World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:7, No:7, 2013

A New Approach for Defining Angular DMD Using Near Field Aperturing

S. Al-Sowayan and K. L. Lear

***Abstract*—**A new technique to quantify the differential mode delay (DMD) in multimode fiber (MMF) is been presented. The technique measures DMD based on angular launch and measurements of the difference in modal delay using variable apertures at the fiber face. The result of the angular spatial filtering revealed less excitation of higher order modes when the laser beam is filtered at higher angles. This result would indicate that DMD profiles would experience a data pattern dependency.

***Keywords*—**Fiber measurements, Fiber optic communications.

I. Introduction

When a signal is transmitted through a channel, the channel should have a bandwidth that can accommodate the bandwidth required by the signal. The channel bandwidth can be derived from its impulse response. A moderate number of papers have been reported in the literature dealing with MMF fiber impulse response or effectively the bandwidth of the fiber. Fiber optic channels with perfect mode mixing are usually modeled by a Gaussian impulse response [1]. Few publications have been presented in the literature that relate the bandwidth of the GIMMF fiber to the optical source being used, either light-emitting diode (LED) or vertical cavity surface-emitting laser (VCSEL). It has been shown that Graded index multimode fibers (GIMMF) bandwidth is sensitive to optical power launch conditions, which in turn depends on the source type and coupling [2]-[5]. Differential mode delay (DMD) is very critical in defining the MMF bandwidth which has been defined as the variation in propagation delay that occurs because of the different group velocities of different modes of the multimode fiber (MMF). DMD profiles have been always measured as the delay in modes with respect to launch spot position. DMD measurements have been performed in time domain using kilometer lengths of fiber [6], [7] or using frequency-domain phase-shift technique [8].

In this letter an angular measurement of the DMD profile has been performed that is portions of a light beam that is produced by a single mode laser is angularly spatially filtered by near field aperturing before being coupled into a 62.5/125 µm graded-index MMF.

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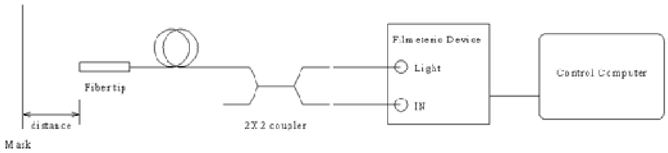

Fig. 1 Experimental Setup

II. Experiment

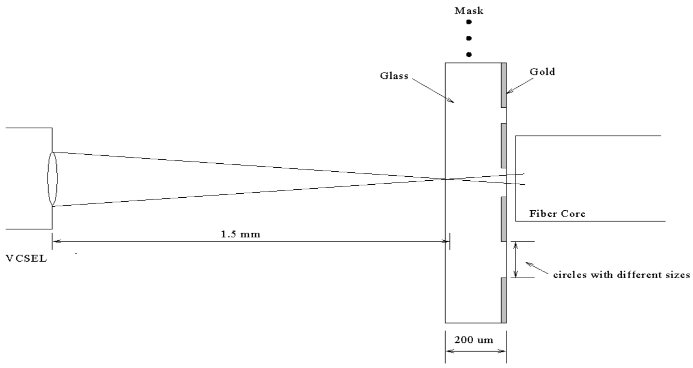

Fig. 2 Mask Setup

The impulse response of a 1km 62.5/125µm MMF was investigated as a function of the aperture used from the mask set using the experimental setup of Fig. 1. Isolated, ~750ps duration, electrical pulses at a repetition rate of 41.7 MHz from an Agilent 81250 data generator were used to gain-switch VCSELs. The commercial, 850nm VCSELs in transmitter optical subassembly (TOSA) packages were single mode, implant-confined structures specified for 2.5 Gb/s operation. The mask set and the MMF was controlled using a motorized micropositioning translation stage. The output of the MMF was connected directly to an Agilent model 86100A digital oscilloscope with an FC optical channel plug-in (model 86101A) to measure the temporal shape of the output pulse. The bandwidth of the optical channel was specified to be at least 3GHz. A way of having a similar beam shape enter the fiber is by fixing the distance between the spatial filter and the fiber on the order of 10µm by computing fresnel diffraction. This can be accomplished with a mask set in which gold of 300nm thickness is deposited on a glass slide. The mask set consists of circles of different diameters, and the light is allowed to go through the glass with these circles. The distance between the MMF fiber tip and the glass is measured precisely by the use of a white light spectrometer (Filmetrics model). This is done using the set-up shown in Fig. 2, where the raw reflectance was measured from the MMF fiber tip and displayed on the computer. The maximum reflectance is known from our previous information. Consequently, by separating the glass from the fiber, the reflectance would go down by a percent that would be proportional to the separation distance, and thus we can maintain the required separation of about 10μm.

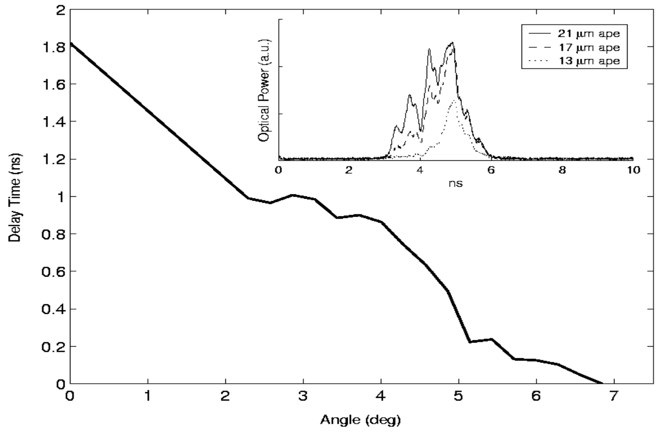

Fig. 3 DMD profile measurement

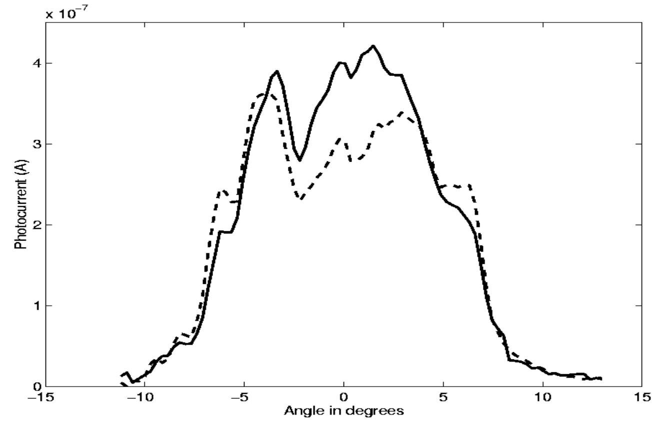

Fig. 4 Beam divergence angle distribution at 1.25 Gbps for alternating ones and zeros pattern (solid), alternating sixteen ones and sixteen zeros (dashed)

III. Results and Discussion

When carrying out the experiment with mask set only about 10μm from fiber, inset of Fig. 3 shows three results of using the 21μm diameter aperture (solid), 17μm diameter aperture (dashed), and 13μm diameter aperture (dotted), which shows the difference in which group of modes are excited by each aperture. It is clear from this figure that the response of the 21 μm offset cone excites less high order modes than 17μm. The body of Fig. 3 shows the DMD measurements as a function of angle of the beam coupled into the MMF which shows a high DMD in the on axis beam which clearly prove a defect at the center of the MMF of having a distinct peak in refractive index profile at the center. At the of axis of the beam the DMD become somewhat flat which means if the portion of the on axis beam is filtered out the bandwidth of the system could be improved.

Our previous work [9] shows that VCSEL's beam divergence is a data pattern dependent which is shown in Fig. 4. It is clear that the high data pattern has more on axis power in the beam which face more DMD according to Fig. 3 and lower power at the off axis portion of the beam where DMD is low. The case of the low data rate the situation is reversed.

IV. Conclusion

Experiments described here demonstrate that when an angular spatial filtering of a laser beam coupled into a MMF as aperture size gets smaller less high order modes excited. Angular DMD profile measurements have been introduced using a near filed filtering. DMD profile has been shown to be a data pattern dependent.

Acknowledgment

S Al-Sowayan would like to thank the optoelectronics lab in Electrical and Computer Engineering Department at Colorado State University to give the chance to perform the experiments, also would like to thank Mr. Mohammad Asad Ali from Electrical Engineering Department at Al Imam Mohammad Ibn Saud Islamic University for helping in editing and organizing the article.

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Dr. Sulaiman Al-Sowayan received his B.Sc. in electrical engineering in 1994 form king Saud University in Riyadh, Saudi Arabia (with honor), he got his M.Sc. and Ph.D. form Colorado state University, USA in 2000 and 2004 respectively. He published several papers in the field of using wavelet analysis with radar data and signal processing methods in fiber optic communications. After earring his Ph.D. he worked for one year as post doctorate in EE department at Colorado State University then he joined college of telecom and information in Riyadh as assistant professor. Three years later (until now) he joined the electrical engineering department at Al-Imam Muhammad Ibn Saud Islamic University as assistant professor.

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