Ain Shams University
Faculty of Science
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Measuring Absolute Distance Using Frequency Scanning Interferometry

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By

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Abstract

Unlike the conventional displacement interferometers where only the incremental displacement of a target is measured, absolute distance interferometers measure distance to a fixed target. In this thesis, frequency scanning interferometry (FSI) is used to measure distances from 1 to 5 meters absolutely. The FSI system consists mainly of, an external cavity tunable diode laser, Michelson interferometer, Fabry-Perot cavity, and a simple beam collimation system.

The external cavity tunable diode laser (ECDL) has a wavelength scanning range of 10 nm that covers the wavelength range from 665 nm to 675 nm. As with most of the tunable lasers, the ECDL contains one mode-hop in the middle of the scanning range. This mode-hop is considered as a drawback when the laser is used for distance measurements. The Michelson interferometer is a typical one with two high reflective mirrors and a beam splitter and a photodetector to detect the fringes. The Fabry-Pérot cavity is made out of a spacer and two mirrors with reflectivity of 50:50. The cavity spacer is made from an ultra-low-expansion glass (ULE-glass) of a thermal expansion of 0 ± 30 ppb/°C (from 5°C to 35°C). The thermal expansion of ULE-glass is lower 100 times than the normal glass. Therefore, the FP cavity length is independent from the environmental temperature changes and can be used as a frequency reference to determine the laser scanning range.

The distances from 1 to 5 m are measured by scanning the ECDL while acquiring interference signals from both the Michelson interferometer and the FP cavity. A software program is developed to count the acquired fringes in such a way that it avoids counting the fractional fringes and removes the mode-hop defected parts of the fringes without significantly affecting the accuracy of the distance measurement. The achieved distance repeatability of the constructed system is ±3.9 L µm.

A high accurate positioning stage with 1 μm accuracy over the 26 mm scanning range is used to estimate the setup accuracy. The combined uncertainty of the setup is found to ±59 L µm which is limited by the accuracy of the used calibration stage.

Key words: Frequency scanning, Interference, Absolute distance, Michelson interferometer, Fabry-Pérot interferometer.

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Chapter 1

Introduction

Length metrology plays a crucial role in industry and commerce. However, to facilitate the international trade, length measurements must be traceable to the national primary standard and hence to the international standards through a chain of measurements. The unit of length, the meter, is one of the seven base units in the International System of units (SI). It is currently defined as *“The length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second”* [1, 2].

In several applications, like geodesy, the term "*distance*" is used instead of length to describe the length of the path from the observer to a target. However, if only incremental motion of the target relative to the initial position is measured, the term "displacement" is used. It is worth also to mention that, in several scientific publications, the term "*Absolute distance*" is used to clearly distinguish between distance and displacement.

In this chapter, a historical overview about length metrology, traceability of some length measurements, description of some optical techniques used in length metrology, and application of frequency scanning interferometry in absolute distance measurement are discussed.

1.1 Historical background

Throughout the history, many standards of length were established starting from the body parts to the wavelength and speed of light waves. The