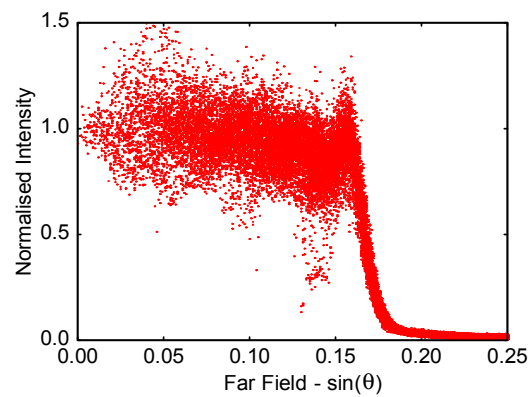


Figure 3. Far field profile of launch spot.

To measure the angular divergence of the launch beam and assess its numerical aperture the receive board was translated along its z-axis and the beam profile through the launch beam focus measured. The spot size was assessed at the focus and for the beam illustrated in Figures 2 & 3 found to be 48 μm FWHM. The angular divergence of the beam was calculated from the beam profiles measured far

away from the focus and the numerical aperture for the beam illustrated in Figures 2 & 3 was found to be 0.17. The measured angular divergence was used to scale the x-axis of Figure 3.

IV. Measurement of Attenuation and Isolation

The attenuation^[3], A , of an optical waveguide within an OPCB is defined as

$$A = 10 \text{ LOG} \left(\frac{P_0}{P_1} \right) \quad (1)$$

where P_0 represents the power striking the input surface of the waveguide and P_1 the power exiting the waveguide. The attenuation defined here includes both the input and output coupling losses and the propagation loss of the waveguide.

The isolation^[3], I , between optical waveguides is defined as

$$I = 10 \text{ LOG} \left(\frac{P_1}{P_2} \right) \quad (2)$$

where P_1 is the power exiting the waveguide into which the light was intentionally launched and P_2 is the power exiting the waveguide to which the isolation is being measured.

Using the system described in section I. The powers P_0 , P_1 and P_2 are measured using the receive CCD2. All the CCD measurements are an average of 1000 frames taken to both reduce the noise and average the speckle. The image is masked with a virtual 100 μm pinhole centred on the waveguide under test and the power taken as the total signal within the mask. The measured powers are normalised to the reference power measured using the pick-off detector on the launch board, DET1. The attenuation and isolation was then calculated using equations (1) and (2). To estimate the propagation loss of the waveguide alone a similar short waveguide was measured and the difference in attenuation was divided by the difference in length to give the attenuation coefficient. The launch CCD1 is only used to allow alignment and focussing of the launch spot onto the input surface of the waveguide under test and the receive detector, DET2, was not used.

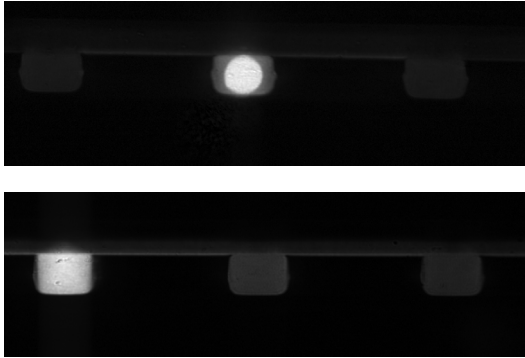


Figure 4. Launch (top) and Receive (bottom) CCD images.

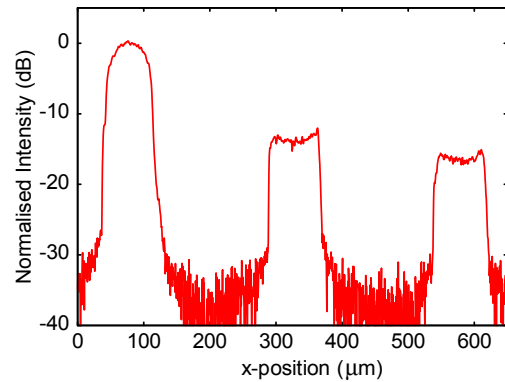


Figure 5. Intensity cross-section through the centre of the waveguides.

V. Results and Uncertainties

Initial results are from an optical printed circuit board produced using Truemode™ polymer and a photolithographic process by Exxelis. The board contained a number of straight waveguides approximately $80 \times 50 \mu\text{m}$ in size on a $250 \mu\text{m}$ pitch. These waveguides were produced several years ago and do not represent current state of the art.

The attenuation of the 83 mm long waveguide was found to be 2.9 dB including the input and output coupling while that of a 15 mm long waveguide was 1.5 dB. This gives an attenuation coefficient for

the waveguide of ~ 0.2 dB/cm. The isolation between the illuminated waveguide and its nearest neighbour was found to be just 11.5 dB for the 83 mm long waveguide while the isolation to the second neighbour was slightly better at 14.4 dB.

The uncertainties involved in these measurements are contributions associated with launch condition, the waveguide condition, the power measurements and the measurement repeatability and reproducibility. The uncertainties associated the power measurement include the linearity of the receive CCD and the reference detector. The uncertainties associated with the launch condition are caused by uncertainty in the wavelength of the source, uncertainty on the spot size and uncertainty of the launch NA in combination with the variation of the attenuation of the waveguide under test caused by variations in these launch factors. While uncertainties associated with the waveguide condition include the quality of the end faces and the alignment of the end face. All of these sources of uncertainty require further study.

Conclusion

We have developed a system to measure the attenuation and isolation of planar optical waveguides. The launch optics can produce a spot with size from 5 - 100 μm in diameter and with a numerical aperture 0.05 - 0.35. The set up has been used to measure the attenuation and isolation of some polymer planar waveguides. It is intended to use this set up to do a more systematic study of the attenuation and isolation of these and other optical waveguides as a function of the optical launch.

Acknowledgement

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