Tunable Graphene-Integrated Cascaded Silicon Microring Resonators

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Abstract: We theoretically and numerically demonstrate a tunable graphene-integrated cascaded tapered racetrack microring resonator (TRMRR) system. We have derived transmission field amplitudes of such cascaded system without graphene. The deposition of graphene on the PNF region produces an opto-electronically tunable transmission with an appreciable extinction by harnessing the unique advantages of graphene and cascaded resonator system. The proposed device can be potentially used for sensing and modulator applications.
Keywords: Silicon resonator, Graphene, Photonic Integrated Circuit

1. Introduction

On-chip, CMOS compatible microring resonators (MRRs) being an essential component in integrated photonic circuits have been explored for a plethora of applications ranging from laser cavities, wavelength filters, wavelength-division multiplexers, delay lines, optical switches, sensing and many more [1]. A basic MRR consists of a straight waveguide (bus) which is evanescently coupled to the bent waveguide (ring). The coupling gap between the bus and the ring plays a critical role in dictating the strength of coupled field in the ring and hence the quality of resonance. The coupling gap is crucially dependant on the fabrication process. The usage of multiple cascaded MRRs instead of a single MRR is a viable method by which the stringent coupling gap dependency can be lifted [2]. In addition, a cascaded MRR system provides improved extinction ratio in the resonant dips than a single resonator. In this work a cascaded racetrack MRR configuration is proposed where graphene, a two-dimensional material has been placed on top of the straight non-coupled arm of the resonator. The waveguide in the non-coupled arm of the MRR has been adiabatically tapered down, which is referred as a photonic nanofence (PNF) region. It has been reported that the usage of a PNF region can dramatically improve the sensing capability of a conventional MRR [3]. In this work, 0.34 nm thick layer of graphene been placed in the tapered region. The change in chemical potential of graphene yields a wavelength tunable resonance spectrum of the proposed device.

2. Proposed Design, Results and Discussion

The proposed cascaded TRMRR system has been shown in Fig.1. The device consists of a single bus waveguide which is evanescently coupled to two tapered racetrack microring resonators in parallel configuration, marked as *I* and *II*. The resonators have radii of $R_I = 5$ µm and $R_{II} = 3$ µm, respectively, with a straight arm length of 10 µm. For both resonators, the waveguide width (W) and height (H) for the non-tapered section are 600 nm and 220 nm respectively. The waveguide has been adiabatically tapered down to a PNF region having a width $W_I = 350$ nm in the non-coupled arm of both resonators. The resonator geometry for the parallelly cascaded configuration is adiabatically tapered for the racetracks at the region away from the bus waveguide

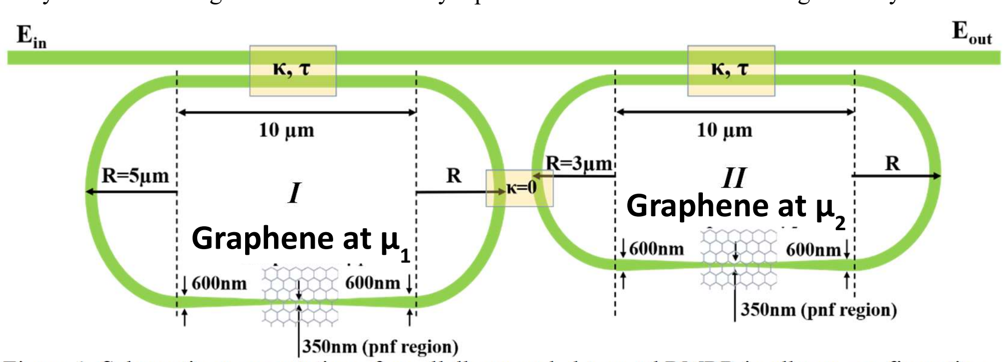

Figure 1: Schematic representation of parallelly cascaded tapered RMRR in all pass configuration.

(of thickness 600nm) to a thickness of 350nm. The region between the down-tapered region corresponding to the photonic nanofence (pnf) is where the scatter is loaded. The pnf length (l) is 3.5μm and that of adiabatically tapered transition region (l_a) is 3.25μm.

Using Transfer Matrix Method, for a single tapered racetrack, the field amplitudes can be obtained as,

$$\frac{E_{out}}{E_{in}} = \frac{M_{21} + M_{22}e^{i\frac{2\pi}{\lambda}n''l}}{M_{11} + M_{12}e^{i\frac{2\pi}{\lambda}n''l}} = e^{-i\frac{2\pi}{\lambda}n_c l_c}\left[\frac{\tau - ae^{-i\frac{2\pi}{\lambda}\sum n_k l_k}}{1 - \tau ae^{-i\frac{2\pi}{\lambda}\sum n_k l_k}}\right]$$

where $a = e^{-\alpha d}$ is the loss due to bending or scattering with α being amplitude attenuation coefficient [4]. τ is the self-coupling coefficient, n_k is the effective refractive index in region k of length l_k. The square of absolute value of E_{out}/E_{in} is taken as transmittance. The effective index of Graphene that has been placed in the pnf region has been calculated through finite element

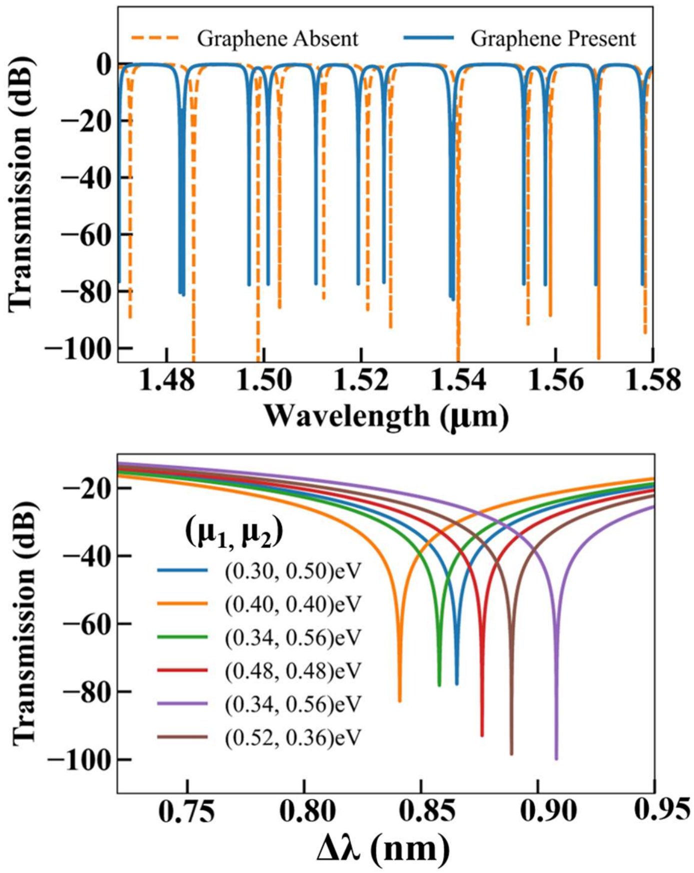

Figure 2: (a) Transmission spectrum for the proposed resonator with and without Graphene at pnf. (b) Tuning of spectra in presence of Graphene at chemical potential μ_1 and μ_2 in the pnf region of ring I and II respectively.

simulation. The cross coupling hasn't been considered in current simulations. A blueshift in resonance spectrum is observed upon presence of Graphene at different chemical potentials in the photonic nano fence region.

3. Conclusion

We observe the tuning of the spectra due to opto-electronic properties of Graphene in a cascaded configuration of tapered racetrack microring resonator making it useful for various sensing applications.

4. References

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