Tunable Graphene-Integrated Cascaded Silicon Microring Resonators

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Poster ID: Pc19
XLV Symposium of the Optical Society of India
COPaQ 2022
Conference on Optics, Photonics & Quantum Optics

Abstract : We theoretically and numerically demonstrate a tunable graphene-integrated cascaded tapered racetrack microring resonator (TRMRR) system. The deposition of graphene in the tapered 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.

Introduction

- 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.
- Parallelly cascaded MRR system provides improved extinction ratio in the resonant dips than a single 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.

Resonator Configuration

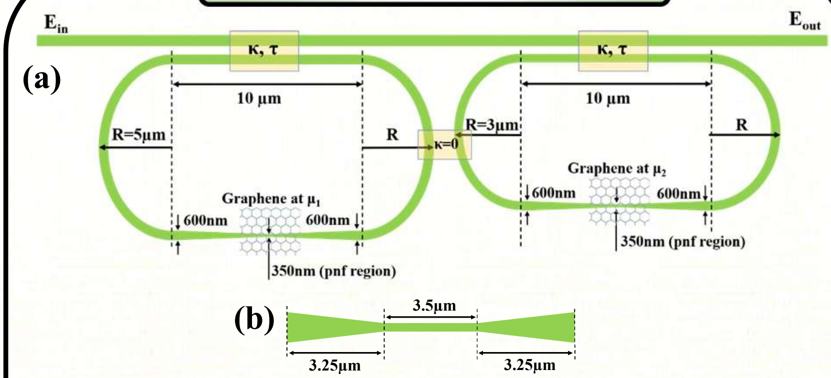

Fig. 1: (a) Schematic of proposed resonator. Two tapered racetrack microrings have been parallelly cascaded in an all pass configuration. Coupling between the two racetracks is absent. (b) Schematic of adiabatically tapered length of the resonator.

Theoretical Modelling & Results

- Using Unitary Transfer Matrix Method (UTMM) we model the transmission spectra of the proposed configuration as,

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

- Transmission ignores the coupling length. Tuning coupling length results in better control over coupling coefficients.
- The scattering losses induced due to graphene at various potentials is modelled as

$$a = e^{-\left(\frac{2\pi}{\lambda_0}n_{pnf}l_{pnf} + \alpha L\right)}$$

- The etching of PNF leads to improved results but with increased losses proposed to overcome with coupling smaller rings or disk resonators serially coupled to the racetrack.

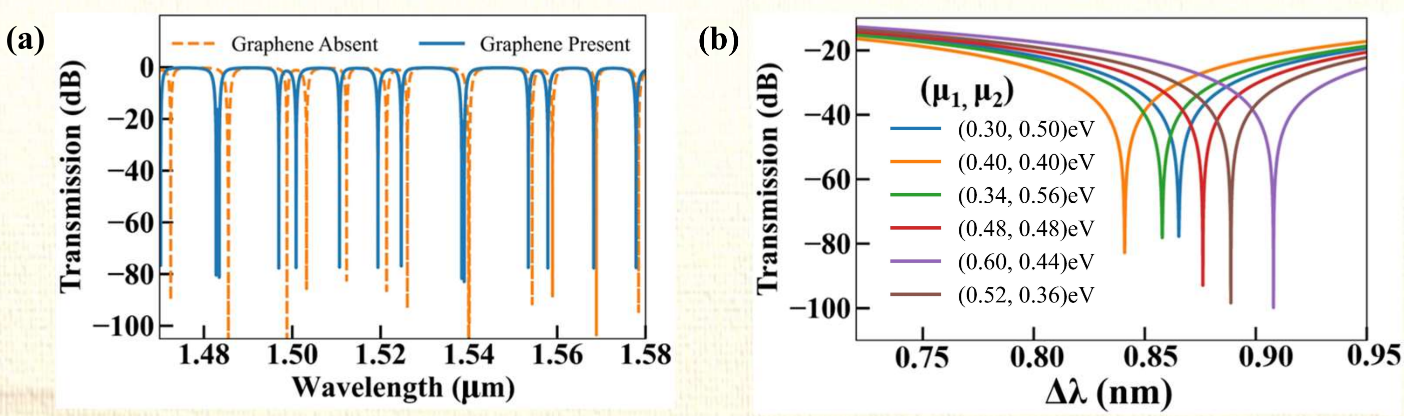

Fig.2: (a) Tuning of spectra in presence of Graphene at chemical potential μ_1 and μ_2 in the pnf region of ring I and II respectively. (b) Tuning of spectra respect to a dip around 1550nm at various ordered potential sets. The effective indices at pnf solved using standard computational methods.

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 bio-sensing and filtering applications in photonic integrated circuits (PIC's) owing to its improved extinctions.

References

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