AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics and Communications Engineering Department

Optical MEMS Interferometer for Spectrometry Applications

A Thesis

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Submitted by

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ABSTRACT OF THE THESIS

"Optical MEMS Interferometer for Spectrometry Applications"

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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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Contents

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 Electromagnatic Field
Young's Modulus

$E_L^{\triangle x}$ 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

Is 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 Statoic Stiffness inTransvers 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
$Ns_{extracted}$	Extracted Source Noise
n	Refractive Index, Number of Spectral Elements
$n(t)$	Relative Intensity Noise (RIN)
r	Postion Vector
$R(z)$	Measure of Wave Front Raduis 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

$\triangle x$ 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
$\mathrm{E}(\nu)$	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
$\triangle\nu$	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