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EXPERIMENTAL INVESTIGATION OF DIFFERENT SPLICE LOSS ESTIMATION TECHNIQUES

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Abstract

We tested Optical Time Domain Reflectometer and Transmitted Power techniques on 150 splices between different fibre reels. We compared these results with Near Field Intensity measurements. We got a good agreement between all these techniques.

Introduction

The power budget of optical links can be affected by the losses induced by succeeding connectors or splices. If these values are not too high in the case of the connection between two identical fibres, this is not always true when the fibres do not have the same optogeometrical characteristics. For instance, connecting classical single-mode fibres with Dispersion Compensating Fibres or Doped Fibres affects the power budget significantly[1]. These are the reasons why splice losses have to be estimated accurately. If splices or connectors losses are easy to measure when we splice the same fibre type (cut-back technique), this is not true anymore when we have two reels of different fibres. In this case, losses have to be measured by using different techniques such as Optical Frequency Domain Reflectometer (OFDR), Optical Time Domain Reflectometer (OTDR) or a Transmitted Power (TP) based method. The OTDR is more appropriate for the measurement of high distances. The so-called TP method can be applied in both cases[2]. In this work, we tested OTDR and TP techniques on the splices between two fibre reels. We first spliced two reels of the same fibre (standard fibre). Then we measured the splices between two different fibres (standard fibre and Dispersion Shifted Fibres-DSF). Finally we compared the results with calculated splice loss values derived from Near Field Intensity measurements on the tested fibres.

Splice loss measurements

The Transmitted Power technique has been proposed in reference 2 and is based on the set-up shown in figure 1. The measurement is organised in two steps. In the first step, a powermeter (PMW1) measures the transmitted power through the two spliced fibres. Then we cut the splice, we remove fibre 2 and we measure the transmitted power through the remaining fibre. PMW2, another powermeter, measures the power stability of the laser. The measured splice loss α_{spl} is given by relation (1)

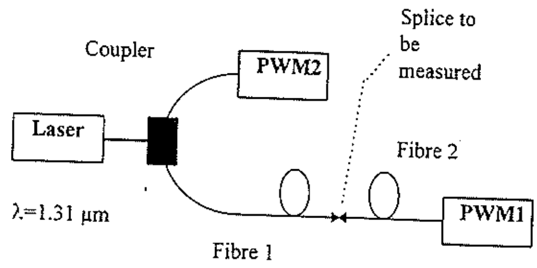

FIGURE 1. Transmitted Power set-up

$$\alpha_{spl} = P_2 - P_1 + \alpha L + \Delta P_{Laser} \qquad (1)$$

where P_1 is the power measured through fibre2, P_2 is the power measured through fibre1 when fibre2 is removed. α and L are respectively the attenuation and the length of fibre2. ΔP_{Laser} is the laser power stability measured at PWM2. In our experiment, fibre1 is always the same standard fibre while fibre2 can be a conventional or a DSF. The splice loss estimation with OTDR is described in reference [3]. In the case of splices between identical fibres, we just measured the trace from one end while in the case of splices between different fibres, we measured traces from both ends (laser and PWM 1) of the set-up in figure 1. OTDR measurements have been done at 1.31 µm.

TABLE 1. measured splice loss mean values and standard deviations

	α_{spl} from TP (dB)	α_{spl} from OTDR (dB)	α_{spl} difference between the two techniques, (dB)
Splice between two standard fibre (115 splices)	0.11 ± 0.10	0.11 ± 0.09	0.01 ± 0.05
Splice between a DSF and a standard fibre (31 splices)	0.62 ± 0.15	0.58 ± 0.14	0.04 ± 0.04

Table 1 shows the splice losses mean values of all the measurements we carried out on 115 splices between two standard fibres having the same optogeometrical properties. Figure 2 exhibits these measurements results. We applied the same techniques to the measurement of 31 splices we made between a standard fibre and a DSF. The results are shown in Figure 3. We get a very good level of confidence between the mean values derived from these two techniques as exhibited in figure 2 and 3. High losses measured by OTDR remain high in the case of the TP method. The observation was also true for lower splice loss values. There is a strong correlation between results provided by both techniques.

Splice loss calculations

We used two definitions described in reference 5 for the Splice-Loss calculation. The first definition allows the direct estimation just by knowing the Near Field Intensity distributions (NFI) of the tested fibres 4. The splice-loss is then given by relation (2). The other definition, expressed by relation (3), is derived from the well known formula based on the spot-size of the two fibres. We assumed no lateral displacement, no offset and no angle. We used a home made set-up to measure the NFI. The method used is known as the Transmitted Near Field Technique [4] and is described in the G.650 ITU recommendation. The spot-size definition concerned in this work is related to Petermann 2 formula. It has been chosen as the reference one in the G.650 ITU Recommendation for the derivation of the Mode Field Diameter from NFI patterns. The two considered relations are the following ones.

	α_{spl1} (dB)	α_{spl2} (dB)
Splice between a DSF and a standard fibre	1.09	1.16

TABLE 2. calculated splice loss values; only one sample of each fibre has been characterised.

$$\alpha_{spl1} = -10\log_{10}\frac{\left|\int_0^\infty \sqrt{I_1(r)}\sqrt{I_2(r)}rdr\right|^2}{\int_0^\infty I_1(r)rdr\int_0^\infty I_2(r)rdr} \quad (2)$$

$$\alpha_{spl2} = -20\log_{10}\frac{2w_1w_2}{w_1^2+w_2^2} \quad (3)$$

In these relations, $I_1(r)$ and $I_2(r)$ are the NFI distributions while w_1 and w_2 are their spot-size of the two spliced fibres. These values are higher than all the measured ones. In fact the used formulas are derived from the assumption that the interface between the two fibres is not fused but just joined. So there is no continuous transition between the two fibres. That is the reason why these formulas could be considered as worse case splice loss values. The splice loss calculated from (2) gives a smaller figure than with formula (3). The relation based on the spot-size is derived from the assumption that the intensity has a gaussian shape which is true only near the cut-off wavelength. Meanwhile it is easier to use the spot-size based formula.

Conclusions

Our purpose was to show insofar the OTDR and the TP are reliable techniques for the characterisation of insertion losses. These results can be easily extended to insertion losses due to connectors. The TP can be applied to long fibres as well as short ones. These are the reasons why the TP method is a promising one for the estimation of insertion losses due to connectors or splices in applications involving different kinds of fibres as fibre lasers, fibre amplifiers or systems involving Dispersion Compensating Fibres. The measured mean values we got can be considered as splice loss reference values while the calculated ones are the worse case figures.

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References

1. F. Ravet, L. Meuleman, M. Vandroogenbroek, D. Daniaux, M. Blondel, "Full characterisation of a Dispersion Compensating Fibre for its possible use in an Optical Access Network", *Proceedings NOC' 96*, June 1996.
2. W. Zheng, O. Hultén, R. Rylander, "Erbium Doped Fiber splicing and splice loss estimation", *Journal of Lightwave Technology*, vol. 12, N°3, March 1994, pp.430-435.
3. F. P. Kapron, B. P. Adams, E. A. Thomas, J. W. Peters, "Fiber-Optic reflection measurements using OCWR and OTDR techniques", *Journal of Lightwave Technology*, vol. 7, N°8, August 1989, pp.430-435.

4. F. Ravet, B. Heens, E. Jaunart, P. Mégret, M. Blondel, "Optogeometrical characterisation of Erbium Doped Fibres", *Proceedings EFOC&N 95*, Brighton, vol. 3, pp.246-249, June 1995.
5. N. Kashima, "Passive Optical Components for Optical Fibre Transmission", Artech House, 1995, pp.58-62.

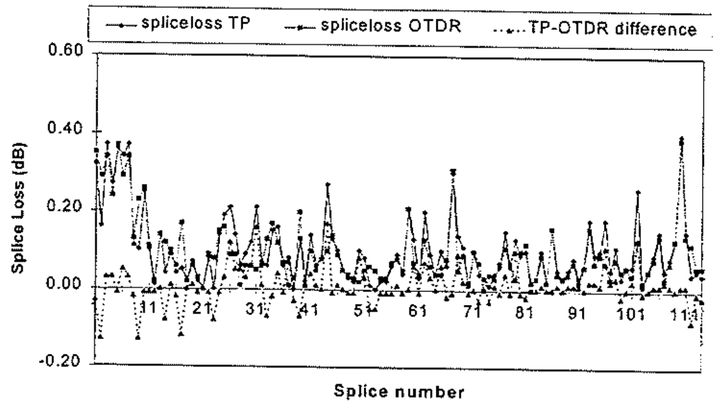

FIGURE 2: The continuous curves are related to the measured splice loss while the dashed curve presents the difference between the two measurement techniques; the fibre spliced have the same optogeometrical characteristics (two standard fibres).

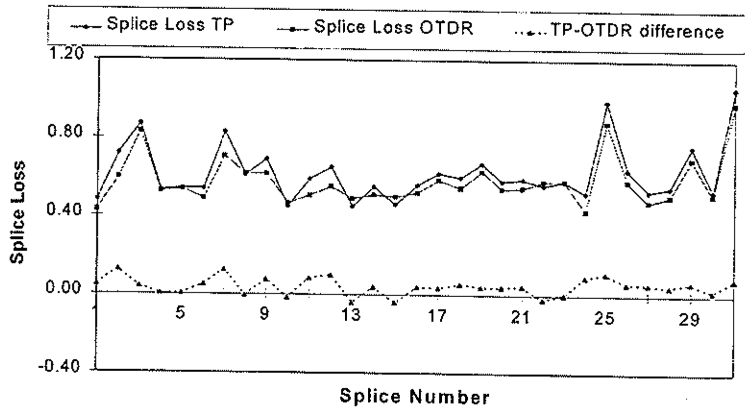

FIGURE 3: The continuous curves are related to the measured splice loss while the dashed curve presents the difference between the two measurement techniques; the fibre spliced have different optogeometrical characteristics (standard fibre and DSF).

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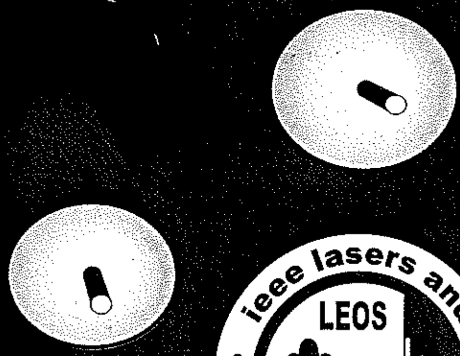

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