



Ain Shams University
Faculty of Engineering
Electronics and Communications Department

MEMS Fabry-Perot Spectrometer

A Thesis

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Submitted by:

Yomna Medhat Abdel Karim Eltagoury
B.Sc. of Electrical Engineering
(Electronics and Communications Department)
Ain Shams University, 2012.

Supervised by:

Prof. Dr. Diao Abdel Maguid Khalil
Dr. Yasser Mohammed Sabry Gad

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Faculty of Engineering – Ain Shams University
Electronics and Communications Engineering Department

Thesis Title: **“MEMS Fabry-Perot Spectrometer”**

Submitted by: **Yomna Medhat Abdel Kariem Eltagoury**

Degree: **Master of Science in Electrical Engineering**

Examiners' Committee

Prof. Dr. Kamel Mohamed Mahmoud Hassan

Future University

Faculty of Engineering

Electronics and Communications Dept.

Prof. Dr. Hani Fikry Ragai

Ain Shams University

Faculty of Engineering

Electronics and Communications Dept.

Prof. Dr. Diao Abdel Maguid Khalil

Ain Shams University

Faculty of Engineering

Electronics and Communications Dept.

Date: 21 /10 /2017

Statement

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communication Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communication Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

Name: Yomna Medhat Abdel Kariem Eltagoury

Date: 21 /10 /2017

Curriculum Vitae

Name: Yomna Medhat Abdel Kariem Eltagoury

Date of Birth: 07/09/1990

Place of Birth: Cairo, Egypt

First University Degree: B.Sc. in Electrical Engineering

Name of University: Ain Shams University

Date of Degree: June 2012

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Yomna Eltagoury

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THESIS SUMMARY

This thesis aims to study and develop MEMS spectrometers based on Fabry-Perot (FP) interferometers and electrostatic actuators. For this purpose, we developed high speed electrostatic actuators and compared between different architectures. A novel Fourier Transform InfraRed (FT-IR) spectrometer architecture based on cascaded FP interferometers was introduced and analyzed thoroughly. Two designs for the cascaded FP FT-IR spectrometers based on Deep-Reactive-Ion-Etching (DRIE) technology over Silicon-On-Insulator (SOI) wafer were proposed and implemented. Successful demonstration of the spectrometer based the proposed designs was realized. The proposed MEMS spectrometer has the advantage of ultra-compact optics and high resolving power compared to the conventional architecture.

The thesis is divided into six chapters as listed below:

Chapter 1: gives a brief introduction of the motivation, objectives, major contributions and organization of the thesis.

Chapter 2: introduces a review on the types of optical spectrometer, namely, diffraction grating, tunable filter and FTIR spectrometers. An overview on the MEMS technology and the electrostatic actuation is briefly given. The FT-IR spectrometer theory of operation and the main system specifications are discussed. Finally, a brief comparison of the state-of-the-art miniaturized spectrometer is presented.

Chapter 3: reports the design, fabrication and characterization of high-speed MEMS actuators with in-plane motion; achieving the highest product of the travel range and frequency under atmospheric pressure. Two actuators are reported having resonance

frequencies of about 26.1 kHz and 93.5 kHz and achieving a single-side travel range of about 9.1 μm and 2 μm . An opto-mechanical characterization method is applied accounting for the diffraction effect in the microscale. The experimental results are compared to the theoretical analysis.

Chapter 4: introduces and analyzes the system of FTIR spectrometer based on cascaded interferometers. The system is analyzed for different combinations of interferometers by studying in details the overall transfer function and the generated interferogram and the corresponding spectrum. Two architectures based on FP interferometers are studied and optimization study for the different design parameter is carried out.

Chapter 5: presents two designs of the FP-FTIR spectrometer. The designs are modeled using Fourier optics to account for the diffraction effect. The implementation of the designs using DRIE technology on SOI is explained. Finally, the experimental results of the developed spectrometer are presented, demonstrating the success of the ultra-compact optics and the high resolving power compared to the conventional architecture.

Chapter 6: gives the conclusion of this thesis and introduces several recommendations and suggestions for the future work.

Key words:

Fabry-Perot interferometer, Micro-electro-mechanical systems (MEMS) technology, High speed actuators, Fourier transform spectroscopy, Dispersion, Micro-optical bench technology, Near-infrared (NIR) spectrometer, Fourier optics.

CONTENTS

ACKNOWLEDGEMENT	I
THESIS SUMMARY	III
CONTENTS.....	V
LIST OF FIGURES	IX
LIST OF TABLES	XVII
LIST OF SYMBOLS	XIX
ABBREVIATIONS	XXI
1 INTRODUCTION	23
1.1 MOTIVATION AND OBJECTIVES	23
1.2 MAIN CONTRIBUTIONS	24
1.3 THESIS OUTLINE	26
2 REVIEW OF MEMS SPECTROMETERS	29
2.1 INTRODUCTION	29
2.2 TYPES OF OPTICAL SPECTROMETER	31
2.2.1 <i>Diffraction grating spectrometer</i>	32
2.2.2 <i>Tunable filter spectrometer</i>	33
2.2.3 <i>Fourier transform spectrometer</i>	37
2.3 MEMS TECHNOLOGY	42
2.3.1 <i>MEMS fabrication technology</i>	43
2.3.2 <i>MEMS actuators</i>	48

2.4	MINIATURIZED SPECTROMETER STATE OF THE ART	55
2.5	SUMMARY.....	62
3	HIGH SPEED MEMS ACTUATOR.....	63
3.1	INTRODUCTION	63
3.2	ACTUATOR DESIGN	67
3.2.1	<i>Figure of Merit</i>	68
3.3	FINITE ELEMENT ANALYSIS.....	72
3.3.1	<i>Design A</i>	72
3.3.2	<i>Design B</i>	75
3.4	DEVICE FABRICATION	77
3.5	OPTO-MECHANICAL CHARACTERIZATION METHOD	79
3.5.1	<i>Analysis of the Characterization Method</i>	80
3.5.2	<i>Characterization Setup</i>	82
3.6	EXPERIMENTAL RESULTS	83
3.6.1	<i>Mirror travel range</i>	83
3.6.2	<i>Frequency Response</i>	86
3.7	SUMMARY.....	88
4	SYSTEM ANALYSIS OF FTIR SPECTROMETER BASED ON CASCADED INTERFEROMETERS.....	89
4.1	INTRODUCTION	89
4.2	STATIC MICHELSON & SCANNING MICHELSON INTERFEROMETERS.....	91
4.3	STATIC FP & SCANNING MICHELSON INTERFEROMETERS	93
4.4	STATIC MICHELSON & SCANNING FP INTERFEROMETERS.....	99
4.5	STATIC FP & SCANNING FP INTERFEROMETERS.....	101

4.5.1	<i>Dispersion effect</i>	106
4.5.2	<i>Optimum mirror reflectivity</i>	108
4.5.3	<i>Optimum cavity length</i>	110
4.6	SCANNING FP INTERFEROMETERS	113
4.6.1	<i>Mirror (interface) reflectivity</i>	117
4.6.2	<i>Design cavity length</i>	118
4.7	SUMMARY.....	121
5	OPTICAL MODEL AND EXPERIMENTAL RESULTS	123
5.1	INTRODUCTION	123
5.2	FOURIER OPTICS MODEL	123
5.3	CASCADED STATIC-SCANNING FP INTERFEROMETERS.....	126
5.3.1	<i>Simulation results</i>	128
5.3.2	<i>Measurement results</i>	134
5.4	CASCADED SCANNING FP INTERFEROMETERS.....	142
5.4.1	<i>Simulation results</i>	143
5.4.2	<i>Measurement results</i>	149
5.5	SUMMARY.....	155
6	CONCLUSION AND FUTURE WORK.....	157
6.1	CONCLUSIONS.....	157
6.2	FUTURE WORK.....	159
	AUTHOR'S PUBLICATIONS	161
	APPENDIX 1.....	163
	THE FORMULA OF THE COEFFICIENTS OF FP TF USING FOURIER SERIES.....	163