

# Tunable Silicon Fabry-Perot microcavity

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**Abstract:** We demonstrate a 20- $\mu\text{m}$ -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.

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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- $\mu\text{m}$ -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<sub>2</sub> periods etched down to the buried oxide (BOX) layer. p<sup>+</sup> and n<sup>+</sup> 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<sub>2</sub> covers the whole structure. Fig. 2 shows a scanning electron microscope photograph of the planar F-P microcavity.

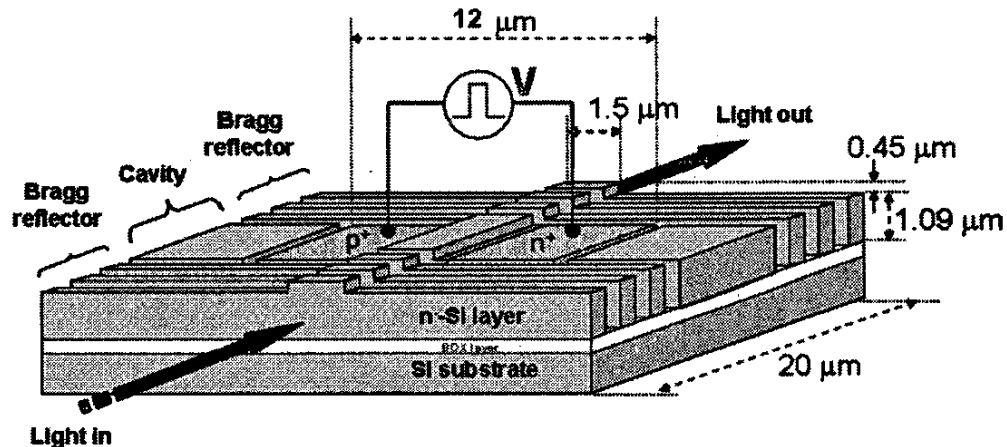


Fig. 1. Schematic of a tunable Si F-P microcavity. A lateral p-i-n diode is used to drive current into the cavity region.

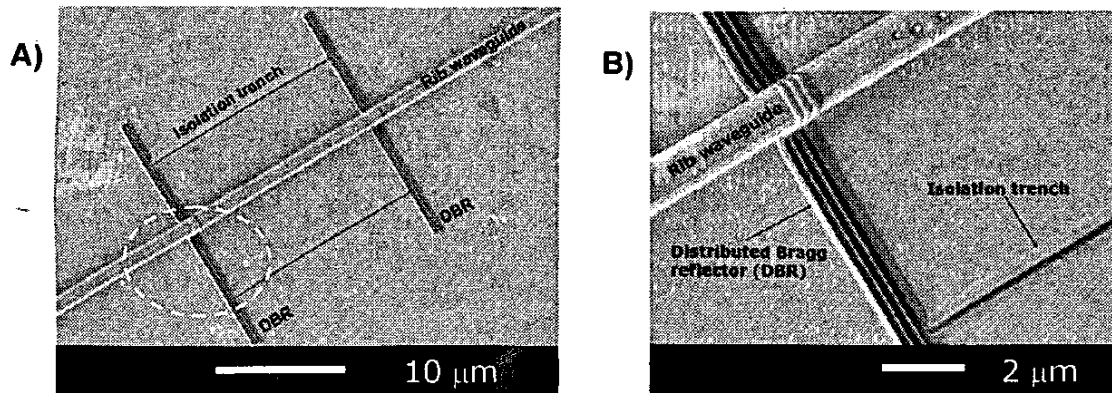


Fig. 2. A) Top view SEM photograph of a planar F-P microcavity integrated on a SOI ridge waveguide. B) Enlargement of the dotted region in A).

### 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  $\mu\text{m}$  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.

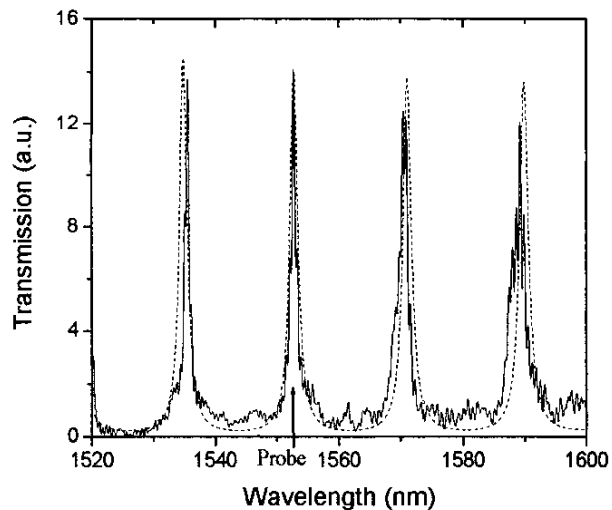


Fig. 3. Experimental (solid line) and calculated [5] (dashed line) transmittivity spectra of the F-P microcavity for the fundamental TE-like mode in the 1520-1600 nm wavelength range.

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  $(P_{\text{OFF}} - P_{\text{ON}})/P_{\text{OFF}}$ , where  $P_{\text{OFF}}$  and  $P_{\text{ON}}$  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].

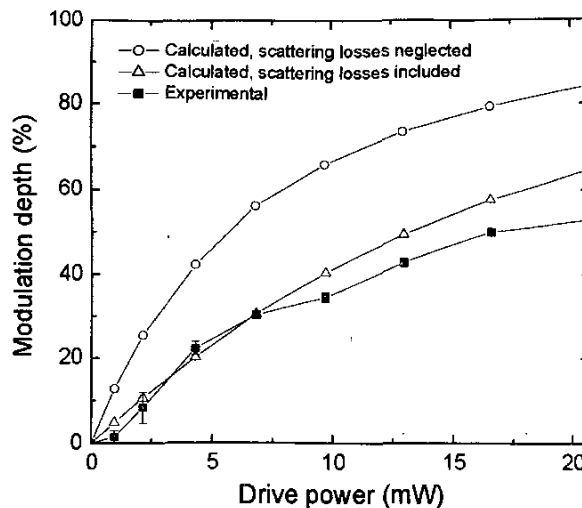


Fig. 4. Experimental (square dots) and calculated (triangular dots) modulation depth of the studied device at 1552.89 nm as a function of the dissipated power. The calculated modulation depth of a similar device with negligible scattering losses is shown in circular dots.

The dependence of the change in index with temperature,  $\Delta n_{\text{eff}}/\Delta T$ , provides an indication of the relative contributions of the free-carrier effect and the thermal effect to the signal modulation. We estimated  $\Delta n_{\text{eff}}/\Delta T = +8.7 \times 10^{-5} \text{ K}^{-1}$ , revealing a dominating thermal modulation mechanism. However, the obtained  $\Delta n_{\text{eff}}/\Delta T$  is significantly smaller than the reported thermo-optic coefficient of Si,  $+1.86 \times 10^{-4} \text{ K}^{-1}$  [3], suggesting the existence of free-carrier dispersion which opposes the thermo-optic effect.

#### 4. Conclusion

We demonstrate a 20- $\mu\text{m}$ -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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