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A NEW TECHNIQUE FOR THE RELATIVE MEASUREMENT OF SCATTER LEVELS IN SINGLE MODE FIBRES.

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Introduction

The ability to measure relative scatter levels in single-mode fibres is essential for minimising fibre losses in telecommunications fibres operating in the 2nd and 3rd window for optical communications. In this way fabrication processes can be optimised in response to small improvements in measured scatter levels. Surprisingly, there is no simple way in which this can be done with sufficient accuracy to suit current very-low fibre scatter losses.

We therefore describe a new sensitive technique to separate the Rayleigh scatter loss from the total loss in a single mode fibre. In this, a reference fibre, the scatter loss of which may, if required, be determined by calorimetric techniques, is spliced to the fibre under investigation. The splice loss is then probed using OTDR. The backscattered light powers from each side of the splice are compared by using the test and reference fibres in turn as the launch fibre. The technique is particularly suited to determining very small changes in scatter from fibre to fibre and is therefore ideal for process control and optimisation.

Theory

It may be shown from ref. 1 that, in the case of single-mode step-index fibres operating around second-mode cutoff, the ratio of the scatter loss coefficients α_{S1} and α_{S2} of two fibres is given by

$$\frac{\alpha_{s_1}}{\alpha_{s_2}} = \left(\frac{\omega_1}{\omega_2}\right)^2 \left(\frac{n_1}{n_2}\right)^3 \cdot \left(\frac{R_1}{R_2}\right)^{\frac{1}{2}}$$

where $R_1 = P_{12}/P_{11}$ and $R_2 = P_{21}/P_{22}$ are the ratios of the backscattered powers of the fibres at the splice as defined in figure 1; n_1 and n_2 are the core refractive indices, and ω_1, ω_2 are the spot sizes of fibre 1 and 2 respectively. The spot sizes here are defined as the $(1/e^2)$ power diameter of the Gaussian approximation to the power distribution of the fundamental mode in the fibre[2]. The ratio of the scatter losses between a test and a reference fibre may therefore be readily obtained from measurements of the relative backscattered powers, fibre spot sizes and core refractive indices.

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Experiment

Backscatter measurements were carried out at 1.3 μm on a number of single-mode step index fibres[3], the parameters of which are summarized in Table 1. The fibres used all had a step-index GeO_2-doped core and a matched cladding, with the exception of fibre 5 which had a slightly depressed cladding. As a standard we used fibre 1, a low-loss fibre that exhibited a total attenuation of 0.39+/-.02 dB/km at 1.3 μm. The backscatter traces were obtained using commercial equipment[4] operated with a 750 nsec. pulse width and 5×10^5 averages to optimise the signal-to-noise ratio. The fibre spot sizes were measured using the transverse offset method and the refractive index profiles by the refracted near-field technique[4].

Results and Discussion

The ratio $R_s = \alpha_t/\alpha_s$, where α_t/α_s is the ratio of the scatter losses of the test fibres and the standard fibre respectively, is plotted in Fig.2 as a function of GeO_2 concentration in the core. The accuracy obtainable is limited by the accuracy to which the mode field diameters could be measured. The resulting errors in the scatter loss ratios were about 4 to 7% and are indicated on the figure with error bars. Assuming a scatter loss of silica of ~0.3 dB/km at 1.3μm, differences of less than 0.015 dB/km in scatter loss may be detected.

As expected, an increase in Rayleigh scatter loss proportional to the square root of the GeO_2 concentration is observed[5] and this goes some way to explain the commonly-observed higher attenuation of fibres with large GeO_2 concentrations. The measured variations in total fibre loss are greater than would be expected solely due to changes in GeO_2concentration and are due to process imperfections, as may be observed by plotting fibre losses against $(\text{wavelength})^{-4}$.

The measurement technique described here may be applied to any type of single-mode fibre, provided an expression for the relative backscatter capture fractions of the two fibres is computed. Thus triangular core, depressed-clad or even W fibres could be measured.

Conclusions

We have described a new sensitive technique for the measurement of relative scatter-losses in single-mode optical fibres. As an indication of the use of the method, results showing the measured increase in scatter loss with increase in GeO_2 concentration in the fibre have been presented.

Acknowledgements

The authors would like to thank Pirelli General plc and York VSOP for supplying fibres. We would also like to thank York Technology Ltd. for valuable assistance with the spot size measurements. The work was carried out under the JOERS programme. A readership (DNP) and Research Fellowship (SBP) were provided by Pirelli General plc.

References

1) A.H.Hartog and M.P.Gold. "On the theory of backscattering in single-mode optical fibres." Journal of Lightwave Technology, Vol.LT-2 (2), 76-82, 1984.

2) D.Marcuse. "Gaussian approximation of the fundamental modes in graded index fibres", J.Opt.Soc., Vol.68, pp.103-109, 1978.

3) Fibres 1-3 were supplied by Pirelli General plc. and fibre 5 by York VSOP Ltd. Fibre 4 was made in our own laboratory.

4) York Technology FCm 1000.

5) H.Murata, S.Inao, Y.Matsuda, and T.Kuroha, "Optimum design for optical fibre used in optical cable system", Proceedings, 4th European Conference on Optical Communications, Genoa, pp.242-248, 1978.

Fibre Number	Spot-size μm	Cut-off nm	Total Loss dB/km	R_S	GeO_2 Concentration %
1	11.0	1250	0.39	1	2.3
2	9.8	1250	0.54	1.08	3.5
3	9.5	1250	0.56	1.10	3.5
4	8.5	1200	0.6	1.09	4.0
5	6.3	1250	0.7	1.23	6.8

Table 1 Fibre parameters.

Fig.1 Definition of backscattered power parameters.

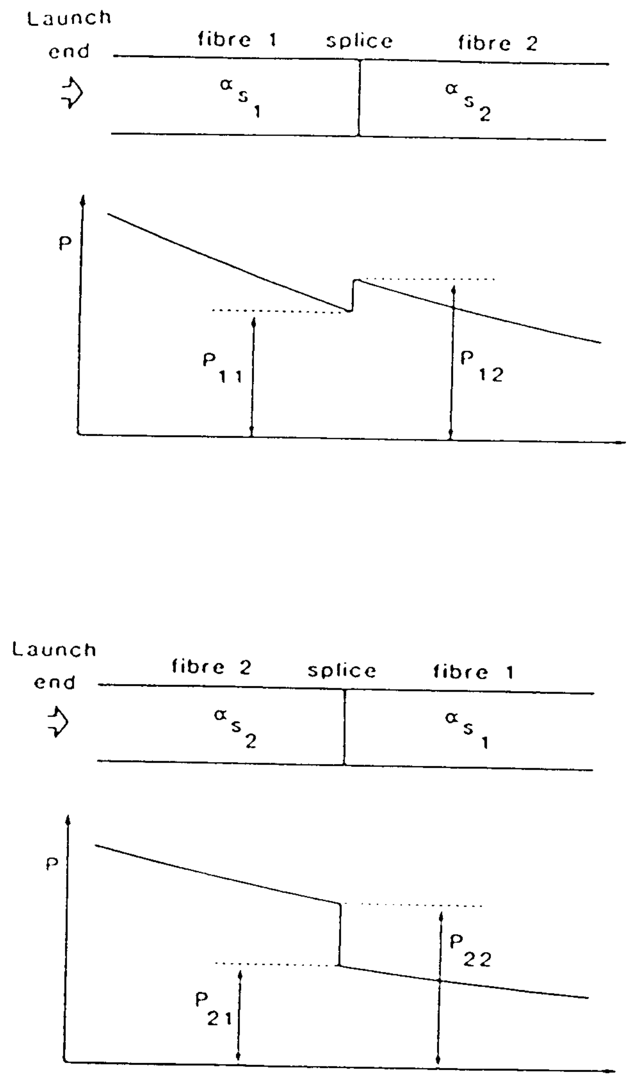

Fig.2 Results showing the increase in scattering with increase in GeO_2 concentration in the fibre core.