DESIGN OF INTERFERENCE-BASED ALL OPTICAL PHOTONIC CRYSTAL LOGIC GATES

By

Hussein Mohamed El-Sayed Hussein

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Engineering Physics

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Under the Supervision of

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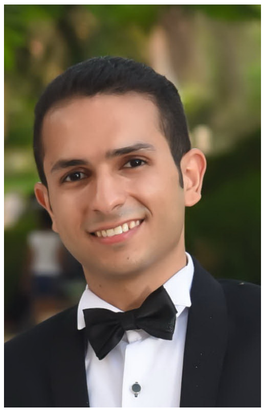
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Title of Thesis:

Design of Interference-Based All Optical Photonic Crystal Logic Gates

Key Words:
Photonic Band Gap; Plane Wave Expansion; Finite-Difference Time-Domain; Optical Interference; Logic Gates

Summary:

A novel design of all-optical logic gates is proposed using the 2D square lattice PhC structure built with dielectric rods surrounded by air. The theory of operation to realize the logic gates functionality is based on the optical interference phenomenon, where logic '1' corresponds to a constructive interference, while the logic '0' corresponds to a destructive interference. The proposed logic gates have compact size and exhibit wide range of operating wavelengths between 1266.9 nm and 1996 nm with center operating wavelength 1550 nm to fulfill various requirements of different applications. We used The PWE and FDTD mathematical methods to analyze the signal's behavior inside the PhC and to calculate the PBG. The calculated maximum contrast ratio in dB for AND, XOR, NOR, NAND and XNOR is found to have values of 6.02, 12.155, 9.02, 8.58 and 9.59, respectively.

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Dedication

To my parents, my wife Safaa and my friends

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Symbols

λ	Wave length
λ_o	Wave length in vacuum
f	Frequency
T	Periodic time
ω	Angular frequency
Ω	Normalized frequency
$\mathbf{K}$	Wave vector
ϵ_o	Permittivity of free space
ϵ_r	Relative permittivity
μ_o	Permeability of free space
μ_r	Relative permeability
c	Speed of light in vacuum
n	Refractive index
a	Lattice constant
$\mathbf{R}$	Crystal lattice vector
$\mathbf{G}$	Reciprocal lattice vector
$\mathbf{E}$	Electric field vector
$\mathbf{H}$	Magnetic field vector
$\mathbf{D}$	Electric displacement field vector
$\mathbf{B}$	Magnetic flux density vector
ρ	Electric charge density
$\mathbf{J}$	Electric current density vector
$\mathbf{T}$	Transmittance
$\mathbf{R}$	Reflectance
$\mathbf{A}$	Absorbance

Abbreviations

1D	One-Dimensional
2D	Two-Dimensional
3D	Three-Dimensional
CMOS	Complementary Metal-Oxide-Semiconductor
CPU	Central Processing Unit
CW	ClockWise
CCW	Counter ClockWise
FDTD	Finite-Difference Time-Domain
Ge	Germanium
IBZ	Irreducible Brillouin Zone
MMI	Multi-Mode Interference
PBG	Photonic Band Gap
PCF	Potonic Crystal Fiber
PhC	Photonic Crystal
PWE	Plane wave expansion
PML	Perfectly Matched Layer
Si	Silicon
TE	Transverse Electric
TIR	Total Internal Reflection
TM	Transverse Magnetic
TMM	Transfer Matrix Method