Tunable Silicon Fabry-Perot microcavity

C. Angulo Barrios, V.R. Almeida, R.R. Panepucci, B.S. Schmidt and M. Lipson
School of Electrical and Computer Engineering, Cornell University, Ithaca NY 14853
cb265@cornell.edu

Abstract: We demonstrate a 20-μm-long tunable optical Fabry-Perot resonator integrated on a silicon-on-insulator waveguide. The device is electrically driven and shows a modulation depth as high as 53% for a power consumption of only 20 mW.

OCIS codes: (230.3120) Integrated optics devices; (230.5750) Resonators; (250.5750) Waveguide modulators

1. Introduction

Silicon-based optical tunable devices are key components for the realization of CMOS compatible optoelectronic circuits. Since crystalline Si does not have linear electro-optic effect, its refractive index is varied through either thermo-optic effect or free-carrier effect. Typical refractive index changes created by these methods are small (on the order of 10^{-3}) and therefore Si tunable planar devices demonstrated so far [1-4] require long interaction lengths and high power consumption.

High finesse microcavities are ideal for achieving tunability in a short length since their transmission is highly sensitive to small index changes in the cavity [5]. In this paper, we report on the fabrication and characterization of a 20-μm-long tunable F-P cavity on silicon-on-insulator (SOI).

2. Device structure and fabrication

Fig. 1 shows a schematic of the device [5]. It consists of a planar F-P cavity formed by two distributed Bragg reflectors (DBR) in an undoped SOI rib waveguide. Both DBRs consist of three Si/SiO_2 periods etched down to the buried oxide (BOX) layer. p^+ and n^+ areas are defined in the cavity region at each side of the rib, defining a p-i-n diode. The p-i-n diode is laterally limited by isolation trenches down to the BOX layer. SiO_2 covers the whole structure. Fig. 2 shows a scanning electron microscope photograph of the planar F-P microcavity.

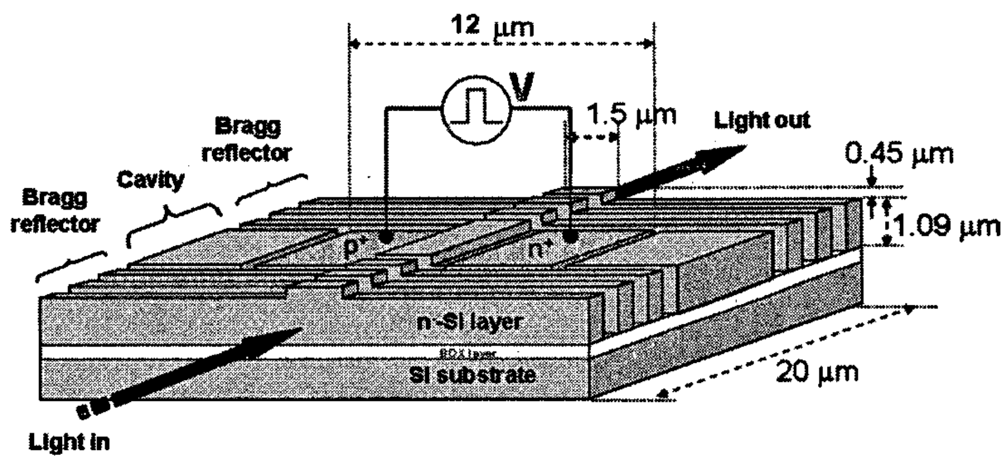

Fig. 1. Schematic of a tunable Si F-P microcavity. A lateral p-i-n diode is used to drive current into the cavity region.

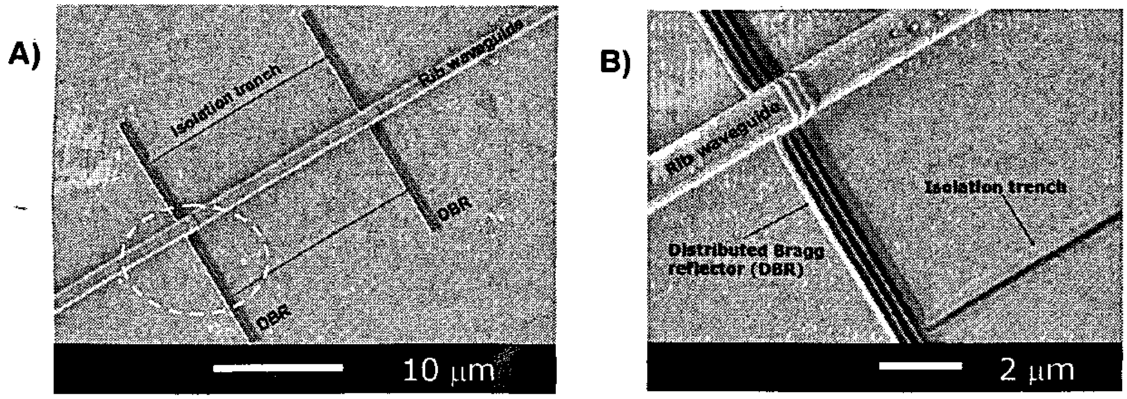

Fig. 2. A) Top view SEM photograph of a planar F-P microcavity integrated on a SOI ridge waveguide. B) Enlargement of the doted region in A).

3. Results and discussion

Fig. 3 shows the transmission spectrum of the fabricated microcavity over the 1520-1600 nm wavelength range. The full width at half maximum of the resonance peak at 1.553 μm is 1.54 nm. This represents a finesse of 11.2. To our knowledge, this is the highest finesse reported for a planar F-P waveguide microcavity in Si.

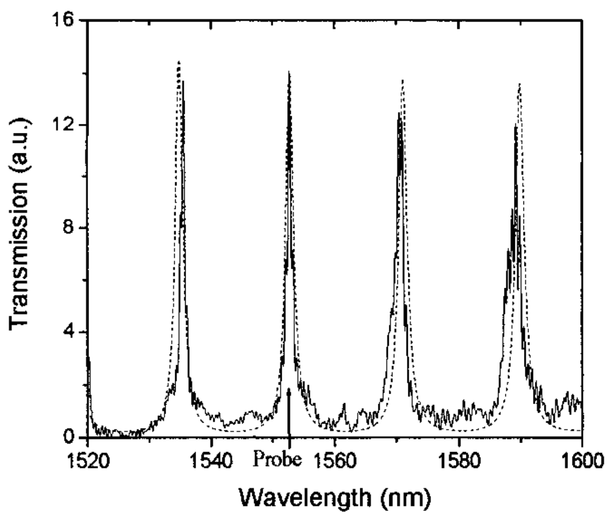

Fig. 3. Experimental (solid line) and calculated [5] (dashed line) transmittivity spectra of the F-P microcavity for the fundamental TE-like mode in the 1520-1600 nm wavelength range.

Fig. 4 shows the measured modulation depth (M) of the device at 1552.89 nm as a function of the dissipated power (P_d). M is defined as $(P_{OFF}-P_{ON})/P_{OFF}$, where P_{OFF} and P_{ON} are the transmitted optical powers in the OFF and ON states, respectively. A maximum M of 53% is obtained at P_d=20 mW. This dissipated power is two orders of magnitude smaller than that reported for longer F-P cavity devices [3,4].

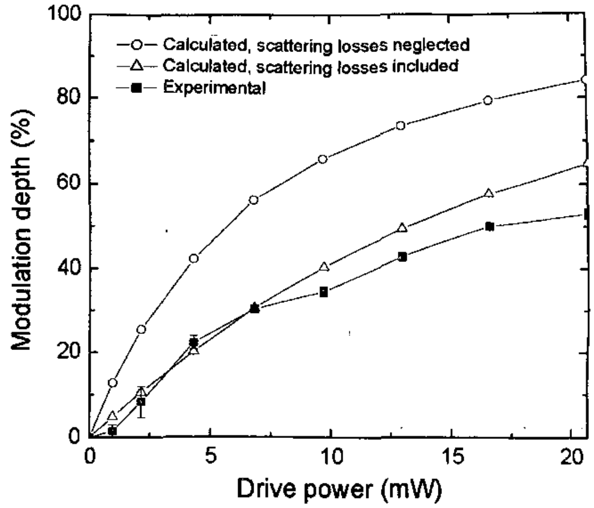

Fig. 4. Experimental (square dots) and calculated (triangular dots) modulation depth of the studied device at 1552.89 nm as a function of the dissipated power. The calculated modulation depth of a similar device with negligible scattering losses is shown in circular dots.

The dependence of the change in index with temperature, $\Delta n_{eff}/\Delta T$, provides an indication of the relative contributions of the free-carrier effect and the thermal effect to the signal modulation. We estimated $\Delta n_{eff}/\Delta T=+8.7\times10^{-5}\ K^{-1}$, revealing a dominating thermal modulation mechanism. However, the obtained $\Delta n_{eff}/\Delta T$ is significantly smaller than the reported thermo-optic coefficient of Si, $+1.86\times10^{-4}\ K^{-1}$ [3], suggesting the existence of free-carrier dispersion which opposes the thermo-optic effect.

4. Conclusion

We demonstrate a 20-μm-long electrically-driven tunable F-P microcavity on Si. The high finesse of the cavity increases the sensitivity of the device to small index changes and enables high modulation at low power consumption.

5. References

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