Ain Shams University
Physics department
Faculty of Science

Examination of Phase Objects Applying Interferometric – Based Techniques

Thesis

***In Partial Fulfillment of the Requirements for the Degree of Doctor of philosophy of science in Physic science* (optics)**

Submitted to
Physics Department
Faculty of Science
Ain Shams University

By

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M.Sc. Physics, Ain Shams University (2006)

2013

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ACKNOWLEGEMENT

I wish to express my thanks to *Dr. H. A. El-Hennawi*, Prof. of Physics Faculty of Science, *Dr. H. El-Ghandoor*, Prof. of Physics, Faculty of Science, Ain Shams University. Thanks also extended to *Dr. F. El-Diasty*, Prof. of Physics, Faculty of Science, Ain Shams University, for their supervision, suggesting the problem and constructive criticism throughout the course of this work and preparing the manuscript.

Acknowledgement also extended to the Head of Physics Department for his corporation. Thanks are extended to all members of Department of Physics, Faculty of Science, Ain Shams University for their valuable discussions and advices.

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Preface

Optical fibers have several applications such as optical telecommunication, interferometric sensors, fiber lasers, fiber gratings, accelerometers, amplitude modulators, tunable filters, frequency shifters, strain gauges, chromatic dispersion compensators and fiber amplifiers.

Several methods can be used to characterize optical fibers, such as the far-field pattern method, the near-field pattern method electron beam microprobe method, the reflection method and interferometric method. Among these methods lens-fiber interference method and multiple-beam fiber interferometry are the most accurate and sensitive techniques that can provide more quantitative and qualitative information.

Multiple-beam Fizeau fringes in transmission crossing GRIN optical fiber perpendicular to its optic axis suffer a shift that represents the optical phase difference exists in each point across the fiber cross-section. The shape, magnitude, and direction of the fringe shift inside the fiber depend on the relative values of the mean refractive indices of fiber regions and immersion liquid.

lens-fiber interference method is used to calculate the refractive indices of GRIN optical fiber from its transverse interference pattern.

Dispersion is one of the main problems in optical fiber communications systems, where the main types of dispersions are intramodal dispersion and intermodal dispersion. Therefore the relations between dispersions and some optical fiber parameters are studied such as relative refractive index difference and wavelength of the light pulse

Aim of the present work

1. In the present work, analytical expressions for the shape of Fizeau fringes across the cross-section of GRIN optical fiber containing a dip in the core index profile has been derived. Mathematical expressions used to determine, for the first time, the fiber dip parameters such as index difference and the dip shape parameters. Interferometric method, multiple-beam Fizeau fringes crossing GRIN fibers immersed in matching liquid wedge interferometer is used to investigate the structure of the optical fiber dip.
2. The lens-fiber interference technique employed with the computer-aided image analysis via the addition of images of the experimental and theoretical interferograms. This method gives an accurate value of the determined dip refractive index of GR-IN optical fiber. Comparing between the results of the two systems, lens-fiber interference method and multiple-beam fiber interferometry.

The following work is concerned with the obtained experimental results and data reduction. Optical fibers have many advance and exciting applications, in particular optical telecommunication. These applications are in basic depending on the fiber structure and on its index profile. Therefore, precise and accurate determination of this profile and their dispersion needed. Multiple-beam interference fringes used to measure the characteristic parameters of graded index fiber with central dip.

Objectives of the thesis

1. Construct experimental setup of multiple-beam Fizeau fringes method in transmission that is required to investigate the fiber.
2. Construct experimental setup of lens-fiber interference method that is used to study the fiber structure.
3. Compare the results of the two methods; lens-fiber interference method and multiple-beam Fizeau interferometry.

4. The effect of the central dip on the dispersion parameters
5. Determination of fiber transmission parameters:
    a) Refractive index profile of fiber
    b) Intermodal Dispersion
    c) Intramodal Dispersion
    d) root-mean square pulse broadening
    e) Transmission rate

Summary

The present thesis comprises six chapters; Chapter 1 is an introductory chapter concerned with the definition of optical fibers, the types and description of the experimental techniques which have been used to investigate optical fiber structure.

Chapter 2 summarizes previous work of multiple-beam Fizeau fringes for optical fiber characterization .Many authors applied interferometric techniques to study the optical properties of fibers.

Chapter 3 deals with the theory of multiple-beam Fizeau fringes applied to optical fibers as a phase object. The mathematical expression describes the shape of fringes crossing multi-mode GRIN optical fiber with central dip derived. Multiple-beam Fizeau fringes are dialed with providing information on the correlation between the fiber structure and its other properties and the effect of central dip on optical fiber transmission parameters. The mathematical equations of dispersion parameters, which include, intramodal and intermodal dispersions were derived.

Chapter 4 describes experimental setup of multiple-beam Fizeau fringes which was used to study the graded index optical fibers, study the effect of central dip on the fiber parameters has been achieved. The errors in measuring index of refraction are determined.

Chapter 5 discussed the obtained experimental results and their comparison with the calculated results of multiple-beam Fizeau fringes applied to GRIN fiber with central dip. For through the discussion the two possible cases for the dip index profile (step - or graded-index) are carried out. It has been found that the dip index profile is graded in nature. Through which the radial profile variations of many important optical fiber parameters, such as

refractive index profile, dispersion parameters are carried out, intermodal dispersion, intramodal dispersion and root-mean square pulse broadening of the fiber material are also obtained. The effect of core central dip on the fiber dispersion profiles of these parameters together is investigated.

Chapter 6 presents in details the laser sheet-lens fiber interferometer technique. The mathematical expression for the transverse interference pattern of GRIN optical fiber with central dip has been derived. An experimental verification and data reduction for GRIN fiber with central dip was reported.

Chapter I

Characterization of optical fibers

1. Introduction

Optical fibers as circular dielectric optical waveguides are made of silica glass with the lowest loss and the most carefully controlled index. Doping with impurity oxides such as Germenia GeO_2, Titania TiO_2, Caesia Cs_2O, Alumina Al_2O_3, Zirconia ZrO_2 and Phosphorus pentaoxide P_2O_5 raises the refractive index of pure silica in the core region [1]. Doping with Boria B_2O_3 or Fluorine F inferiors the refractive index of the cladding [2]. Rare-earth ions such as $ErCl_3$ and Nd_2O_3 have been used in order to make fiber amplifiers and fiber lasers [3]. Polymer optical fibers are also achieved with increased attention for short-haul transmission of light, although these fibers are limited to multi-mode dimensions [4-9].

Optical fibers are ideal optical transmission medium for many reasons;

1. Extremely long continuous length (>100's of km's) of fiber can be fabricated.
2. Fibers possess a high degree of cross-sectional uniformity along the fiber length. It means that the properties of the guided light do not change along the transmission path.
3. Fibers have extremely low loss due to:
    - high-purity glass makes low absorption loss.
    - high-quality and homogeneous glass provides low Rayleigh scattering loss.
    - small and accurately controlled core-cladding refractive index difference enables low interface scattering loss.