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Electronics and Communications Engineering Department

Optical MEMS Interferometer for Spectrometry Applications

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Submitted by

Haitham Abd El Salam Ahmed Omran

B.Sc. of Electrical Engineering
(Electronics and Communications Department)
Ain Shams University, 2004

Supervised By

**Prof. Dr. Daa A. M. Khalil
Dr. Bassam A. Saadany**

Cairo, 2010

Curriculum Vitae

Name of Researcher	Haitham Abd El Salam Ahmed Omran
Date of Birth	17/02/1982
Place of Birth	Cairo, Egypt
First University Degree	B.Sc. in Electrical Engineering
Name of University	Ain Shams University
Date of Degree	June 2004

ABSTRACT OF THE THESIS

“Optical MEMS Interferometer for Spectrometry Applications”

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Haitham Abd El Salam Ahmed Omran

A novel miniature Mach-Zehnder (MZ) interferometer is proposed. The micro-machined MZ interferometer is fabricated on an SOI wafer using Deep Reactive Ion Etching (DRIE) technology. The new structure is based on the use of two Si/Air beam splitters, and two metallic mirrors fabricated monolithically in a small footprint measuring 1 mm x 2 mm on the die. By moving the mirrors using an integrated comb drive MEMS actuator, the structure is tested to perform the function of a Fourier Transform Infrared (FT-IR) spectrometer, where two wavelengths 1550 nm and 1575 nm have been successfully identified showing a spectral resolution of 25 nm. White Source measurements have been also done on the MZ spectrometer; however, the results were affected by the dispersion in silicon. A solution for such dispersion problem is proposed and presented in this thesis.

The successful implementation of this four element interferometer in an integrated form opens the door for the development of more complex optical structures that are self aligned and fabricated in a one step lithography process

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List of Symbols and Abbreviations

A Electromagnetic Field Amplitude

a Grating Constant

A_D Detector Area

A_G Effective Area of the Grating

A_M Effective Area of the Mirrors

A_p Surface Area of Capacitor Plate

B Damping Coefficient

C Capacitance

D Optical Path Difference

D_e Specific Detectivity

d	Moving Mirror Displacement Separation between the Tip of Moving Finger and the Stator
E	Electromagnetic Field Young's Modulus
$E_L^{\Delta x}$	Spectrum of Sampled Truncated Interferogram
F	Interference Record
F_e	Electrostatic Force Developed by a Comb Actuator
F_L	Electrostatic Lateral Force
F_p	Electrostatic Force due to Comb Finger Width
F_T	Electrostatic Transversal Force
f	Focal Length of the Collimating Mirror
g	Separation between Capacitor Plate
h	Slit Height
I	Intensity
I_s	Intensity Sum of Output 1 and Output 2
K	Propagation Constant
K_x	Electrostatic Stiffness in Lateral Direction

k_x	Spring Constant in Lateral Direction
K_y	Electro Static Stiffness in Transvers Direction
L	Maximum Optical Path Difference Length of Comb Finger
M	Number of Resolution Elements
M_{eff}	Effective Mass of Total Moving Parts
N	Number of Moving Fingers
N_{rms}	Root Mean Square Spectral Noise
$N_{s_{extracted}}$	Extracted Source Noise
n	Refractive Index, Number of Spectral Elements
$n(t)$	Relative Intensity Noise (RIN)
r	Position Vector
$R(z)$	Measure of Wave Front Radius of Curvature
t	Time
t_1, r_1	Transmission and Reflection Coefficient at First air/Si Splitter
t_2, r_2	Transmission and Reflection Coefficient at Second air/Si Splitter
t_3, r_3	Transmission and Reflection Coefficient at Second Si/air Splitter
$u(r)$	Complex Amplitude

$u(r, t)$ Monochromatic Wave Complex Representation

$U(T)$ Spectral Brightness

V Voltage

V_{PI} Pull-in Voltage

L_p Spring Beam Length

$W(z)$ Measure of Beam Width

W_L Instrumental Function of a Fourier Transform Spectrometer

W_o Half Spot Size

w_p Spring Beam Width

Δx Sampling Interval

X Length a Capacitor Plate

X_{cr} Critical Displacement

x_i Intial Overlap between Comb Fingers

Z Width of a Capacitor Plate

z Propagation Distance of Gaussian Beam

Z_0 Rayleigh Range

δ Phase Difference

$\frac{\Theta_I}{\Theta_G}$	Jacquinot Advantage
λ	Wavelength
$E(\nu)$	Power Spectral Density per Unit Area
ν	Wavenumber
Ω	Solid Angle
ω	Angular Frequency
$\phi(r)$	Phase
Θ	Throughput
Θ_G	Throughput of Grating Spectrometer
Θ_I	Throughpput of an FT-IR Spectrometer
$\Delta\nu$	Spectral Resolution
ε	Permittivity
ξ	Efficiency
$N(\nu)$	Spectral Noise
$T(\nu)$	Transmission Spectra
BS	Beam Splitter
DRIE	Deep Reactive Ion Etching

DSP Digital Signal Processing

FFT Fast Fourier Transform

FT Fourier Transform

FT-IR Fourier Transform Infrared

ICP Inductive Coupled Plasma

IOB Integrated Optical Bench

MEMS MicroElectroMechanical System

MM MultiMode

MZ Mach-Zehnder

NEP Noise Equivalent Power

NIR Near Infrared

OB Optical Bench

OPD Optical Path Difference