MEASUREMENT OF FIBRE COATING GEOMETRY BY GREY-SCALE ANALYSIS

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INTRODUCTION To preserve the mechanical strength of newly-pulled optical fibres it is usual to apply one or more protective polymer coatings to the fibre. Generally two coating layers are applied; the inner coating to strip out cladding-modes and also minimise microbending effects, the outer coating to provide mechanical and chemical protection.

The thickness of the coatings is important to ensure the fibre's mechanical and optical performance. The concentricity of the coatings is particularly important in the manufacture of ribbon cable. The established method (1) for measuring the geometry of fibre coatings consists of positioning the fibre in an oil filled cell, at right angles to the axis of a microscope, and measuring the positions of the coating boundaries using a filar eyepiece. The measurement repeatability of this method can no longer be considered adequate in the light of recent improvements in fibre glass geometry measurement technology (2) where repeatabilities of 0.1um are routinely achieved. A new method has therefore been developed, based on established grey-scale analysis techniques.

EXPERIMENTAL APPARATUS An intensity profile obtained using a conventional microscope illumination system is shown in figure 1. A CCD camera was used to record the image profile. The positions of the coating and cladding boundaries are difficult to locate accurately and the image is not suitable for computer analysis. In order to improve visibility of the boundaries a measurement system employing dark-field illumination has been developed. Here the illumination is arranged so that it is outside the collection numerical aperture, NA, of the imaging objective. Thus when no fibre is present no light reaches the camera. When a fibre is inserted into the cell light is deviated by the fibre into the collection NA of the objective and an image is formed at the camera. Figure 2 shows the intensity profile obtained from a double-coated fibre. The image consists of six bright peaks corresponding to the coating and cladding boundaries. The peaks are sufficiently sharp to allow computer optimisation and analysis.

The experimental set-up is shown schematically in figure 3, where the central component of the system is a novel wedge-shaped prism. Illumination at 850nm, provided by a large core fibre, is collimated by a lens, and directed on to the front surfaces of the prism. Light from the upper face, in the diagram, is refracted downwards and then reflected by Total Internal Reflection upwards towards the measurement cell. Similarly for light incident in the lower half of the diagram. The two beams cross in the centre of the cell, which is filled with oil, and emerge through the front window of the cell with an NA which is outside that of the imaging objective. The presence of a fibre in the cell causes the light paths to be deviated, by the processes of refraction and relection, into the collection NA of the optical system. An image is thus formed which consists of a series of bright peaks corresponding to the coating and cladding boundaries.

The practical implementation of this technique is shown in figure 4. A plastic moulded collimating lens is located on the projections at the wedged end of the prism. The measurement cell itself is demountable to allow easy access for cleaning with an O-ring seal and spring-clip retainers. The fibre is inserted into the cell through a precision ferrule and is further located by a second blind ferrule at the bottom of the cell. In order to fully characterize the geometry of the coating, provision is also made to rotate the fibre about its axis. The prism itself is manufactured from perspex.

Further advantages of this technique are that the camera allows a section of fibre about 0.5mm long to be seen on the monitor, allowing the cleanliness of the cell to be assessed. Also the presence of bubbles, which sometimes occur in fibres at the interface between the inner coating and the cladding, can readily be seen and their positions measured. Secondly, the system needs no special imaging optics, the prism assembly can be used on commercial grey-scale instruments.

<u>MEASUREMENT PROCEDURE AND DATA ANALYSIS</u> The geometrical parameters of importance are the diameters and non-circularities/ovalities of the coating layers, and the concentricities with respect to the cladding. From these parameters the thickness of the coating layers may also be determined. The measurement procedure is as follows. The fibre is inserted into the cell and located in the alignment ferrules. The focus position is then optimised by analysing scan data from the camera. Measurements are made at 30 degree intervals resulting in a series of edge points for each boundary. Ellipses are fitted to the sets of edge points giving the diameters and non-circularities of each coating, and the concentricities are computed from the relative centre positions of the ellipses. The complete measurement, including re-optimisation of the focus for each fibre position, takes less than 90 seconds.

<u>RESULTS</u> Some typical repeatability data are shown in figure 5. The mean and maximum standard deviations, SD, from 9 sets of

measurements are shown, where each set consists of 12 re-insertions of the fibre under test. The mean SD on the diameter of each layer was better than 0.2um with a worst case of 0.33um. The mean SD on the concentricity of each layer was better than 0.25um with a worst case of 0.41um. These results are a significant improvement on the conventional filar eyepiece method.

From the coating geometry values the thickness of the coatings may also be determined. Measurements on a range of fibres have shown some fibres with variations of up to 9um in the thickness of the outer coating and 11um in the inner coating.

CALIBRATION To calibrate the side-view measurement system, reference fibres or glass rods of certified diameters may be used. In order to determine the effect of measuring fibres coated with different materials a series of fibres from 11 manufacturers was obtained. The refractive index of the inner and outer coatings of these fibres were then measured using the refracted near-field method. It was found that the use of 3 calibration fibres, or glass rods, enabled a calibration accuracy on outer diameter of 0.6um to be achieved over the range of fibres investigated.

It was found that the calibration factor for the inner coating diameter could be determined from the calibration factor for the outer coating. This is due to the fact that the refractive index differences between the inner and outer coatings on the range of fibres measured were similar. An accuracy on inner coating diameter of approximately 1um may be achieved

The measurement of non-circularity is self-calibrating as it is a ratio measurement. Concentricity calibration depends on only nominal dimensional calibration of the optical system.

SUMMARY A practical system for fibre coating geometry measurement based on the established side-view method has been described. The new implementation makes use of computerised control and data processing techniques to achieve typical repeatabilities of 0.2um on diameter and 0.25um on concentricity.

REFERENCES

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(2) 'The First International Fibre Geometry Round Robin', Kane W.T., 'Optical Fibre Measurement Conference', York UK, Sept 1991.

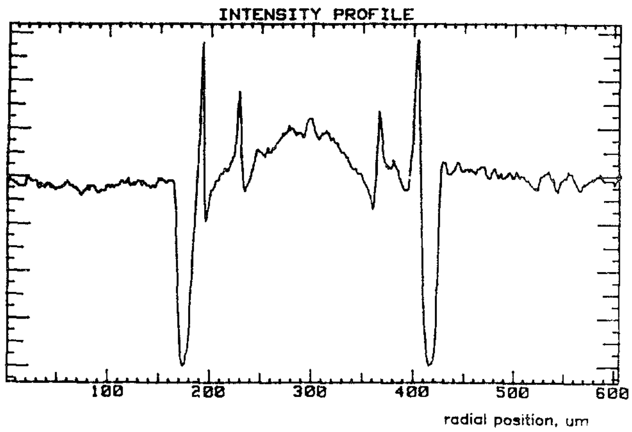

Fig 1. Conventional intensity profile.

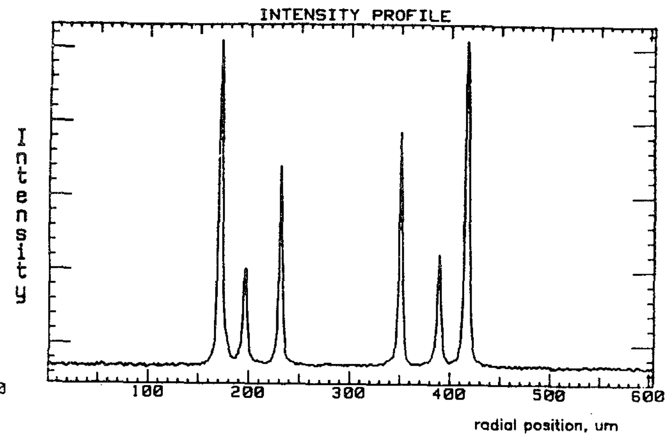

Fig 2. Dark-field intensity profile.

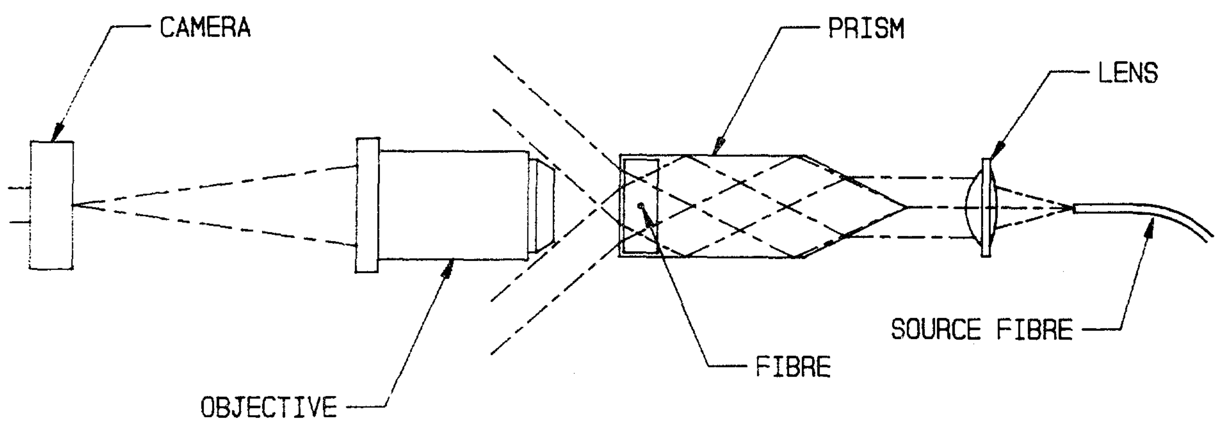

Fig 3. Optical set-up of the side-view system.

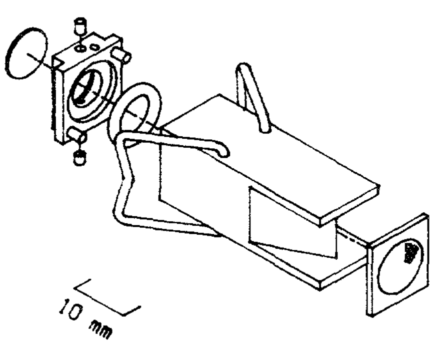

Fig 4. View of prism components.

Parameter	Mean std dev	Max std dev
outer coating diam	0.17um	0.33um
inner coating diam	0.16um	0.33um
cladding diam	0.11um	0.24um
outer coating non-circ	0.15%	0.37%
inner coating non-circ	0.23%	0.44%
cladding non-cir	0.15%	0.23%
outer coating conc	0.15um	0.26um
inner coating conc	0.23um	0.41um

Fig 5. Repeatability of side-view system.