بسم الله الرحمن الرحيم

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تم رفع هذه الرسالة بواسطة / حسام الدين محمد مغربي

بقسم التوثيق الإلكتروني بمركز الشبكات وتكنولوجيا المعلومات دون أدنى مسئولية عن محتوى هذه الرسالة.

ملاحظات : لا يوجد

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics and Communications

Silicon Photonics Micro Ring Resonator

A Thesis submitted in partial fulfilment of the requirements of the degree of
Master of Science in Electrical Engineering
(Electronics Engineering and Electrical Communications)

by
Rabab Abdel-Basset Mohamed Salam Shalaby
Bachelor of Science in Electrical Engineering
(Electronics Engineering and Electrical Communications)
Faculty of Engineering, Ain Shams University, 2006

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June 2022

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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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THESIS SUMMARY

Nowadays, silicon photonics have significant momentum in both scientific and industrials fields and considered as the leading technology for photonic integrated circuits (PICs). It has several applications such as data centers, high-performance computing, high-speed optical communications, microwave photonics, terahertz technology, on-chip optical interconnect and on-chip sensors. It owns the benefits of high-volume productions and the compatibility of silicon-on-insulator (SOI) waveguides with complementary metal-oxide-semiconductor (CMOS) fabrication process at low cost. For those reasons, many silicon-based photonics components such as waveguides, ring resonators, modulators, switches, light sources, detectors, photonic crystal and plasmonic devices have been explored in the literature.

This thesis aims to study the integrated optical micro ring resonators based on silicon photonics technology. Racetrack ring resonator is composed of a combination of straight and bend waveguides. For this purpose, a detailed analysis of inverted ridge silicon photonics straight waveguide and bend waveguide structure is accomplished focusing on mode conversion effects and back reflections at the interfaces between the straight and bend waveguides. A model for the bend waveguide based on multiple reflections and interference is introduced and a study of the effect of radii of curvature for the bend waveguide performance on the mode conversion and reflection coefficient is presented. A matrix model for analyzing the whole photonic circuit, embedding the back reflection effects and mode conversion, is developed and used to evaluate the effect of the bend waveguide. A silicon photonic chip is designed and fabricated including bend waveguides and ring resonator. A method for characterization based on optical frequency domain reflectometry (OFDR) is suggested. The experimental response of the fabricated structures is measured and a discussion for the possible impact of fabrication tolerance is presented.

The thesis is divided into six chapters including lists of contents, tables, and figures as well as list of references. The chapters are described below:

Chapter 1:

This chapter gives a brief introduction to the motivation, objectives, major contributions, as well as organization of the thesis.

Chapter 2:

This chapter surveys the silicon photonic technology, the different structures of ring resonators and their applications, the analysis of bend waveguide in literature, the characterization techniques, and light coupling techniques for the silicon photonics structures.

Chapter 3:

This chapter introduces a detailed study of the straight and bend silicon waveguide structures, field profiles, effective refractive indices and their dependence on the dimensions and wavelength using modal analysis and finite difference time domain (FDTD) methods. Then a model for the bend waveguide as a low-finesses Fabry Perot (FP) resonator is introduced. The effect of the radius of curvature of the bend waveguide on mode conversion and the reflection coefficient is given.

Chapter 4:

This chapter presents the scattering matrix and transfer matrix representation of the bend waveguide. A simple photonic circuit is proposed and the effect of the bend waveguide on the performance of the structure is studied using the matrix representation. FDTD is used to simulate the circuit and the results are compared with the matrix approach.

Chapter 5:

In this chapter, the structures implemented in the fabricated silicon photonics chip are introduced. The sensitivity to the fabrication tolerance is analyzed for single ring resonator and nested coupled cavities. A suggested technique for parameters extraction is given and the experimental results are compared to the theoretical expectations.

Chapter 6:

This chapter gives the conclusion of the thesis and introduces several suggestions for the future work.

Keywords:

Micro ring resonators, bend waveguide, parameter extraction, coupled resonators, scattering matrix, optical frequency domain reflectometry OFDR.

ACKNOWLEDGMENT

Praise be to God, the Most Gracious, and the Most Merciful. God taught man what he does not know. I would like to thank God Almighty for giving me the opportunity, strength, and ability to complete this work.

First, I would like to offer the reward of this work to my mother's soul. I did my best to complete this work for her.

My sincere gratitude goes to my big family, my father, my mother-in-law, my brothers, and my sister. This work would not have been possible without their prayer, continuous encouragement, support, and assistance.

My sincere gratitude and appreciation to my small family, my husband, and my children. They support me all the time. My husband, and teacher, Hussein Kotb helped me all the time. No words can express my feelings for them.

All my deep gratitude to my advisor Prof. Diaa Khalil, who guided me through my research to the best. He has been an inspiration for me throughout my career. I would not be able to finish this work without his continuous support, valuable guidance, encouragement, and confidence in me.

My sincere appreciation to my co-advisor Dr. Yasser Sabry for his continuous help, valuable comments, discussions, support, eager for perfection, and flexibility to accept my ideas and refine them to reach better results. His encouragement and support led me pass the tough moments through of my research.

Special thanks go to Prof. Mahmoud Hanafi who accepted me as a member of the research team at Lab for Laser and Optical Communications (LLOC), Ain Shams University. His discussions are always helpful and valuable.

I would like to acknowledge the fabrication catalyst (FabCat) service fund by the technology innovation and entrepreneurship center (TIEC) in Egypt for fabricating the chips using IMEC- ePIXfab passive technology.

Special thanks to Prof. Osama Terra and Prof. Mahmoud Hanafi for their time and effort in reviewing my work.

Great thanks for Eng. George Adib and Eng. Mahmoud Abbas for their effort in designing the fabricated structures of the chip.

Special appreciation goes to Eng. Ahmed Osman who helped me in a great way in my research.

I would like to thank Eng. Ahmed Amr for his help in designing a 3D printing holder for the fiber array which I used in my measurements.

I cannot forget also to thank my dear colleagues and friends in LLOC for their support and help.

Rabab Shalaby

Cairo, Egypt

June 2022

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