New Optical Interferometric Techniques for Measurement and Testing

A thesis submitted to

The Maharaja Sayajirao University of Baroda

for the award of degree of

Doctor of Philosophy

in

Applied Physics

by

Vani K Chhaniwal

Photonics Laboratory
Applied Physics Department
Faculty of Technology & Engineering
The M S University of Baroda
Vadodara 390001, Gujarat. INDIA.

July 2004

Summary

This thesis entitled "New optical interferometric techniques for measurement and testing" discusses new optical methods developed for testing and measurement. Most of the developed methods are easy to implement and do not require stringent optical conditions like that of existing methods.

The first of the developed methods deals with diffusivity measurements in transparent liquid solutions. The study of diffusion is very important from the point of view of chemical engineers for designing chemical equipments and also for the investigation of mass transfer processes. Three optical methods are developed to measure diffusion coefficients. All the three methods yielded accurate results. The method using the parallel plate yielded very accurate results. One of the advantages of this technique is that it is less sensitive to external disturbances. In the future, efforts will be made to investigate the influence of source wavelength on the diffusivity measurement. This will be done using different laser sources to find which wavelength yields accurate diffusivity values. Michelson interferometric method also yielded accurate results. But this method is more sensitive to disturbances. The measurement using white light and artificial fringes is an easy method.

One of the future scopes is to make the method fully automatic, with real-time diffusivity measurement and refractive index profiling. As the beam-bending depends upon the refractive index, by measuring the change in beam bending one can study the process of diffusion in real-time. Future work will also involve the development of other optical methods for diffusion studies, which may include moiré interferometry, imaging of the beam bending etc.

Textile yarn is made up of many fibers. But some of the fibers protrude out from the yarn body. These fibers constitute the hairiness of the textile yarn. Hairiness is an important property of the textile yarn in which the textile industry is interested. The measurement of the hairiness of textile yarns is very important for the characterization of the yarn. A method for measurement of yarn hairiness from the scattered light from the yarn hairs is developed The polarized scattered light from the yarn hairs are filtered out using an analyzer. The methods yielded very accurate results. The variation in the detector output with hairiness is found to be linear.

In the future, the method will be made dynamic. For this a detector with a sampling rate of approximately 1kHz is necessary. The system will be made fully automatic by interfacing with a PC. Software for the hairiness measurement will also be developed, which will yield the hairiness, the standard deviation of hairiness etc.

Liquid crystals do not melt in a single step during its transition to the isotropic state from the solid state. Several phase transitions may occur in between these two states. The study of these phase transitions is very important from the point of view of the applications of liquid crystals. Methods like photographic microscopy and differential scanning calorimetry (DSC) are used to determine the phase transitions in liquid crystals. A method using the laser speckles formed by light scattered from liquid crystal samples is developed to measure their transition temperatures. The number of speckles is found to decrease drastically at phase transition temperatures. A plot of the change in the number of speckles with temperature yields the transition temperature.

The method will be extended in future to study the structure properties of the liquid crystals at transition temperatures

High quality of optical components is necessary for very precise optical experiments. Quality testing of optical components therefore becomes a necessity. The testing methods developed during the course of this work are also discussed.

A spherical wavefront is converted into a collimated wavefront by passing it through a convex lens placed exactly a distance equal to the focal length of the lens from a point source. There are many methods for testing of collimation of wavefronts. These methods include techniques utilizing interferometry and self imaging. But all these methods depend upon a qualitative evaluation of the resulting interferogram. A new method utilizing optically active materials to test the collimation of a wavefront is developed. The plane of polarization of a polarized beam will rotate when passed through an optically active material depending upon the distance traveled inside the medium. This effect is used for collimation testing. The output from an analyzer placed after the optically active medium is least when the beam is exactly collimated. The results are very accurate.

In the future, the method will be extended to study the refractive index of transparent materials and also for study of dispersion in glass materials.

The knowledge of the refractive index of a particular glass material can lead to information like its reflectance and transmittance, which are very important in designing optical elements. There are many methods to find the refractive index of a lens. The methods to determine refractive index of lenses include liquid immersion method and interferometry. A method using Michelson interferometer is developed to measure the refractive index of thin biconvex lenses by measuring the focal length and radius of curvature of the lenses. The test lens itself acts as the collimating lens. The position where the test lens gives a fringe free detector plane corresponds to the focal length of the lens. The same method is used to measure the radius of curvature. Using the thin lens formula refractive indices of the lens material is determined. The results are very accurate. The dispersion curve of the glass material is created by measuring the refractive index at three wavelengths. The Sellmeier dispersion formula is fitted to yield the dispersion coefficients of the glass material.

Linear polarizers are used for producing linearly produced light from incident unpolarized light. The most commonly used linear sheet polarizers are based on dichroism. This type of polarizers are extensively used especially in low power and visual applications When such a pair of polarizers with perpendicular polarization directions are used, the output intensity should be zero ideally. But due to non absolute absorption of one of the orthogonal components, this quantity will always be greater than zero. The parameter that determines the leakage of the absorbed component is the extinction ratio and open transmittance. A method using Michelson interferometer geometry is developed to test linear polarizers. The visibility of the real interference fringes are used to determine the extinction ratio and open transmittance. The results obtained matched well with the literature values.

In future, the dependence of the extinction ratio and open transmittance of the polarizers on wavelength of the incident light will be investigated.

Beamsplitters play important role in most of the sensitive optical experiments like in interferometry, holography, phase conjugation etc. For all these experiments, proper splitting of the incident energy is very essential which requires proper design of a beamsplitter. In a Michelson Interferometric experimental setup, if a diverging laser beam falls on such a beamsplitter, then for unequal arms length two or more sets of circular fringes, instead of one set of circular fringes are obtained. This happens for many of the commercially available beamsplitters. This is basically due to the improper coating of the front or back surface. A method to determine the beam ratios of the beams split by a beamsplitter is developed using Michelson interferometer geometry. Visibility of the interfering beams is determined by scanning the resulting real fringes when the path difference is approximately zero. These visibilities are used to determine the corresponding beam ratios. The results showed that the tested beamsplitters of specification 50:50 never split the beam in the specified ratio.

The future work is to test the beamsplitters using the same method to investigate the dependence of beam ratios on the incident wavelength.

During the course of this work some new optical methods for measurement and testing are developed mostly using low power He-Ne lasers. The developed methods are accurate and easy to implement and less sensitive to external disturbances. Coupling of image processing with the experimental methods yielded accurate results. In the future, effort will be made to develop real-time optical testing techniques.