PM Coupler fabrication using on line signature analysis system

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1. INTRODUCTION

Fused PM couplers are very crucial optical components in high-speed communication and interferometric fiber optic sensors. Low polarization crosstalk is preferred characteristics of these polarization-maintaining couplers. Positioning and alignment of polarization axis of the PM fibers are very essential process to attain good Polarization Extinction ratio. Even though, with microscopic inspection of cross section, one can identify the axes of a PM fiber, special techniques are to be used to identify the position of the axes of the fused region, by viewing through the side of the fiber.

Conventionally, index matching gel is used to enable clear viewing of the axis of the PM fibers at the stripped region. This method is not a preferred one for volume production, since after identification of the axes, one has to clean the fiber from gel completely, which brings in inconsistency in the performance of the fused couplers.

In this paper, we describe a novel method to align the PM axis of fibers using transmitted intensity pattern signature analysis technique. The acquired intensity pattern is converted to 2D differential signature, which facilitates aligning the axis less than +/- 1 deg. It is possible to achieve the polarization extinction ratio above 20dB for the couplers fabricated in this method. With the obtained consistency, this process can be easily adopted for volume fabrication.

A specially designed mechanical assembly enables retaining the axis of two PM fiber parallel. The chucks are capable of holding 2 and 3 fibers so that 2x2, as well as 3x3 PM couplers can be fabricated .

2. FUSED FIBER COUPLER FABRICATION

Conventional fused fiber couplers are fabricated by fusion and pulling of the stripped single mode fibers. Special machines are used for the controlled fusion and elongation of the two fibers, which enable the coupling of light from one fiber to other. By Controlling the process parameters, variety of products can be fabricated which included WFC, WIC, WDMs, Tap etc interleavers etc. After fusion process, fused region of the fibers is protected in quarts substrate with suitable epoxy.

Power transferred between the fibers is given by [6]

$$P = F^2 \sin^2 (Cz/F)$$

F^2 is the maximum power transferred, C is the coupling coefficient and z is the coupling length.

Fabrication process for polarization maintaining couplers is similar to normal SM couplers. In PM fibers because due to the inherent birefringence β, the refractive index along the two orthogonal axes are different and propagation constants are also different at these axis.

$$\beta = n_x - n_y$$

Since the slow axis and the fast axis of the PM have different propagation constants, polarized beam for each axis have different coupling coefficient. [3]

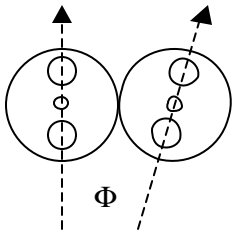
To keep the polarization cross talk to better value, alignment of polarization axis of the two fibers is very essential in PM coupler fabrication. Also twisting of the fibers before fusion is not recommended for PM coupler fabrication.

3. AXIS ALIGNMENT OF PM FIBERS

Most important parameter of a PM coupler is polarisation extinction ratio, which indicates the extent to which the polarisation is maintained during the splitting of power in the coupling region. Polarisation extinction ratio is given by the equation

$$PER = 10 \log (\tan^2 (\Phi))$$

Here Φ is the angle between the axis of PM fibres. Axis alignment is essential to keep the power on both fibres at same polarisation axis. To achieve a polarisation better than 20dB angular misalignment must be less than 6 degree.



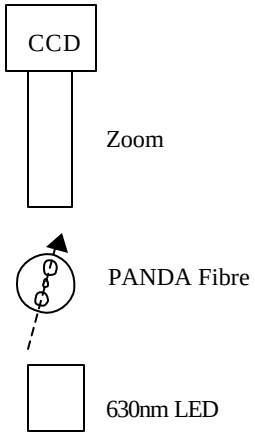
Fig(1) PANDA fibres with angle Φ between slow axis.

Principle axis of the two PANDA fibres used for coupler fabrication should be aligned in parallel to maintain the polarisation states in the fused coupler. [1] In order to maintaining the polarisation through the fused tapered region of the coupler, accurate alignment of the axis is required before fusion and tapering process.

Axis alignment is based on the transmitted light intensity pattern based signature analysis as described below. Light transmitted through the stripped PM fibre will be a characteristic of orientation of the PM fibre slow axis with the image-capturing axis. Difference in refractive index of the stress roads and cladding and the size of the SAPs are reflected as variation in the transmitted image intensity pattern.

4. EXPERIMENAL SET UP FOR AXIS ALINGMENT

Experimental set up consists of a variable zoom lens, which is mounted with a CCD camera; CCD camera is interfaced to the PC through image acquisition card. Light source of 630nm is kept below the experimental PM fibers. Image of the transmitted intensity of the LED will a characteristic pattern of the orientation of the slow axis to the source zoom axis. Simultaneous monitoring of the end face image of the PM fiber and transmitted intensity image pattern give the behavior of the pattern with the axis orientation.

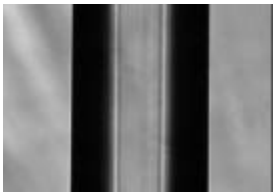


Fig(2) Schematic of e of image acquisition system.

The image is captured to the PC through a image acquisition card and is converted to intensity profile to view the quantitative measure of the intensity variation. Images are captured for every 0.5-degree angle from 0 to 360 degree. The Image and the corresponding intensity patter repeat after each 180-degree of rotation due to the symmetry of the PM fiber.

5. SIGNATURE ANALYSIS

The figures 3 to 7 show the experimental transmitted intensity image patterns of PANDA fiber, from angle 0 to 360 degree at the steps of 45 degrees. Right side figures give the intensity pattern of the corresponding left side images.



0 Degree

Fig. (3) a

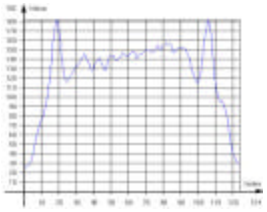
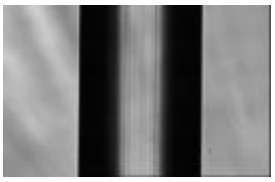


Fig. (3) b



90 degree

Fig. (4) a

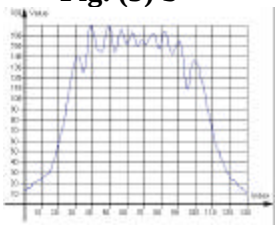
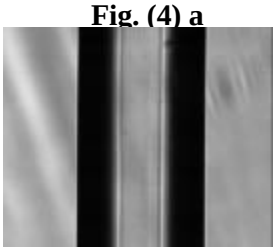


Fig. (4) b



180 Degree

Fig. (5) a

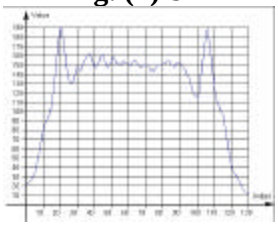
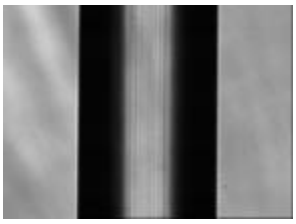


Fig. (5) b



270 Degree

Fig. (6) a

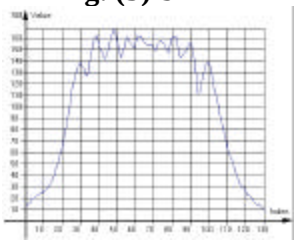
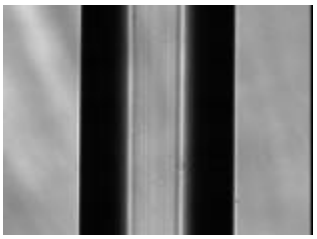


Fig. (6) b



360 Degree

Fig. (7) a

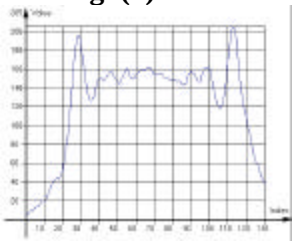
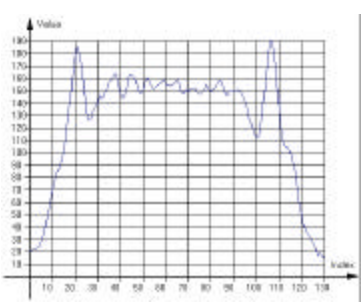


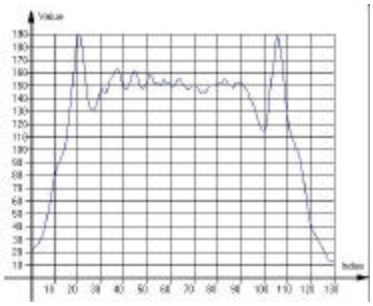
Fig. (7) b

Here at different orientation, 0 degree, 180 degree and the 360-degree , gives the same image patterns because of the symmetry involved in the PM fiber. While the slow axis of the PM fiber matches with source- zoom axis, two bright fringes appear in the pattern. For the fast axis aligned, the bright fringes become very fade. Slight deviation of the slow axis from camera-zoom axis will appear as the intensity difference in the bright fringes, which can be observed as, difference in the symmetric peaks of the intensity profile.

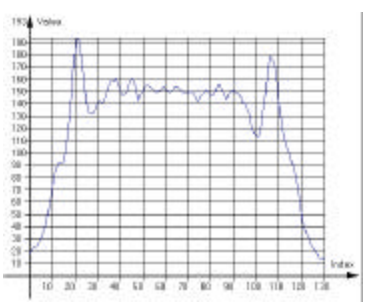
The changes in the intensity peak around 0 degree for difference of 0.5 degree is as follows



Fig(8) a



Fig(8) b



Fig(8) c

Intensity patterns at –0.5 degree, 0 degree and 0.5 degree are shown n the figures Fig(8) a, Fig(8) b, Fig(8) c.

6. PM COUPLER FABRICATION

A pair of stripped PANDA fibers is placed in the coupler fabrication station. The slow axes of the two fibers are aligned using the above-mentioned method. The aligned PM fibers are glued together using UV curable epoxy with the support of specially designed fiber holders. This enables fusion of the PM fiber without twisting. 1550nm highly polarized laser is launched to slow axis of the input PM fiber. Polarization extinction ratio better than 20dB is obtained for the couplers fabricated with low excess loss less than 0.4dB.

A specially designed motorized Rotating chucks and magnetic holder allow the smooth rotation of the PM fibers during the alignment. Rotating chucks are capable of software assisted synchronized rotation. Separate mechanical fiber groves are designed for 2x2 and 3x3 couplers fabrication.

7. RESULTS AND CONCLUSION

The PM axis alignment method demonstrated is highly useful for the volume manufacturing of the PM couplers and WDMs with better polarisation extinction ratio. It is also possible to fabricate WDMs, 3x3 couplers , and tap couplers based on PM fibres. Profile of the transmitted intensity image enables the operator to align the axis of the PM fibres better than ± 1 degree.

8. References

1. M.Kawachi, B.S.Kawachi, K.O.Hill, and T.Edahiro, “Fabrication of singe polarisation single mode-fiber couplers,”, Electronic.. Lett. 18, 962 (1982)

2. Itaru Yokohama, Kazunori Chida, and Juichi Noda, Low excess loss conditions of polarisation-maintaining fibre couplers Applied Optics, Vol.27, No.23 1988.

3 Yasuhiro Ouchi, Masakazu, Royokichi Matsumoto, ”Polarisation maintaining optical components with Fused-taper structure.”. Fujikura technical review, 2003

4. Y.Anjan and S. Habbel “Environmental Performance of fused PM couplers for Fibre Gyro Applications.IEEE Photonics technology letters, Vol 3. NO. June 1991

5.Itru Yokohama, “Analysis of mode coupling behaviour in fused polarisation maintaining fibre couplers”. Applied Optics Vol28 No:19, Oct 89.

6. V.J.Tekippe, D.R.Moore, and D.K.Paul, Gould Fiber Optics, 1121 Benfield Blvd, Millersville MD 21108 USA

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