FIBER LENGTH AND ATTENUATION MEASUREMENT BY UTILIZING POLARIZED BEAM SPLITTER AND FIBER COUPLER IN OPTICAL TIME DOMAIN REFLECTOMETER

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ABSTRACT

In this study, attention was made to measure the length of the fiber and the coefficient of the fiber attenuation using novel configurations. Laser diode with a fundamental wavelength of (808 ± 10) nm with a maximum power of 50 mW was employed. The measurement was made by using a polarized beam splitter and a beam coupler. The laser was operated in pulsed mode with a 75 ns pulse width which delivered an average power of 15 mW and continuous mode with a 50 % duty cycle. A preamplified Si PIN photodetector was used to detect the backscattered light. The fiber length measurement was compared utilizing a conventional Anritsu OTDR with an 850 nm wavelength. The length of the fiber obtained is 1313.99 m with a deviation of 0.46 % from a beam splitter measurement with a corresponding attenuation coefficient of 2.65 $dBkm^{-1}$ with a deviation of 16.22 % and 1303.89 m with a deviation of 0.38 % for the beam coupler with the corresponding attenuation coefficient of 2.58 $dB.km^{-1}$ with a deviation of 13.16 %.

Keywords**:** Fiber Length, Attenuation, OTDR, Polarized Beam Splitter, Fiber Coupler

INTRODUCTION

Evolution of OTDR followed from a publication in 1976 by Barnoski and Jensen that described backscattering in optical fibers and illustrated its potential use for fiber characterization [1]. The technique of OTDR has a primary advantage of not requiring any cuts in the fiber as it works by measuring backscattered light rather than transmitted light. This backscattered information can be used to measure loss in cable plants as well as locate fiber breaks, splices and connectors. Rayleigh scattering and Fresnel reflection principally produce the backscattered light which shall be discussed in brief.

The objective of this research is to develop an OTDR system to determine the length and attenuation of a multimode optical fiber by using a fiber coupler and a beam splitter. Later this result was compared with a conventional Anritsu OTDR.

THEORY

Rayleigh scattering reflects light in all directions throughout the length of the fiber. This factor is the dominant loss mechanism in most high-quality fibers. Suppose that the input optical power into a fiber of length, L is P_{in} and the output optical power at the destination end is P_{out} and intensity anywhere in the fiber at a distance x from the input is

P. The attenuation coefficient, α_{dB} is defined as the fractional decrease in the optical power per unit distance

$$\alpha_{dB} = -\frac{1}{P}\frac{dP}{dx} \tag{1}$$

We can integrate this over the length, *L* of the fiber to relate α to P_{out} and P_{in} by

$$\alpha_{dB} = -\frac{1}{L}\ln\left(\frac{P_{out}}{P_{in}}\right) \tag{2}$$

We can just as well define attenuation in terms of light intensity but we have used power to follow convention since attenuation tests on optical fibers measure the optical power. In general, optical power attenuation in an optical fiber is expressed in terms of decibels per unit length of fiber, typically dB per km [2]. The attenuation of the signal in decibels per unit length is defined in terms of the logarithm to base 10 by

$$\alpha_{dB} = -\frac{1}{L}10\log\left(\frac{P_{out}}{P_{in}}\right) \tag{3}$$

Fresnel reflection concerns about the amount of light reflection occur at a plane boundary between two dielectrics. The reflection coefficient, *r* is the ratio of the reflected electric field to the incident electric field. For normal incidence the Fresnel's equation simplifies into

$$r = \frac{n_1 - n_2}{n_1 + n_2} \tag{4}$$

where n_1 is the refractive index in the incident region and n_2 is the index in the transmitted region. If $n_2 > n_1$, the reflection coefficient becomes negative and this indicates a 180° phase shift between the incident and the reflected electric fields [2, 3]. The reflectance, R is the ratio of the reflected-beam intensity to the incident-beam intensity. Because the intensity in an optic beam is proportional to the square of its electric field, the reflectance is equal to the square of the reflection coefficient. Thus,

$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2 \tag{5}$$

A perfect fiber end reflects about 4 percent of the power incident on it.

In addition to determination of attenuation and component losses, an OTDR also can be used to measure length and locate breaks in an optical fiber. The fiber length, L can be calculated from the time difference between the pulses reflected from the front and far ends of the fiber. If this time difference is *t*, then the length L is given by:

$$L = \frac{ct}{2n} \tag{6}$$

where *n* is the refractive index of the fiber core. The factor 2 accounts for the round trip made by the pulse [2].

EXPERIMENTAL METHOD

The set up for the polarized beam splitter is shown in Figure 1, whereas the modification setup with a fiber coupler is shown in Figure 2 [4]. For length measurement, the controller unit is set to operate the diode laser in the pulsed mode. The laser pulse width is 75 ns with energy of 1 nJ per pulse; the average power of the laser is 15 mW.

The control unit is set to 50 % duty cycle to operate the diode laser in continuous mode to measure the value of attenuation coefficient. The number of photons launched into the optical fiber was increased by increasing the current on the laser diode controller or by enlarging the pulse length. During the phase of the switched on radiation, one fills the fibers with photons which produces the scattering light at the Rayleigh scattering centers which is directed towards the fiber entrance. The switching off the light pulse, results in a rapid reduction of the backscattering light produced at the fiber entrance surface.

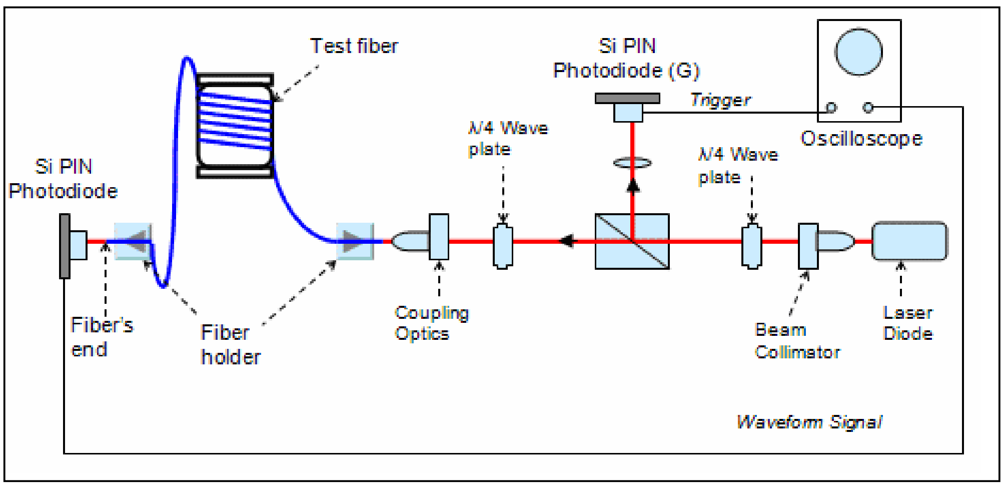

Figure 1: Schematic diagram of experimental set up with a polarized beam splitter.

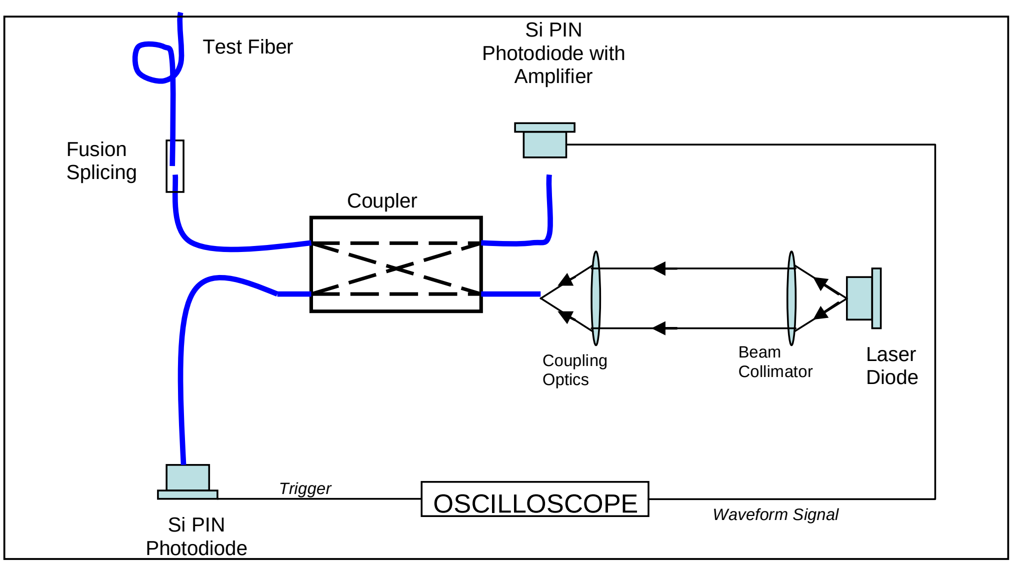

Figure 2: Schematic diagram of experimental set up with an optical fiber coupler.

RESULTS AND DISCUSSION

The fiber length measurement using a polarized beam splitter is (1314 ± 21) m, whereas with the fiber coupler the fiber length is (1304 ± 11) m.

The typical result obtained for the measurement of the optical fiber attenuation by using a continuous wave with a polarized beam splitter is shown in Figure 3.

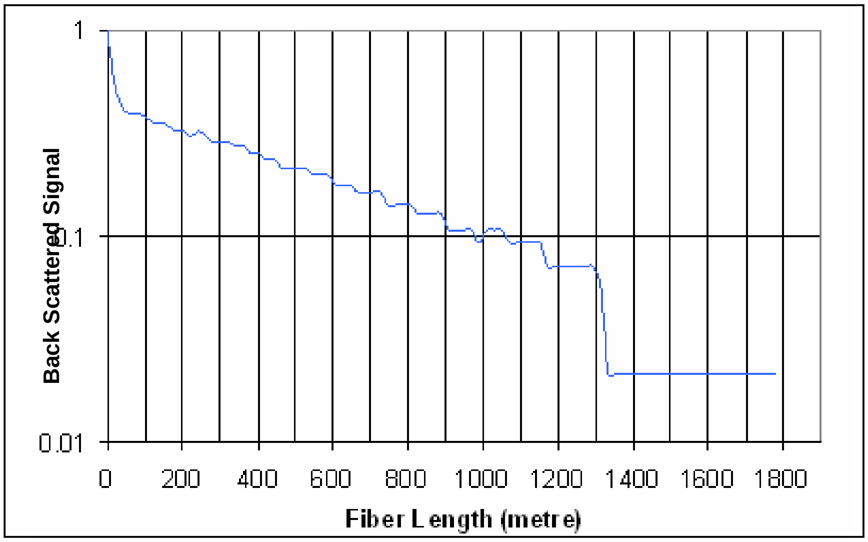

Figure 3: Logarithmical division of the backscattered signal versus fiber length.

The linear part of the slope contains the loss or attenuation beam. By calculating the gradient for selected two points on the graph yields the attenuation coefficient of, α_{dB} = (2.65 ± 0.03) dB.km^{-1}.

The typical result obtained for the measurement of the optical fiber attenuation by using a continuous wave with a fiber coupler is shown in Figure 4. The total loss for the whole system is 10.08 dB. The loss at the optical coupler is 3.05 dB and the loss at the fusion splice is 0.25 dB. By subtracting the external loss from the system the total loss through the fiber from the two way flows is obtained as 6.78 dB. The attenuation coefficient α_{dB} could be determined as:

$$\alpha_{dB} = \frac{Total\ \ Loss(dB)}{dis\tan ce(km)} \tag{7}$$

From the calculation the value of the attenuation coefficient is, α_{dB} = (2.58 ± 0.02) dB.km^{-1}.

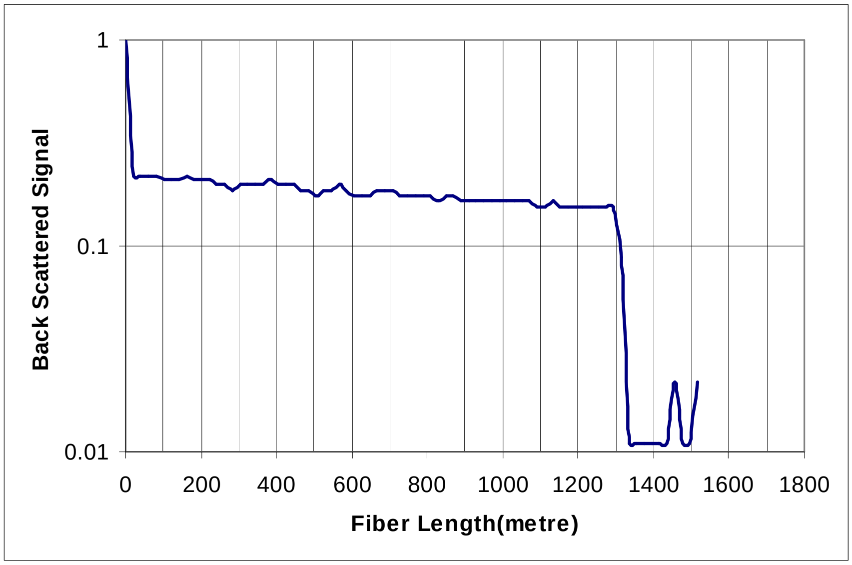

Figure 4: Logarithmical division of the backscattered signal versus fiber length.

The measured value of attenuation coefficient by using MEOS OTDR with a beam splitter yields a higher value by 0.07 dB.km^{-1} or 2.71 % compared to optical coupler. Whereas the average value for the MEOS OTDR is 2.62 dB.km^{-1}. In comparison with Anritsu OTDR the measured difference could be achieved up to 14.91 %. Thus the attenuation coefficient measured by using Anritsu OTDR is found to be lower in comparison to MEOS OTDR.

The measurement of fiber length by using a pulsed laser from MEOS OTDR by utilizing a beam splitter and an optical fiber coupler yields a difference of 0.77 %. The optical fiber length measurement by using a continuous wave from MEOS OTDR by utilizing a beam splitter and a beam coupler yields almost the same value in comparison with the Anritsu OTDR where the excess fiber length of 5.99 m or 0.46 % is realized.

CONCLUSION

The OTDR system has been modified by using a fiber coupler. The length and attenuation of fiber optic were measured and compared with a conventional Anritsu OTDR.

The multimode optical fiber length is obtained as (1313.99 ± 21.10) m with calculated attenuation coefficient of (2.65 ± 0.03) dB.km^{-1} which measured using a polarized beam splitter. The measurement using a beam coupler yields a fiber length of (1303.89 ± 10.99) m with the calculated fiber attenuation is (2.58 ± 0.02) dB.km^{-1}. The deviation of fiber length and attenuation between the two methods are 0.77 % and 2.71 %. The beam coupler provides better accuracy with an acceptable tolerance compared to a polarized beam splitter measurement. The OTDR device can be designed in compact, rugged and low cost by utilizing the fiber coupler.

This measurement, however vary with the actual measurement using Anritsu OTDR by an average of 14.69 % in the attenuation coefficient measurement and by average of 0.42 % for fiber length. This phenomenon is influenced by the light source's wavelength [5].

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