Performance comparison of intensity-modulated and interferometric fiber optic sensors for displacement measurement

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Introduction

Fiber optic sensors are small, lightweight, can be easily multiplexed, are immune to electromagnetic interference, and are not spark emitting, making them preferable to traditional electronic sensors for many applications. Further, advances made in the last several decades have encouraged the development of fiber optic sensing configurations which outperform their electrical counterparts. The vast majority of extrinsic fiber optic displacement sensors can be classified under one of two approaches: (1) intensity-modulated sensors and (2) interferometric (or phase-modulated) sensors. The term e*xtrinsic* refers to a sensor which does not maintain direct physical contact with the device under test (DUT); necessitating that the optical test signal transmits from a fiber to interact with the DUT and ultimately reflects back into a fiber with information regarding the DUT (Figure 1 and 2). Intensity-modulated sensors exploit the relationship between the distance *d* in Figure 1**Error! Reference source not found.** and the intensity of the optical signal reflected off the surface of the DUT. Interferometric sensors exploit the relationship between the distance *d* and interference patterns which result from multiple reflected optical signals which are out of phase with one another (

Figure 2).

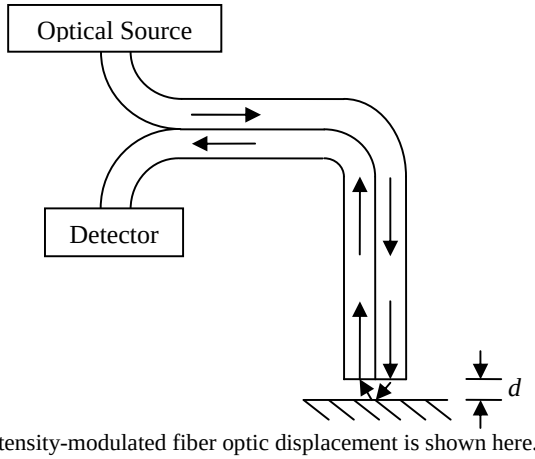

Figure 1. A schematic of an extrinsic, intensity-modulated fiber optic displacement is shown here.

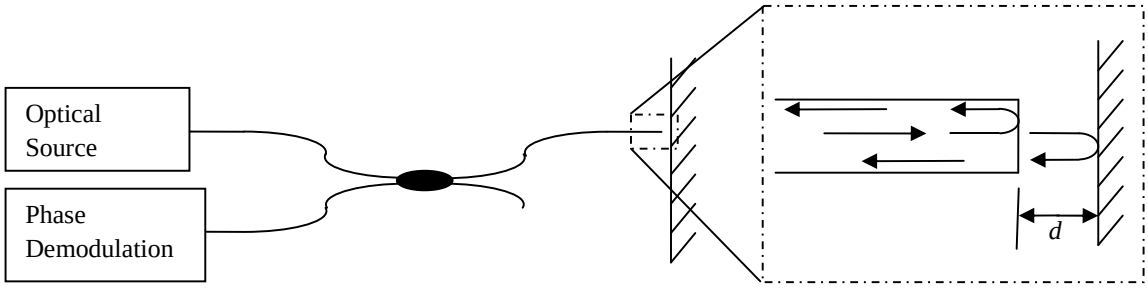

Figure 2. A schematic of an extrinsic, interferometric fiber optic displacement sensor is shown.

While intensity-modulated sensors are generally simpler, require less computation, and can be interrogated at higher sampling rates, they suffer from an inherent lack of robustness due to environmental variability and hardware fluctuations. On the other hand, interferometric sensors offer potentially robust, high-sensitivity, high-resolution performance at the cost of increased computational complexity. More generally, sensors are usually characterized in terms of size, power demand, sensitivity, bandwidth, accuracy, resolution, linear performance range, cross-sensitivity, and noise floor. These properties are often interrelated, such that proper sensor design involves balancing several tradeoffs in order to achieve appropriate performance levels.

Objective

The primary goals of this project are (1) to investigate various optical sensing architectures for acquiring displacement measurements and (2) to characterize their performance specifications (e.g. sensitivity, resolution, displacement range, etc…). A rigorous characterization of sensor performance will necessarily require a thorough understanding of sensor performance metrics and the experimental methods used to measure them. Both intensity-modulated and interferometric sensing configurations will be considered. Students will experimentally characterize the performance of a simple, differential intensity-modulated test setup. This will involve an analytical investigation into the nature of transmitted optical signals and the extension of that work in order to generate a range of optimal sensing performance specifications.

Students will also perform comparisons between the sm125 and sm130 optical interrogator units (available from Micron Optics, Inc.), employing various signal processing techniques, in order to generate a summary of the achievable ranges of performance specifications for these devices as interferometric sensing units. These interrogators sample optical intensity in the wavelength domain, and as a result they lend themselves naturally to an interferometric approach. As part of this comparison, students will also investigate the use of FC/APC and FC/UPC fiber tips and the implications different tip polishes have on sensor performance.

Control of the interferometric sensor interrogators will be implemented using LabVIEW development software, and it will be useful for the students to learn to use LabVIEW (if they have not done so already) in order that they might be capable of testing their own signal processing algorithms.

Schedule

This research project will be conducted over the nine week period from June 7th, 2010 to August 6th, 2010. A tentative schedule (Table 1) outlines the anticipated work plan.

Week	Task
1	Introduction to project

2	Introduction to fiber optic hardware and LabVIEW development software
3	Analytical investigation of transmitting optical signals
4	Experiments characterizing intensity-modulated approach
5	Investigation into signal processing techniques for interferometric approach
6	Implementation of signal processing techniques for interferometric approach
7	Experiments characterizing interferometric approach
8	Experiments characterizing fiber tips
9	Final presentations

Table 1. This table outlines a tentative schedule for the research project.

Background Literature

[1] http://en.wikipedia.org/wiki/Optical_fiber

[2] http://www.bluerr.com/images/Overview_of_FOS2.pdf

[3] http://www.sensorsmag.com/sensors/machine-vision/an-introduction-fiber-optic-sensors-1075

[4] http://www.mtiinstruments.com/products/fiberopticmeasurement.aspx

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