SIMPLE VISUAL INSPECTION TECHNIQUE FOR OPTICAL FIBRE PREFORMS

Indexing terms: Optical fibres, Optical-fibre preforms

A simple visual inspection technique for index profiles in optical-fibre preforms is described. Qualitative results for preform type, index structure and geometry can be obtained.

Introduction: Inspection of preforms for the purpose of quality control in optical fibre manufacture is becoming increasingly important, as it avoids costly and difficult fibre measurements. We have previously reported a spatial-filtering technique[1] which allows viewing of the preform deflection function,[2] from which the refractive-index profile can be computed. The method employs a shadow mask in conjunction with a cylindrical or spherical lens to determine the angular deflection experienced by a complete set of rays traversing the preform transversely. In the present note we report a reduction of this basic idea to allow an immediate qualitative visual inspection of performs for type (i.e. single mode, multimode etc.), layer structure, core and cladding sizes and circularity. The method requires virtually no equipment and, with practice, can be remarkably informative.

Principle: A white screen on which an angled line has been drawn is placed a distance D behind the preform and viewed by eye through the preform (Fig. 1). The preform acts as a complex cylindrical lens and distorts the line according to the inclination of the line β, the distance D to the screen and the refractive-index distribution. Provided the eye is at a sufficient distance, we are observing essentially parallel light which has traversed the preform; this is exactly the reciprocal situation to that reported previously,[1] where parallel light was used to *illuminate* the preform.

A geometrical analysis shows that the co-ordinates x, y (Fig. 1) of the line shape observed through a cylindrical graded-index preform of radial size R_0 and surface index n_0 are given by:

$$x = \frac{1}{\tan\beta}\left[y\left(1 + \tan\frac{\phi}{2}\tan\phi\right) + (R_0 + D)\tan\phi\right] \qquad (1)$$

with

$$\phi = 2\sin^{-1}\left(\frac{y}{R_0 n_0}\right) - 2\alpha + \Phi(y/n_0) \qquad (2)$$

and

$$\alpha = \sin^{-1}\left(\frac{y}{R_0}\right)$$

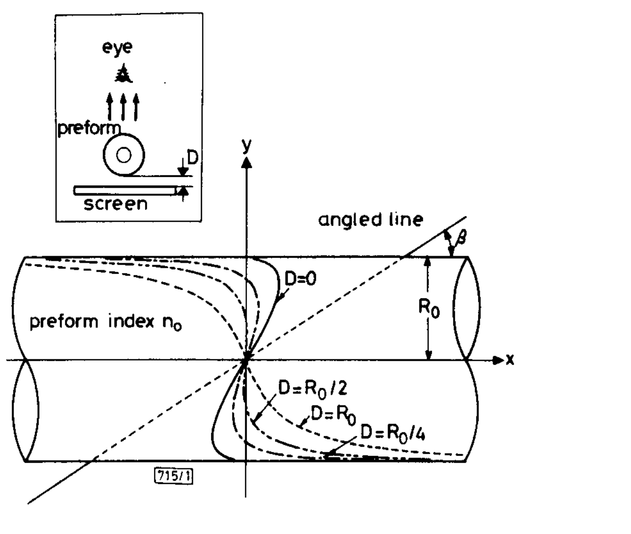

Fig. 1 *Distortion of an angled line when viewed in air through a preform having uniform index n_0*

Curves are plotted for various preform-to-line distances D (see inset for optical arrangement)

Here $\Phi(y/n_0)$ is the deflection angle experienced by the ray whilst travelling within the preform and is due solely to the radial index distribution, i.e. the deflection function.[1,2] Inspection of eqns. 1–3 reveals that the observed line distortion is caused by a combination of the focusing effect of the preform outer surface and the deflection of light $\Phi(y/n_0)$ by the inhomogeneous core. Fig. 1 shows calculated line shapes for various preform to screen distances D and for $\Phi(y/n_0) = 0$, i.e. a homogeneous rod. When the preform has a radial index distribution, a pattern due to the deflection function $\Phi(y/n_0)$ appears superimposed on the curves of Fig. 1, as photographed in Fig. 2 for a typical MCVD preform. The preform shown is the same as that measured previously,[1] and a comparison can therefore be made between the actual deflection function (Reference 1, Fig. 3*a*) and that photographed here.

Experienced analysis of the deflection function (which bears

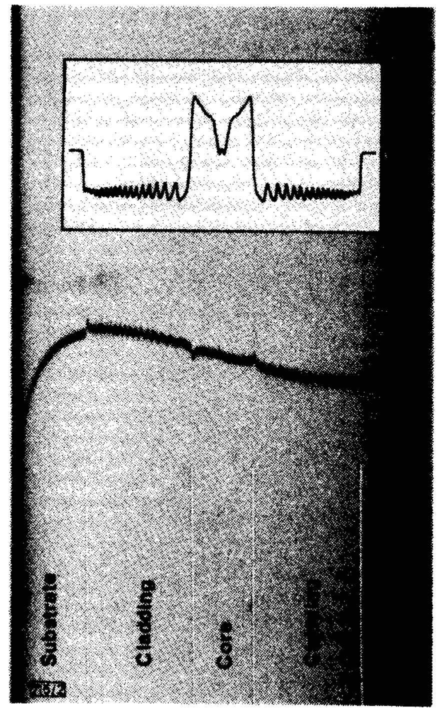

Fig. 2 *Photograph of angled line viewed in air through a monomode-fibre preform, showing the visible deflection-function*

For comparison, inset shows the preform index profile measured by the dynamic spatial-filtering technique

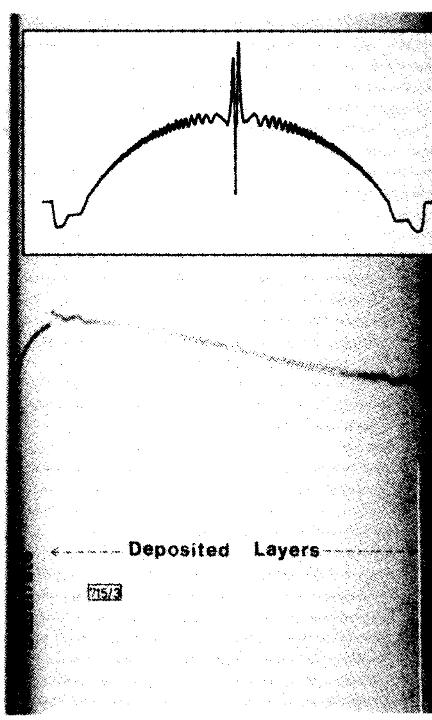

Fig. 3 *As Fig. 2, but for a multimode fibre preform*

a resemblance to the derivative of the index profile) will reveal that this is a single-mode preform with a deposited cladding having 18 layers depressed in index below that of the silica substrate. We infer the latter from the sharp discontinuity at the substrate/cladding boundary. The core is approximately step-index in shape (sharp discontinuity at core/cladding boundary) with a slight central dip. For comparison, the index profile measured by the dynamic spatial-filtering technique[3] is overlayed on Fig. 2 (upper curve).

Note that the preform internal features are magnified by a factor n_0 owing to the lensing effect of the preform outer surface. Taking this into account, we can obtain quantitative measurements of core and cladding diameters.

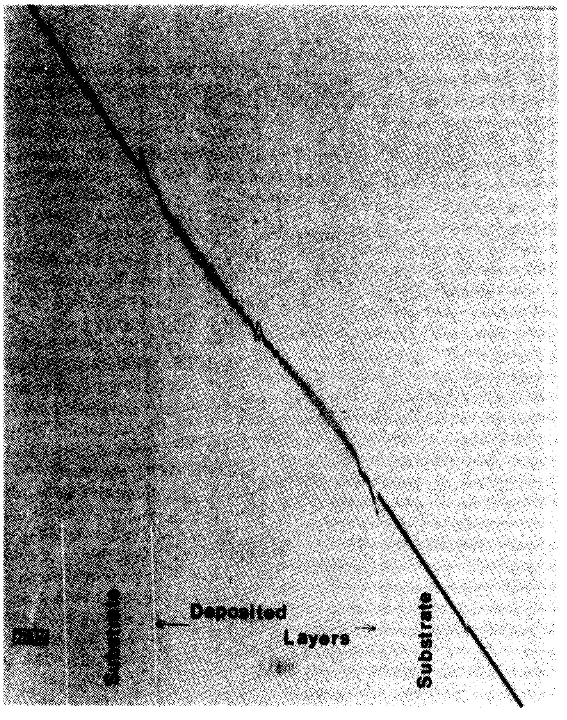

Fig. 4 *As Fig. 3, but with preform immersed in index-matching fluid*
The preform is the same as that shown in Fig. 3

Fig. 3 shows the line pattern for a MCVD multimode graded-index preform and again core and cladding regions are clearly defined, complete with their layer structure. Experienced interpretation indicates that a discontinuity error is present at the core/cladding interface and that a central peak exists due to overcompensation with GeO_2 during collapse. The measured profile is again given for comparison.

A more precise observation free from the strong lensing effect of the preform outer surface can be made by immersing the preform in index-matching liquid, as shown in Fig. 4 for the same preform as in Fig. 3. In this case the co-ordinates of the line are given by

$$x \simeq \frac{1}{\tan \beta}[y + (R_0 + D)\Phi(y)] \qquad (4)$$

where $\Phi(y)$ is the preform deflection function. In fact, precise measurement of these co-ordinates would allow the detailed reconstruction of the index profile. For inspection purposes, however, index matching permits testing for internal circularity without the strong astigmatic effects of what may be a slightly noncircular outer surface. Furthermore, index matching simplifies core and cladding diameter measurements, since no magnification is experienced.

Conclusions: The deflection function of a preform can be directly observed by simply viewing an inclined dark line placed behind the preform. A mathematical transform is required to convert the observed deflection function to the index profile; however, with practice many of the index-profile features can be easily identified. The method can thus be used as a useful visual inspection technique.

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