# STUDIES ON MULTIPLE-PASS INTERFEROMETERS

**Thesis**

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بسم الله الرحمن الرحيم

«رَبِّ أَوزِعنِي أَنْ أَشكُرَ نِعمَتَكَ التِي أَنعَمتَ عَلَيَّ»

صدق الله العظيم

بسم الله الرحمن الرحيم

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# ABSTRACT

*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* $3x10^{-3}$ *rad, the contrast of the doubly-transmitted fringe is tens of times greater than that of the singly-transmitted fringe.*

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CHAPTER II

EXPERIMENTS WITH MULTIPLE-PASS INTERFEROMETERS

# INTRODUCTION

Multiple-beam interference takes place between two optical flats, coated with highly reflecting thin films when illumined 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 $\gamma$ and the change $\beta_1$ and $\beta_2$ 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. Eamy [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 Brillion scattering measurements [12-13] and investigating the Rayleiegh 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.