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Effect of Bending Radius and Bending Location on Insertion Loss in Single Mode Fibers and Polarization Maintaining Fibers

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Abstract

This paper shows the effect of bending radius and bending location on Insertion Loss (IL) in Single Mode Fibers (SMFs) and Polarization Maintaining Fibers (PMFs). Five FC/UPC PMF patchcords were tested for the effect of bending radius on IL, by being coiled from 0 (as reference) to 5 loops at bending radii of 7.5 mm to 17.5 mm in a step of 2.5 mm. Based on the significant IL changes at 7.5-mm radius and no change starting at 15-mm radius, these two radii were chosen for the study of bending location. Fifteen patchcords (5 FC/UPC PMF, 5 LC/UPC PMF and 5 LC/UPC SMF) were coiled for 1 full loop located at 20 cm to 100 cm in a step of 10 cm. At 7.5-mm radius, PMFs reveal their major IL variations strongly depending on bending location, while SMFs have minor variations. In contrast, no IL variations are observed at 15-mm radius for both PMFs and SMFs. This radius was then selected for the final study on a number of coils. All 15 patchcords were coiled up to 15 loops at 15-mm radius. The results exhibit insignificant IL increase for PMFs, but a small increase proportional to the number of coils for SMFs. Consequently, the benefit of these IL studies will validate the proper testing conditions for SMF and PMF patchcords, especially in PMFs, where the measurement of Polarization Extinction Ratio is correlated with IL.

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Keywords: bending radius; bending location; insertion loss

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1. Introduction

Polarization Maintaining Fiber (PMF) is a special type of Single Mode Fiber (SMF), designed to preserve the State of Polarization (SoP) of propagating signal [1]. Currently, PMFs are widely used in hi-speed optical communication such as 40G, 100G and beyond. Coherent transmission, transponder and 100G modulator commonly use PMFs. In addition, PMFs are installed in sensors or detectors. The Polarization Extinction Ratio (PER) is one key parameter of PMFs, defined as a ratio between power in wanted SoP axis and power in unwanted SoP axis [2]. Normally, PMFs are coiled and installed in the field. If the bending radius is small, it can cause internal stress and birefringence, resulting in a significant PER reduction [1]. In our previous works, the impact of thermal cycle [3] and hot temperature [4] on end-face geometry of LC/UPC connectors were studied, but only in SMFs. Nowadays, PMFs with LC/UPC connectors are widely used, so the impact of environment on PER should be investigated. However, prior to a study on PER in PMFs, the effect of bending radius and bending location on Insertion Loss (IL) must be compared between SMFs and PMFs. These studies will help to justify the proper testing conditions, and to isolate any PER change due to varying IL caused by coiling fibers too small. Finally, the combination of bending radius, a number of coils and bending location that has insignificant IL change will be implemented in our future study on the effect of temperature on PER measurement.

A. Zendehnam et al. [5] studied IL in SMFs that were coiled up to 40 turns with bending radii of 4 to 15 mm. Their results show that IL linearly increases with bending radius and a number of coils. In addition, the 15-mm radius gives lower IL than others. N. Sangeetha et al. [6] studied IL in large core multimode fibers. Their results show that the increase in core diameter or wavelength will increase IL, but the increase in bending radius or Numerical Aperture (NA) will decrease IL.

In this paper, the bending radii of 7.5 mm to 17.5 mm in a step of 2.5 mm for PMFs are studied. The bending radius with significant IL increase and the minimum bending radius with insignificant IL increase are selected for next study. Then, the effect of bending location on IL are compared between SMFs and PMFs by coiling fibers 1 full loop located at 20 cm to 100 cm in a step of 10 cm. In final study on the number of coils, all fibers are coiled up to 15 loops, but only at the selected bending radius that shows insignificant change in IL from the first study. The purpose of this paper is to understand the proper testing setup of PMF patchcords for future PER measurement.

The bending loss parameter was not reported until 2006 when a special bend insensitive fiber became the standard ITU-G.657 Characteristics of a Bending-loss Insensitive Single-mode Optical Fibre and Cable for the Access Network [7]. For example, ITU-G.657A2&B2, the bending loss for SMF at 1550 nm wavelength with 7.5-mm radius is < 0.5 dB/turn.

2. Experiment Methodology

Following the measurement procedure in Reference [1], we conduct three tests in this research using SMF (Corning PN: SMF28) and PMF (Corning Panda PN: PM15-U400A) patchcords that are 2-3 meters long. First, five FC/UPC PMF patchcords were tested for the effect of bending radius on IL, by being coiled from 0 (as reference) to 5 loops at bending radii of 7.5 mm to 17.5 mm in a step of 2.5 mm. Second, fifteen patchcords (5 FC/UPC PMF, 5 LC/UPC PMF and 5 LC/UPC SMF) were tested for the effect of bending location on IL, by being coiled for 1 full loop located at 20 cm to 100 cm in a step of 10 cm at selected bending radii from the 1st test. Finally, those fifteen patchcords were tested for the effect of a number of coils on IL, by being coiled from 0 to 15 loops at selected bending radius and location from the 2nd test. All three tests were performed at 1550 nm wavelength by using the Polarization Laser Source (PLS) (Oz Optic Model: PFOSS-02-3-1550-1-ER=40 for FC connector and PFOSS-02-LC-1550-1-ER=35 for LC connector). And, the Optic Power Meter (OPM) (ILX light wave Model: FPM-8210) was used for measuring the optical power. The power difference between PLS's output and OPM's input is known as IL. The test setup is shown in Fig. 1.

The 1st test studied effect of bending radius. Five FC/UPC PMF patchcords (FCP01 to FCP05) were used. FCP01 A-end was connected to PLS, while its B-end was connected to OPM. The un-coiled (zero loop) power was recorded as a reference power. All fibers were coiled at 7.5-mm radius for 1 to 5 loops in random locations. Their ILs were recorded as FCP01AB (7.5) for 7.5 mm-radius, as shown in Fig. 2. Then, all steps were repeated at bending radii: 10 mm, 12.5 mm, 15 mm and 17.5 mm. After finishing, all fibers were alternated by connecting FCP01 B-end to PLS and A-end to OPM. Then the results were recorded as FCP01BA. Two bending radii are selected: 1) maximum radius that has significant change in IL and 2) minimum radius that has no change in IL.