Attenuation and bit error rate for four co-propagating spatially multiplexed optical communication channels of exactly same wavelength in step index multimode fibers

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ABSTRACT

Spatial domain multiplexing (SDM) utilizes co-propagation of exactly the same wavelength in optical fibers to increase the bandwidth by integer multiples. Input signals from multiple independent single mode pigtail laser sources are launched at different input angles into a single multimode carrier fiber. The SDM channels follow helical paths and traverse through the carrier fiber without interfering with each other. The optical energy from the different sources is spatially distributed and takes the form of concentric circular donut shaped rings, where each ring corresponds to an independent laser source. At the output end of the fiber these donut shaped independent channels can be separated either with the help of bulk optics or integrated concentric optical detectors. This presents the experimental setup and results for a four channel SDM system. The attenuation and bit error rate for individual channels of such a system is also presented.

Keywords: Optical multiplexing, helical propagation, bandwidth enhancement

INTRODUCTION

SDM introduces a new dimension in optical multiplexing [1-5] by allowing co-propagation of multiple optical channels of same wavelength inside a single fiber as a function of space. SDM channels follow helical path [6-10] and each channel is confined to a dedicated radial distance from origin of the optical fiber. The intensity of the innermost channel generally resembles a circular spot while the subsequent channels appear as concentric circles wrapped around each other. These co-propagating SDM channels typically operate at exactly the same wavelength, thereby increasing the potential capacity of channel by multiple folds [11-14]. Local area networks (LANs) are good candidates for initial deployment of SDM and this technology can be easily adapted for such applications [15,16]. Experimental attenuation and bit error rate from a prototype SDM system supporting four spatially multiplexed analog channels over a single strand of step index multimode fiber is presented here.

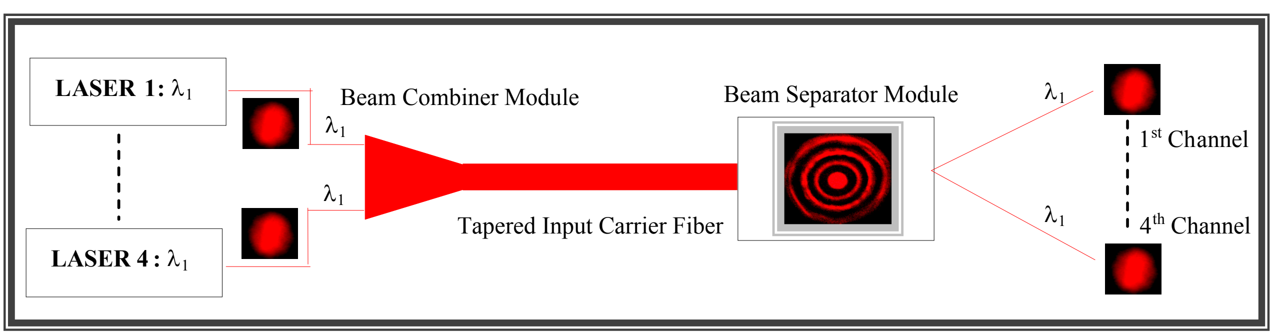

Fig 1 Block diagram of a 4-channel SDM system

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EXPERIMENTAL SETUP

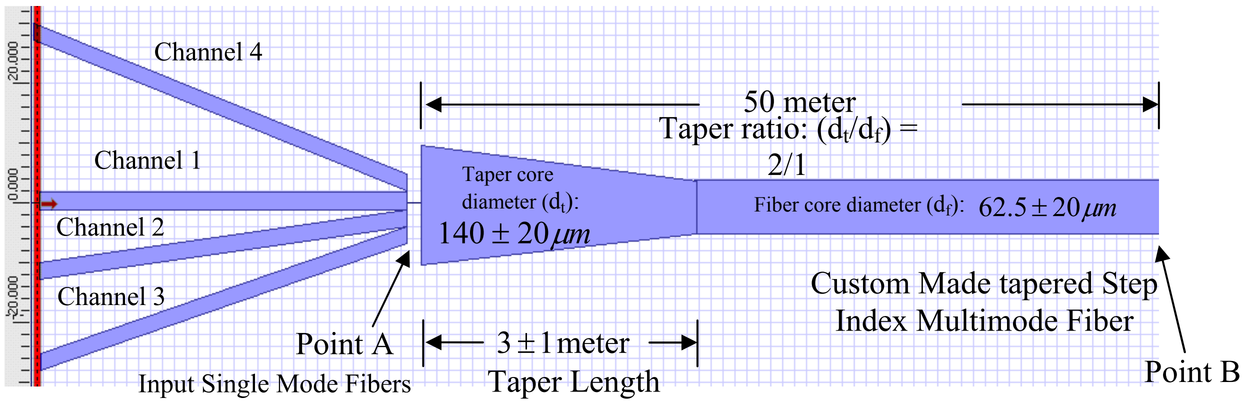


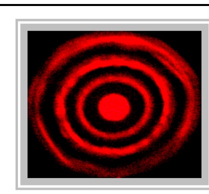
Fig 2 BCM setup and taper parameters

Figure 2 shows the typical SDM experimental setup using a 50 meter long custom made funnel shaped step index multimode fiber that was tapered at the input end to allow better space management and coupling efficiency. Multiple independent single mode pigtailed laser sources of same wavelength are used to launch light in to the custom made carrier fiber. A 2:1 taper ratio for the input end of the funnel shaped fiber was used in this setup and the taper was linearly eased over length of nearly 3 meters.

EXPERIMENTAL DATA

Light from four single mode pig tailed laser sources are coupled into the carrier fiber by orienting the input fibers at different angles relative to the carrier fiber with the help of a spatial multiplexer or beam combining module (BCM). The coupling efficiency of this system is not perfect and the resulting attenuation is also included the system analysis. To determine the BCM coupling losses, optical power is measured at points A and B as shown in figure 2 for all channels. The BCM coupling losses are determined by comparing the optical power values at points A and B. The experimental attenuation of the BCM system is shown in Table 1.

Table 1. Experimental BCM attenuation

SDM Channel	Launch Angle (Degree)	Power at Point 'A' (dBm)	Power at Point 'B' (dBm)	Loss BCM (dBm)	Output: Screen Projection
Channel 1	2	-8.1	-8.9	0.8	
Channel 2	8	-13.8	-14.9	1.1	
Channel 3	14	-14.7	-16.5	1.8	
Channel 4	21	-14.1	-16.9	2.8	

The attenuation values for a kilometer long SDM channel are presented in figure 3. Helical propagation model [1] is used to predict these values, which closely match the experimental data. The individual channels are spatially separated at the output end by employing simple spatial detectors known as the beam separator modules [17-19].

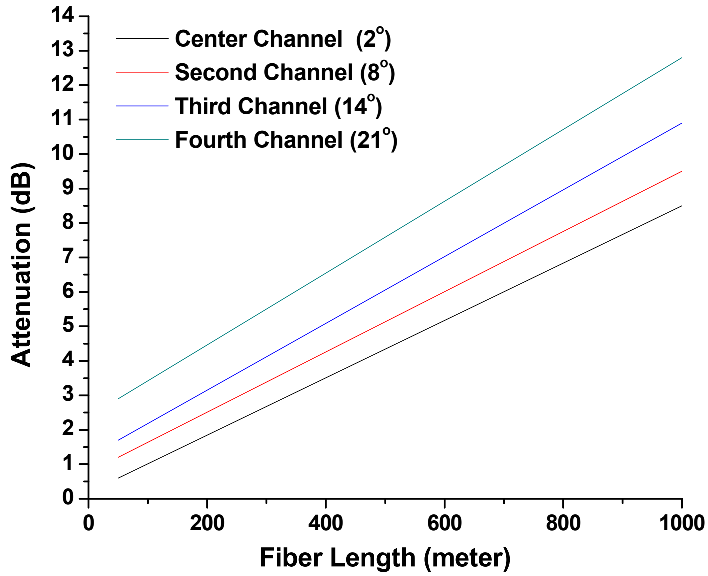


Fig 3 Attenuation Data (Experimental-including BCM loss): 1000 meter

Bit error ratio (BER) of a SDM is presented in figure 4. An attenuation based BER model is used to predict these values.

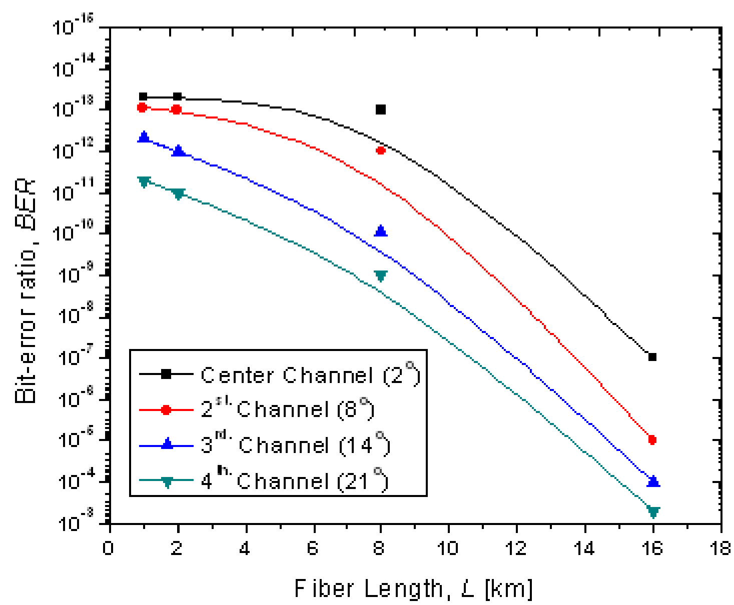


Fig 4 Typical Bit Error Ratio for 4 channel SDM system

CONCLUSION

This reports a novel experimental setup that uses spatial multiplexing techniques to multiplex and transmit four channels of same wavelength over a single strand of step index multimode silica fiber. A four channel SDM system is successfully demonstrated using taper fiber technology, thereby increasing the channel capacity of commercially available multimode fibers by a factor of four. The experimental and predicted attenuation and BER values are also presented. These values suggest that the SDM system can be deployed in the real world applications to increase the optical channel capacity and bandwidth.

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