Ultra-Wide FSR Vertical-Junction Microdisk Modulator With Efficient External Heater

Michael Cullen[1,*], Asher Novick[1,†], Songli Wang[1], Vignesh Gopal [1], Anthony Rizzo[2], Robert Parsons[1], and Keren Bergman[1]

[1] *Department of Electrical Engineering, Columbia University, New York, NY, 10027, USA*
[2] *Air Force Research Laboratory Information Directorate, Rome, NY, 13441, USA*
[†] *Now at Xscape Photonics*

[*] *michael.cullen@columbia.edu*

Abstract: We describe a wide-FSR vertical-junction microdisk modulator design (radius=2μm) featuring an efficient, external half-height doped-silicon heater that affords aggressive size reductions. We measure FSR=58.6 nm and demonstrate data transmission at 16 Gb/s.

1. Introduction & Background

Dense wavelength-division multiplexing (DWDM) systems can leverage the inherent wavelength selectivity of resonant structures, such as filters and modulators, by cascading many along a single bus waveguide. In this configuration, each resonator effectively filters a distinct wavelength channel with minimal inter-channel crosstalk [1]. The finite free spectral range (FSR) and off-resonance insertion loss (IL) limit the number of resonators deployable on a single bus, with links often requiring multiplexing and demultiplexing circuitry [2]. Wide FSR resonator designs are desirable since more channels can fit within one FSR to reduce or eliminate this requirement [3]. However, to achieve wider FSRs, resonant structures must be made smaller while accommodating an integrated heater and without violating commercial foundry design rules. This challenge is further compounded in resonant modulators that house both heater and modulation circuitry, typically limiting disk radii to $\sim 2\ \mu$m for internally heated structures [4]. External heater structures are an alternative that can free valuable space for radius reduction, although previous demonstrations have required additional undercut processes to approach the efficiency of internal heaters [5].

Here, we propose and demonstrate the placement of a half-height, doped-silicon heater externally and coradially to a 2 μm radius vertical junction (VJ) microdisk modulator that pushes the limits of both modulator FSR and thermal efficiency, with a clear path for further radius reduction. This design leverages the phase mismatching and reduced overlap integral afforded by half-etching the external doped-silicon heater, permitting close placement of the heater to the resonator with a 200 nm gap and without disturbing the whispering gallery mode [6]. The disk exhibits a wide 58.6 nm FSR and a high thermal tuning efficiency of 0.6 nm/mW with an extinction ratio (ER) of 18.9 dB. Modulation is demonstrated with an open-eye diagram at 16 Gb/s non-return-to-zero (NRZ) with ER of $\approx$ 3.6 dB at 1.3 V peak-to-peak driving signal. The performance of this device provides valuable insight for future externally-heated resonant modulator designs that rival internally-heated structures while achieving wider FSRs to meet growing DWDM channel count demands.

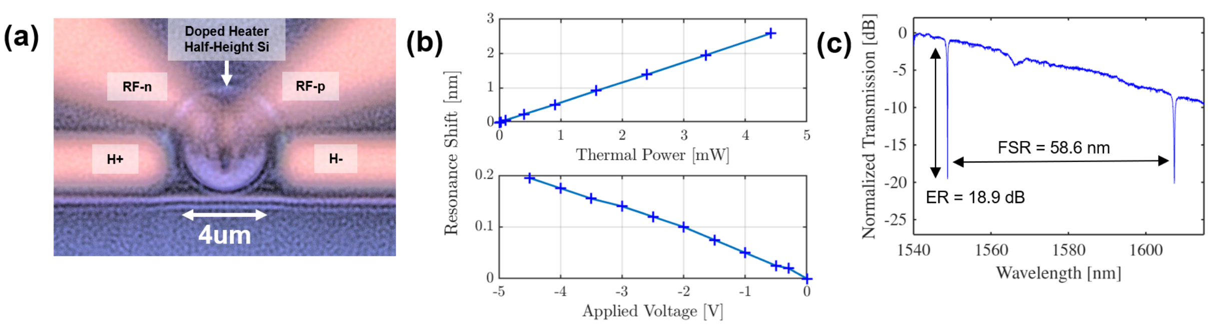

Fig. 1. (a) Micrograph image of the fabricated microdisk modulator with the half-etched doped silicon external heater. (b) Measured thermal tuning efficiency of 0.6 nm/mW (top) and depletion response of 43 pm/V (bottom). (c) Spectral transmission showing ER = 18.9 dB and FSR = 58.6 nm.