

STUDIES ON MULTIPLE-PASS INTERFEROMETERS

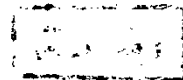
Thesis

Submitted For The Degree Of Master Of Science In Physics

By

Hassan Fathy Hassan Mohammad

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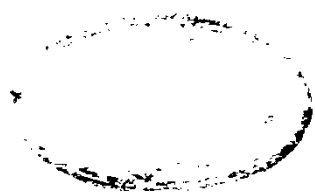
PHYSICS DEPARTMENT

FACULTY OF SCIENCE

AIN SHAMS UNIVERSITY

37328

1991



N. Barakat
M. Medhat

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ
صَدَقَ اللَّهُ الْعَظِيمُ



ACKNOWLEDGEMENT

I wish to express my sincere thanks to professor N. Barakat, professor of experimental physics, physics department, for his continual supervision and encouragement through the years I have worked with him, and who has given support, direction to my work, and has made it known to me that in his eyes I am succeeding in becoming a physicist.

I would like to thank Prof. Dr. A.H. Moussa, head of the physics department, for rendering many facilities.

I wish to express my deep thanks to Dr. M. Medhat, assistant professor, physics department, for his guidance in supervision, interest, encouragement, fruitful assistance, patience, and for giving me the benefit of his experience.

I would like to express my gratitude and appreciation to my colleagues and friends A. Ali, A. Hassanien and A. Radi for helping me greatly in computer work.

My sincere thanks to Miss E. El-Khateeb for her helpful assistance.

I wish to express my thanks to my colleagues and the members belonging to the school of Optics at Ain shams university and the institute of standards for their assistance.

A B S T R A C T

Multiple-pass wedge interferometers are used to produce multiple-beam interference fringes of increased spatial frequency and / or contrast. These fringes provide tools for a variety of applications in topographic investigations, measuring the optical transfer function for the evaluation of lens performance, some spectroscopic studies, and metrological measurements. Multiple-pass wedge interferometers for increased spatial fringe frequency include the case of formation of fizeau fringes on planes of fractional high orders of localization, found away from the interferometer on both sides of it, and the case of selective masking of some beams and allowing the others to interfere. These techniques permit the control of the phase of the interfering beams, such that phase multiplication takes place. The multiple-pass interferometers for increased contrast deal with the optical feedback of the interfering beams, that are whether transmitted or reflected from an interferometer, by reflecting them back into the same interferometer and observing the transmitted fringes.

The effect of the optical phase properties of the mirror coating on the fringe position, profile and characteristics is reported. It is found that the position of the transmitted fringe is shifted towards the direction of increasing or decreasing order of interference as a result of, respectively, increasing or decreasing the value of the phase change which the light suffers upon reflection. The intensity distribution of the reflected fringe system turns to transmission-like fringe system whenever the value of a certain phase term called F tends to a specific value equals $2n\pi$, where n is an integer. The value of F depends on the phase change which the light suffers due to

transmission and that upon reflection air/metal and glass/metal. Hence, three main fringe systems arise and are studied. These are the transmitted, reflected and transmission-like (at reflection) fringe systems. Multiple-pass interferometers for increased spatial fringe frequency are considered in these three fringe systems. Reflected transmission-like fringes formed on planes of localization of high orders, are reported here for the first time. Three main conditions for observing the multiple-pass fizeau fringes of increased contrast are studied. These are the case of observing doubly-transmitted systems, reflected-transmitted systems and reflected (transmission-like) -transmitted systems.

The theory of fringe formation, intensity distribution and characteristics are presented and performed for each kind of fringe system, with special emphases on their spatial frequency and contrast. An interferometer with m passes gives fringes of spatial frequency which is increased m times. With an interferometer of wedge angle equals 3×10^{-3} rad, the contrast of the doubly-transmitted fringe is tens of times greater than that of the singly-transmitted fringe.

C O N T E N T S

ACNOLEDGEMENT	i
ABSTRACT	ii

INTRODUCTION

i.1. Classification of Multiple-Pass Fringe Systems...	4
i.1.1. Two-Beam Interference	4
i.1.2. Multiple-Beam Interference	5
i.1.2.1. Multiple-Pass F-P Interferometer.	6
i.1.2.2. Multiple-Pass Wedge Interferomet-	7
er	7
i.2. Aim of The Present Work	8

CHAPTER I

THEORY OF MULTIPLE-PASS WEDGE INTERFEROMETERS

I.1. Single-Pass Wedge Interferometers	10
I.1.1. The Phase Condition of The Interfering Be-	
ams	11
I.1.2. The Role of The Optical Phase Properties	
of The Coating Layers	12
I.1.3. Intensity Distribution	14
I.1.3.1. Transmitted System	14
I.1.3.2. Reflected System	15
I.1.3.2.a. Fringes With $F=(2n+1)\pi$	17
I.1.3.2.b. Fringes With $F=2n\pi$...	18

I.1.4. Computation of The Intensity Distribution	18
I.2. Effect of Increasing The Wedge Angle and The Angle of Incidence on The Characteristics of The Transmitted Fizeau Fringe	20
I.3. Effect of Changing The Value of F on The Shape and Characteristics of The Reflected System	21
I.4. Formation of Multi-Source Images and Transfer of The Interferograms	22
I.5. Multiple-Pass Interferometers for Increased Spatial Fringe Frequency	24
I.5.1. Formation of Multiple-Pass Fizeau Fringes on Planes of Fractional High Orders of Localization	24
I.5.1.1. In Transmission	25
I.5.1.2. Intensity Distribution	26
I.5.1.3. At Reflection	27
I.5.1.4. Intensity Distribution	27
I.5.1.4.a. Fringes With $F=(2n+1)\Pi$	28
I.5.1.4.b. Fringes With $F=2n\Pi$...	29
I.5.1.5. Computation of Intensity Distribution	29
I.5.2. Formation of Multiple-Pass Fizeau Fringes by Modulating The Phase of The Interfering Beams	31

I.5.2.1. Intensity Distribution	32
I.5.2.2. Computation of Intensity Distribution	34
I.5.3. The Spatial Frequency of The Fringe System	36
I.6. Multiple-Pass Interferometers for Increased Contrast	36
I.6.1. Formation of Fringes in Doubly Transmitted System	37
I.6.1.1. Intensity Distribution	40
I.6.1.2. Computation of Intensity Distribution	42
I.6.2. Formation of Fizeau Fringes in Reflected-Transmitted System	44
I.6.2.1. Intensity Distribution	47
I.6.2.1.a. Fringes With $F=(2n+1)\pi$..	49
I.6.2.1.b. Fringes With $Ff=2n\pi$..	50
I.6.2.2. Computation of Intensity Distribution	50
I.6.3. Comparison Between The Characteristics of The Different Double-Pass Systems	53

CHAPTER II

EXPERIMENTS WITH MULTIPLE-PASS INTERFEROMETERS

II.1. The Optical Set-Up for Formation of Reflected Multiple-Pass Fizeau Fringes of Increased Spatial Frequency	56
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II.2. Observation of Reflected Multiple-Pass Fringes of Increased Spatial Frequency on Planes of Fractional High Orders of Localization	59
II.2.1. Fringes With $F=(2n+1)\Pi$	59
II.2.2. Fringes With $F=2n\Pi$	61
II.3. Observation of Reflected Multiple-Pass Fringes of Increased Spatial Frequency by Modulating The Phase of The Interfering Beams	62
II.4. Optical Set-Up for Observation of Double-Pass Fizeau Fringes of Increased Contrast	63

REFERENCES.

INTRODUCTION

Multiple-beam interference takes place between two optical flats, coated with highly reflecting thin films when illuminated with a parallel beam of monochromatic light. The resultant interference pattern is affected by the reflectivity, transmissivity and phase properties of the coated surfaces, the geometrical condition of the interferometer and the nature of the light used [1].

With coated optical flats rendered parallel, the interference pattern, in transmitted light, consists of a series of sharp bright fringes on an almost completely dark background. In reflected light, the fringes are sharp dark on an almost uniformly bright background [2].

When the two optical flats forming the interferometer are inclined to each other making a small angle, a wedge interferometer is formed. If the two optical flats are uncoated, two-beam interference takes place. Such case was utilized by Fizeau in 1862 . Using highly reflecting coated surfaces [3], multiple-beam interference takes place in transmission [4] and at reflection [5]. When illuminated by a parallel monochromatic beam emerging originally from a point source. these fringes in transmission are sharp bright straight lines on dark background. At reflection, the fringes are sharp dark straight lines on bright background.

The optical-phase properties of thin metallic films namely the change of phase in transmission γ and the change β_1 and β_2 at reflection glass/film and air/film play an important role in the distribution of intensity interference systems. They have marked effect on the characteristics of the fringes. Hamy [6] established that the asymmetry in the fringes, depends on the phase changes which occur upon reflection and transmission through the film. Holden [7] showed that increasing the thickness of the metal film on the component of the interferometer facing the light results in the formation of reflection and transmission fringes that are observed at reflection. Barakat [8] and his co workers reported the formation of multiple beam reflected system of an intensity distribution which is similar to that in transmitted system, (i.e.) transmission like fringes are formed at reflection. This was formed by an air wedge whose two components were coated with silver layer of specific reflectivities such that the optical phase Cu , Mn , Au function termed the F value is equal to $2n\pi$. F being equal to $2\gamma - \beta_1 - \beta_2$.

Multiple-pass interference fringes are formed when the rays pass through a single interferometer more than the traditional single-pass case. This can be achieved, for instance by reflecting the interference pattern formed by a single-pass into the interferometer again [9]. Depending on the additional number of passes

inside the single-pass interferometer, the system of fringes formed finally is called double or multiple-pass system [10]. It is known that multiple-beam fringes can be obtained on planes high orders of localization other than the Feussner surface by observing the fringes formed by a wedge interferometer. Multiple-pass fringes can also be obtained on planes of fractional high orders of localization. In such case, the rays travel inside the interferometer (m) times greater than the case of observation on the Feussner surface or on planes of integral high orders of localization [11]. Multiple-passing offers the advantage that the resulting fringes are either sharper or of controllable spatial frequency. The spatial frequency S of a fringe system is defined as the number of fringes in the field of view per unit length.

Multiple-pass interferometers have been used in a wide range of application, according to the type of the interferometer and the object which is studied. Fabry-Perot multiple-pass interferometer was used for studying the Brillouin scattering measurements [12-13] and investigating the Rayleigh and the Raman scattering. The multiple-pass interferometer were used for thin film thickness measurements [14] and for testing the flatness in optical shop measurements [15]. Multiple-pass interference fringes produced by a Fabry-Perot interferometer can acquire such a high contrast that

enables studying the hyperfine structure of spectral lines. High precision interferometric inspection of topography can be achieved by applying multiple-pass techniques.

i.1. CLASSIFICATION OF MULTIPLE-PASS FRINGE SYSTEMS

Multiple-pass fringe systems can be classified according to the type of interferometer used or according to the type of interference, whether two-beam or multiple-beam. The classification according to the type of interference is adopted.

i.1.1. TWO-BEAM INTERFERENCE

Hariharan and Sen [16], obtained fringes similar in appearance and behavior to three-beam fringes, when the rays that emerged from a two-beam interferometer are reflected back through it. This enhanced the degree of accuracy in measurements. Hariharan and Sen [17] deduced expressions for the intensity distribution of the fringe system in double-passed Jamin and Twyman-Green interferometers. They obtained [18] by using double-pass Twyman-Green interferometer, two separate interferograms showing the symmetrical and asymmetrical parts of the wave aberration of an optical system. They also obtained fringes of equal inclination in the double-passed Michelson interferometer and delivered a theoretical expression for the intensity distribution of the

interference pattern [19].

Langenbeck [20] used multiple-pass Twyman-Green interferometer to test mirror surface. He achieved a sensitivity n times greater than that obtained with the traditional Twyman-Green interferometer, where n is the number of reflections between one mirror of the interferometer and the mirror under test.

Bubis [21] described a modified multiple-pass two-beam interferometer for testing large concave surfaces.

Wilson [22] used a double-pass oblique-incidence two-beam interferometer for testing large pieces having a specular reflection as low as 1%.

Holloway and Emmony [23] obtained a multiple-pass Michelson interferometer to increase the sensitivity of the interferometer five times.

Sakayanagi and Fukuda [24] used multiple-pass Michelson interferometer for obtaining an accurate measurements of length.

i.1.2. MULTIPLE-BEAM INTERFERENCE

In multiple-beam interference two general instruments are considered, namely, the Fabry-Perot and wedge interferometers. According to what advantage of multiple-passing technique is needed, the instruments will be defined whether F-P or wedge interferometer.