Highly Sensitive Optical Line Checker with a Leaking Component Embedded on an Optical Fiber Cord

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Abstract: We have developed a practical optical line checker to judge whether fiber line is live or dark without any transmission failure, achieving detectable optical signal lower limit of -40 dBm in a wide wavelength range.

OCIS codes: (060.2340) Fiber optics component; (060.2300) Fiber measurements

1. Introduction

Broadband optical access services are being rapidly introduced world wide, and optical network construction is increasing [1]. One of main issues for transfers of optical fiber lines at expanding optical lines is to detect live lines definitely because they are used by subscribers and should be kept uncut in every construction work.

An optical line identifier has ever been tried to use for the purpose, however, sensitivity of the identifier was not good enough to find active lines without intercepting live line when optical transmission power is very low at a low wavelength around 1.31 μm [2]. It is because that insertion loss at a 1.31 μm wavelength should be kept low to get insertion loss lower than about 1.0 dB at a 1.55 μm wavelength. Here coupling loss was relatively large because leaking optical power was detected from outside of fiber cords which outer diameter was relatively large. Moreover coupling efficiency of the identifier is greatly affected by type and color of fiber cords and bare fibers.

Here, we propose a new method to find live lines without intercepting even at optical transmission power of as low as -40 dBm at 1.31 μm wavelength, which is expected to be the lowest for usual optical transmission systems, while insertion loss is kept lower than 1.0 dB at 1.55 μm wavelength. Here we have embedded a component on an optical fiber cord to get a weakly leaked optical power only when it is needed in central offices etc.

2. Target optical properties

Target optical properties are listed in Table 1. Measurement wavelengths were set to be 1.31 μm and 1.55 μm as standard wavelengths. Maximum insertion loss at measurement is less than 1 dB to prevent interrupting normal optical transmission. Minimum input optical power to be detected was set to be -40 dBm to apply it for almost all optical transmission systems. Here maximum insertion loss includes instant maximum value from the start of the measurement to the end of it.

Table I Target properties

Wavelength (μm)	1.31 & 1.55
Maximum insertion loss during measurement (dB)	1.0
Minimum input power to be detected (dBm)	-40

3. Structure Proposal and Fabrication

Proposed optical line checker consists of a leaking component embedded in an optical fiber cord and an optical power detector.

(1) Leaking component

Figure 1 shows a cross-section of the leaking component. It contains a bare fiber inside it and the fiber is fixed by adhesive only at the both side of the main body with keeping designed extra length between them. At the longitudinal center of the main body, a fan shape is formed to bend the fiber with designed curvature radius and designed center angle to get designed insertion loss at 1.55 μm wavelength. When the optical line checker is not in use, the bare fiber is kept loss-less state by setting extra-space between the fan shape and the fiber fixing parts at the both side. Therefore the fiber cord can be used as a normal cord unless the optical power checking is performed. Coatings of an optical fiber cord are also fixed by adhesive on the main body at the both side.

The fixing parts of the component are protected by end tubes. Usually the bare fiber and the bending part are covered with a housing tube, and the tube is slide out from the leaking component when optical power is detected. Top view without a housing tube is also shown in Fig. 1.

Outer diameter of the component was 6 mm and its length was 36 mm. It was very compact and its size was smaller than a usual fan-out of multi-fiber cords.

(2) Optical power detector

The optical power detector consists of a main body and a detector head; these two parts are connected by a coaxial cable with 1 m in length. Figure 2 shows its schematic. The detector head housing consists of an upper case and a lower case, and the upper case slide up and down to get the leaking component in at the top of the lower case. Here is a hold space to keep a leaking component in. Photograph of the detector is also shown in Fig. 2.

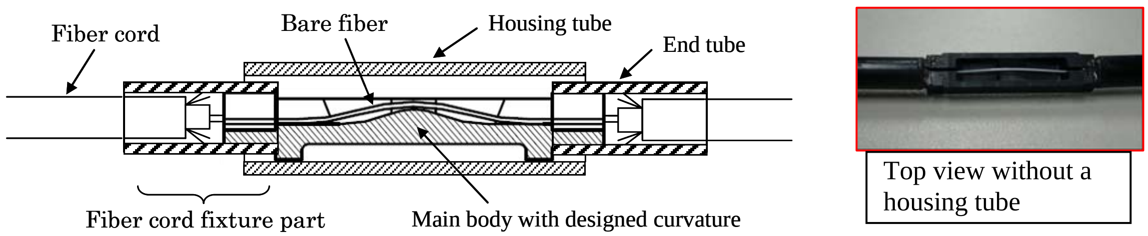


Figure 1 Cross-section & top-view of a leaking component embedded in a fiber cord

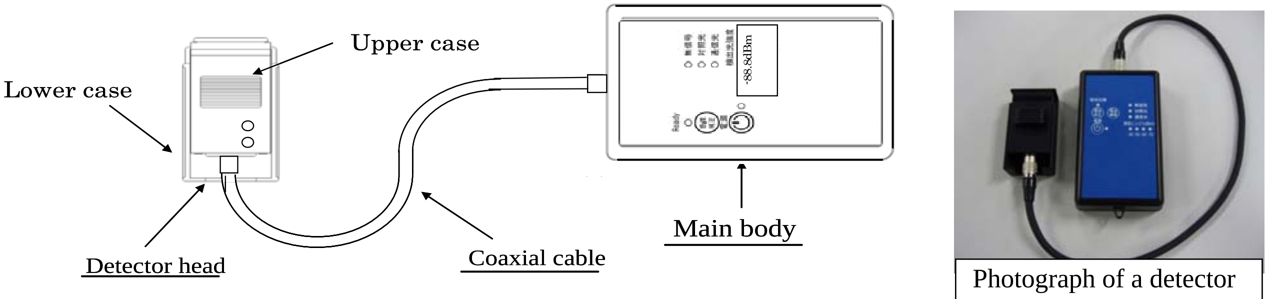
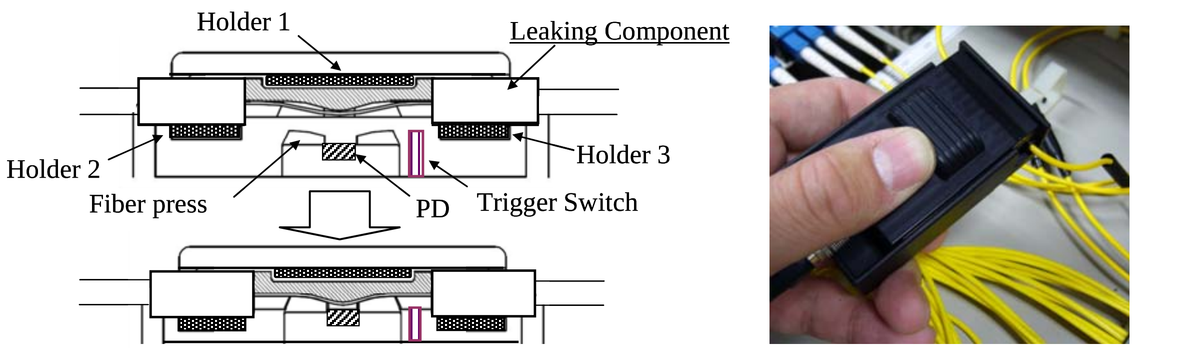


Figure 2 Separate-type detector & its photograph

(3) Measurement process

Figure 3 shows the hold space at the top of the lower case with a fiber press, a photo-detector (PD), leaking component holders (Holder 1, 2 and 3), a trigger switch etc. with a leaking component, and describes procedure for measurement. At first the detector head is held by hand, and the space is opened by sliding the upper case against the lower case. Next the leaking component is inserted in the space and held by Holders 1, 2 and 3. Then the space is closed and the fiber press holds a bare fiber to keep its bending shape stably for measurement. Then PD detects leaking optical power of the bended bare fiber. The photograph shows a measurement procedure.



(a) Insertion process of a leaking component (b) Photograph of measurement procedure

Figure 3 Insertion of a leaking component into the top of a detector head.

4. Experimental

Input optical power (P_0), insertion loss (IL), detected optical power (P) and minimum input power ($MinP_0$) to be detected were measured by using LD (CW) light sources at wavelengths of 1.31 μm and 1.55 μm, a channel selector, a VOA, and a optical power meter. Light source was selected by the channel selector and P_0 was controlled by the VOA. Coupling loss (CL) was calculated from these data as,

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$$CL = P_0 + 10\log(1-10^{(-IL/10)}) - P\,. \qquad (1)$$

5. Results and discussion

Figure 4 shows wavelength properties of IL. ILs were 0.05 dB and 0.5 dB in average at wavelengths of 1.31 mm and 1.55 mm, respectively. They were less than 1.0 dB, and satisfied target specification.

Figure 5 shows wavelength properties of MinP_0. MinP_0s were -48 dBm and -57dBm in average at wavelengths of 1.31 mm and 1.55 mm, respectively. They were less than -40 dBm, and satisfied target specification.

Figure 6 shows wavelength properties of coupling loss. Coupling losses were 10.5 dB and 12.2 dB in average at wavelengths of 1.31 mm and 1.55 mm, respectively. These high efficiencies of optical couplings were obtained by the new structure of the proposed optical line checker. Especial relatively low wavelength dependence of coupling losses was obtained by the optimization of bending curvature of the device.

Temperature cycle test was also performed as a reliability test with temperature range from -25 ^{0}C to 75 ^{0}C. 100 heat cycles were done with a period time of 5.3 hours. Insertion loss was monitored during the test at 1.55 μm wavelength. Insertion loss was very stable during the test and insertion loss perturbation was less than +/- 0.1 dB.

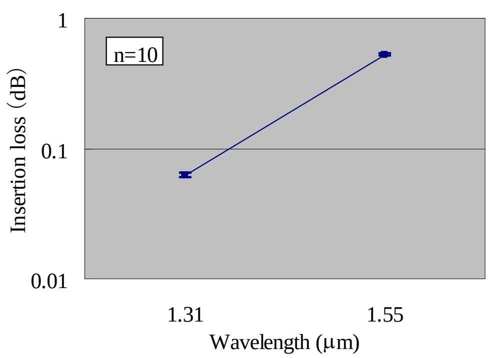

Fig.4 Insertion loss vs. wavelength

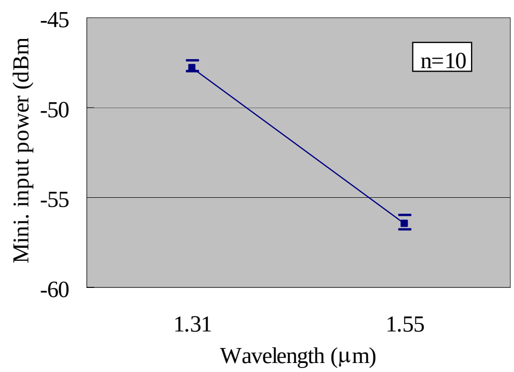

Fig. 5 Minimum input power for detection vs. wavelength

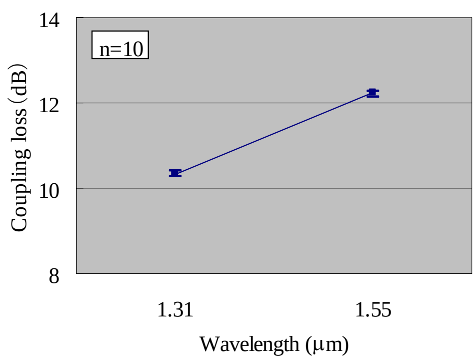

Fig. 6 Coupling loss vs. wavelength

6. Conclusion

New type highly sensitive optical line checker has been developed to judge whether optical fiber line is live or dark without fiber disconnection. It can detect optical signal as low as -40dBm with insertion loss less than 1.0 dB at both wavelengths of 1.31 μm and 1.55 μm. Detection is performed by bending radiation. To get high sensitivity, a leaking component was embedded on an optical fiber cord and bending radius was optimized to minimize wavelength dependence of insertion loss. The device is useful for detecting active state without any intercepting normal optical transmission with low introduction cost and can be widely applied to constructions and transfers of various optical transmission lines. The leaking component was very compact and its handling was very easy. The cost of introducing the component can be minimized for its simple structure.

References

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