SPECKLE BASED FIBRE OPTIC SENSOR FOR THE MEASUREMENT OF THE CHANGE IN REFRACTIVE INDEX IN LIQUID MIXTURES

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The development of fibre optic sensors (FOS) for the measurement of physical parameters is undergoing an accelarated growth. A novel FOS using a speckle pattern generated at the output end of an optical fibre was reported by the authors [1] in an earlier paper. In this paper, measurement of refractive index of a liquid mixture using a speckle based fibre optic sensor (SBFOS) is described.

EXPERIMENTAL TECHNIQUE

Fig.1 shows the experimental set up for making the specklegrams. A pyrex glass fibre of 0.5 mm diameter (drawn in the laboratory) is illuminated by a He-Ne laser through a 10 X microscope objective. A lens is used to collimate the output beam of the fibre. This beam illuminates a rectangular glass cell of 8 x 6 x 1 cms. A high resolution photographic plate is located in the image plane of the lens. The liquid cell is filled with water. When the laser beam passes through the multimode optical fibre, a speckle pattern is generated at the output end of the fibre. This speckle pattern passes through a water in the cell, and an image is formed on the photographic plate. The first exposure is now made. A known quantity of a liquid with a refractive index other than that of water is added to the cell.

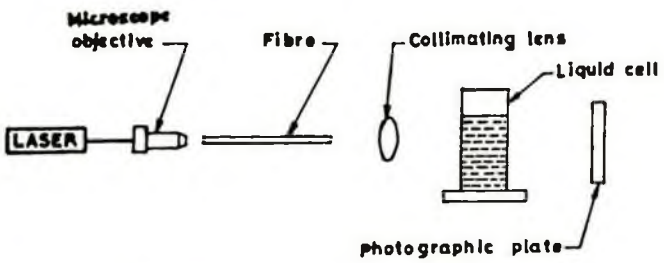


Fig. 1 Schematic of speckle based fibre optic sensor.

After a short time interval, during which the liquid mixture settles, the second exposure is made. The developed specklegram is illuminated with an unexpanded laser beam, when Young's interference fringes are seen on the screen. It can be inferred from this that the speckle pattern is modulated by the change in the refractive index of the phase medium. It amounts to a displacement of the speckle pattern in its own plane. Fig. 2 gives

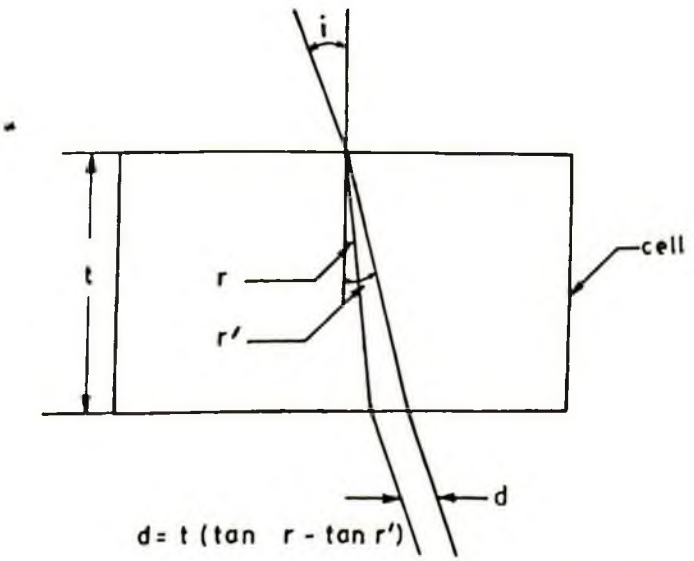


Fig. 2 Schematic of the optical ray showing the shift.

the schematic of the optical ray passing through the liquid cell. The shift in the optical ray due to the change in refractive index of the liquid from n_1 to n_2 is given by

$$d = t \times \sin i \left(\frac{1}{\sqrt{n_1^2 - \sin^2 i}} - \frac{1}{\sqrt{n_2^2 - \sin^2 i}} \right)$$

where i is the angle of incidence of the light beam and t the thickenss of the cell.

As the concentration of the solute increases, the displacement of the speckle pattern also changes. This is accompanied by a change in distance between the interference fringes. It works out that this is a good indicator for the measurement of change in the refractive index.

A series of experiments were conducted using Kodak D163 developer solution added to the water. Kodak SO253 film was used for making the specklegrams. The refractive index of the mixture was measured using the Abbe refractometer.

The in-plane displacement of the speckle was measured by using the formula

$$d_s = \lambda (D)/(m\ d)$$

where D is the distance between the specklegram and the shear, d is the distance between the fringes; λ the wavelength of light and m the magnification. As the refractive index of the mixture increases, the fringes become closer.

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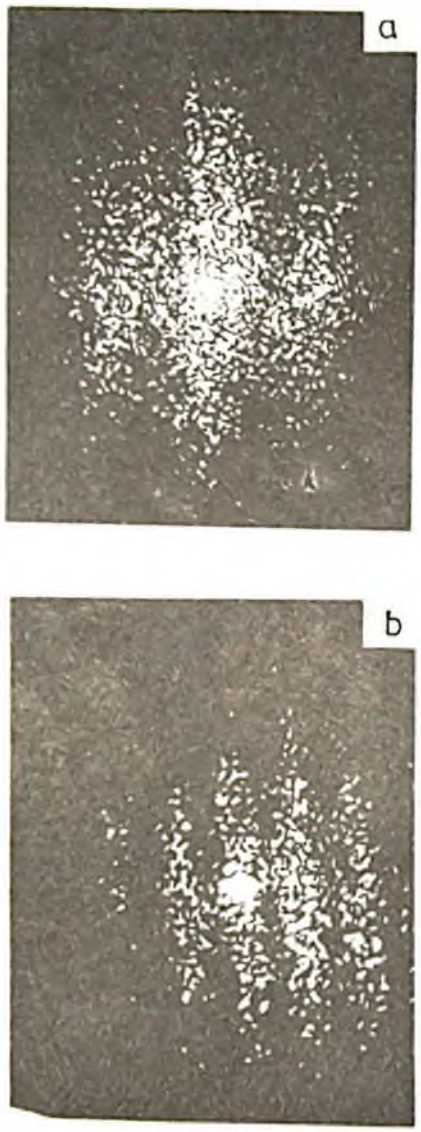


Fig. 3 Specklegrams showing Young's fringes for different concentration of mixtures.
a. $(n_1 - n_2) = .0005$ b. $(n_1 - n_2) = .002$

TABLE 1

No.	Change in refractive index	Shift in microns	
		Experimental	Calculated
1	.0005	7	2.975
2	.001	9	5.95
3	.002	12.8	11.9
4	.003	19	17.75

Table 1 gives measured and calculated values of the shift at the exit face of the liquid cell for various refractive index changes. There is a good agreement between the experimetal and calculated values.

CONCLUSION

A novel technique for the measurement of change in refractive index of liquid mixtures using fibre optic speckle has been described. For real time measurement, it is suggested that electronic speckle pattern interferometry (ESPI) may be used for continuous monitoring in chemical process industries.

REFERENCES

1. B.S. Ramprasad and T.S. Radha Bai, *Opt. Laser Technol.* 16 (1984) 156.