AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Coupled Cavities Ring Laser

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of ScienceinElectrical Engineering

(Electronics Engineering and Electrical Communications)

by

George Albert Adib Abdelsayed

Master of ScienceinElectrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Ain Shams University, 2017

Supervised By

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Cairo - (2017)

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Examiners' Committee

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical gineering, 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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George Albert

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Thesis Summary

This thesis aims to study the development of coupled cavities ring laser in sensing applications using different technologies. For this purpose, a novel architecture of coupled cavities has been proposed based on dual coupler ring resonator coupled to a ring laser cavity. The novel configuration was studied in passive mode of operation (without gain medium) and compared to the conventional configurations of coupled cavities. The effect of introducing a gain medium to compensate the cavity losses was also studied for single and coupled cavities. The active cavity was then used to increase the sensitivity of spectroscopic gas sensing using incoherent broadband cavity enhanced spectroscopy (IBCEAS) technique. The operation of the ring laser with the proposed configuration as sensor was then studied and demonstrated as gyroscopic sensor.

The thesis is divided into six chapters as listed below:

Chapter 1:

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

Chapter 2:

This chapter presents a review of the main concepts related to coupled cavities ring resonators and external cavities lasers. In the beginning, we discuss the different con-

cepts related to ring resonators, the different configurations of coupled cavities ring resonators and their applications.

Chapter 3:

This chapter introduces a novel coupled cavities ring resonators configuration which consists of dual coupler ring resonator coupled to the main cavity. Firstly, we discuss the response of the proposed configuration giving analytical expressions for its different parameters. Secondly, we compare the analytical results with numerical simulations to get the percentage error in the different formulas under different conditions. Thirdly, we compare the proposed configuration with other ring resonators configurations.

Chapter 4:

This chapter proposes a novel technique to characterize resonators with long length and small free spectral range (FSR) using radio frequency (RF) beating signal. This method is used to characterize fiber cavities. Then, the usage of gain medium inside the cavity is discussed to compensate cavity losses. Active ring resonators were measured for both single and coupled cavities showing a great enhancement in cavity full width half maximum (FWHM). A model was proposed to simulate the effect of gain medium in this active optical filter. Finally, the active optical resonator was used to increase the sensitivity of incoherent broadband cavity enhanced spectroscopy for gas sensing applications.

Chapter 5:

This chapter studies the usage of the proposed configuration in laser cavities for non-reciprocal sensing applications. Three major effects were discussed: increase in RF beating signal power, dynamic range extension and enhancement in scale factor using vernier effect. A simple model was suggested to study the effect of the coupled cavity in the laser system. The concept was demonstrated experimentally for gyroscopic applications.

Chapter 6:

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

Key words:

Silicon photonics sensors, Gas sensor, Semiconductor optical amplifier, Microwave photonic filter , Cavity enhanced spectroscopy, Finesse enhancement, Mutli-mode laser, Optical modes beating, Ring sensors, Ring laser gyroscope, Coupled resonators, Fiber optics sensors.