Abstract

Microring resonators have rapidly emerged in the past few years as a new sensing platform for miniaturization of modern integrated optical devices. Ring resonator are having advantages of compactness, stability with respect to back reflections, do not need facets or gratings for optical feedback, strong optical field enhancement inside cavities, high wavelength selectivity, narrow line width, high Q-factor and high sensitivity. These unique characteristics made microring resonator as promising platform for integrated photonics.. A generic ring resonator consists of an optical waveguide which is looped back on it self and coupled with a single or double bus waveguide.

In this thesis, a compact microring resonator (MRR) is proposed and optimized to exhibit high sensitivity and quality factor. Also, force and acceleration sensing applications of MRR are discussed. Electromagnetic computations are done using Finite Difference Time Domain (FDTD) method. Fabrication and characterization of microring is also carried out. While the main emphasis is on design and analysis, this experimental work supports better understanding of practical issues in study of microring resonators. Then, the force sensing application of the optimized microring resonator is presented. The design and modeling of the devices, including the mechanical proper- ties of the microcantilever beam, are done by using a Finite Element Method (FEM). The force sensing characteristics are presented for the force range of 0 to 1 μN. The drawbacks of single MRR can be overcome by using serially coupled double microring resonator(SC-DMRR) and serially coupled double racetrack resonator (SC-DRTR) with vernier effect. They provide, high FSR, low FWHM, high Q-factor and high sensitivity. By using SC-DMRR as an optical sensing element, a novel IO MEMS SC-DMRR based force sensor is proposed, resulting in high Q-factor of 19000 and force sensitivity of 100 pm/ 1μN. Further, in order to increase the sensitivity, a novel SC-DRTR based force sensor is proposed.

The study is expanded to photonic crystal microring resonator (PC-MRR) structures, where a PC-MRR is designed in a hexagonal lattice of air holes on a silicon slab. A novel approach is used to optimize PC-MRR to achieve high Q-factor. A high sensitive force sensor based on PC-MRR integrated with silicon micro cantilever is presented. The force sensing characteristics are presented for forces in the range of 0 to 1 μN. For forces which are in the range of few tens of μN, a force sensor with bilayer cantilever is considered. Further, the PC-MRR equivalent microring resonator is designed and analyzed for comparison between the force sensors. Finally, a novel IO MEMS serially coupled racetrack resonator based accelerometer is proposed and the required characteristics like sensitivity and dynamic range are reported.

In conclusion, IO micro ring resonators are the best candidates to design and develop force and acceleration sensors in the sub-μN sensitivities.