A NEW TECHNIQUE FOR THE RELATIVE

MEASUREMENT OF SCATTER LEVELS

IN SINGLE MODE FIBRES

M.E.Fermann, S.B.Poole, D.N.Payne, F.Martinez

Optical Fibre Group, Department of Electronics and Engineering, Southampton University, Southampton SO9 5NH

ABSTRACT

A new sensitive technique to separate scatter loss contributions from total fibre loss in single-mode fibres based on Optical Time Domain Reflectometry OTDR is described.   Results for telecommunications-grade fibres with different GeO_2 concentration in the fibre core are presented.

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 windows 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 technique which allows the separation of the Rayleigh scatter loss from the total loss in a single mode fibre.   In this method, a reference fibre, the scatter loss of which may be determined by calorimetric techniques, is spliced to the fibre under investigation.   The two fibres are 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 and from this the relative scatter losses of the fibres may be obtained.   The technique is capable of determining very small changes in scatter from fibre to fibre and is, therefore, ideally suited to process control and optimisation.

THEORY

It may be shown from ref.1 that, in the case of the single-mode step-index fibres operating around second-mode cutoff, the ratio of the scatter loss coefficients α_t and α_s of a test and a standard fibre is given by

$$\frac{\alpha_t}{\alpha_s} = \left(\frac{w_t}{w_s}\right)^2 \left(\frac{n_t}{n_s}\right)^3 \left(\frac{R_1}{R_2}\right)^{\frac{1}{2}}$$

where $R_1 = P_{12}/P_{11}$ and $R_2 = P_{21}/P_{22}$ are the ratios of the backscattered powers at the splice as defined in Figure 1; n_t and n_s are the core refractive indices, and w_t, w_s are the spot sizes of fibre t and s 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 power, fibre spot sizes and core refractive indices.

MEASUREMENTS

The measurements were carried out at 1.3 μm on a number of single-mode communication grade step index fibres, the parameters of which are summarised in Table 1. These fibres all had a GeO_2-doped core and a matched silica cladding, with the exception of fibre 5 which had a slightly depressed cladding. The fibres were fabricated using VAD and MCVD techniques. As a standard we used fibre 1, a low-loss fibre that exhibited a total attenuation of $0.39 \pm .02$ dB/km at 1.3 μm. The backscatter traces were obtained using commercial equipment operated with a resolution of 40 and 75 metres. The spot sizes were measured using a transverse offset technique.

RESULTS AND DISCUSSION

The ratio α_t/α_s is plotted in Fig.2 as a function of numerical aperture NA. The accuracy obtainable for these ratios is limited by the accuracy of the spot size measurements. The resulting errors in the scatter loss ratios

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were about 5% and are indicated in the Fig.2 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, the Rayleigh scatter loss increases proportional to NA^4 and this goes some way to explain the commonly-observed higher attenuation of fibres with high NA. Surprisingly, the manufacturing process does not have a measurable effect on scatter loss. The measured variations in total fibre losses are greater than would be expected solely due to changes in NA and are due to OH^- peaks and process imperfections.

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 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 NA have been presented.

ACKNOWLEDGEMENTS

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Fibre Number	Spot-size μm	Cut-off nm	Total loss dB/km	α_t/α_s	NA	Manufacturing process
1	11.0	1250	0.39	1	0.10	VAD
2	9.8	1250	0.54	1.08	0.12	VAD
3	9.5	1250	0.54	1.10	0.12	VAD
4	8.5	1200	0.6	1.09	0.13	MCVD
5	6.3	1250	0.7	1.23	0.17	MCVD
6	7.6	1200	0.5	1.15	0.15	MCVD

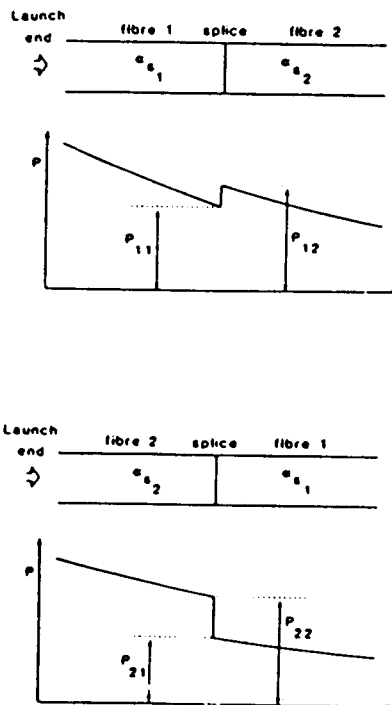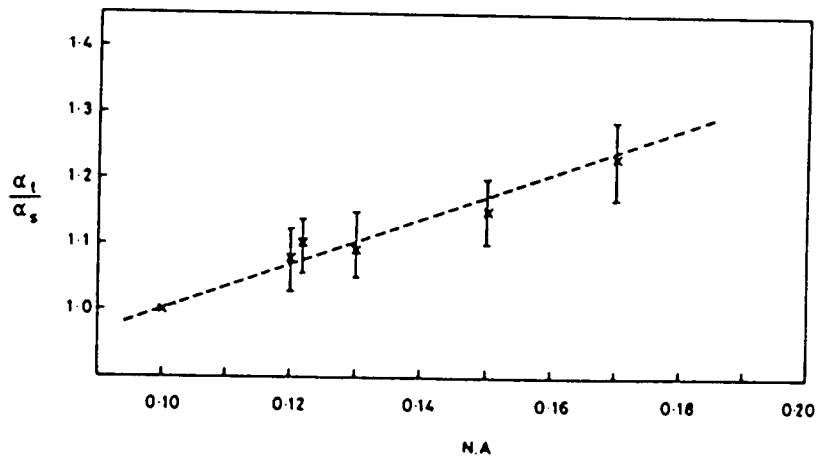Table 1. Fibre parameters.

Fig.1   Definition of Parameters.

Fig.2   Rayleigh Scattering in Single-Mode fibres as a function of NA.