Tunable Grating Fabry-Perot-Based Wavelength Add/Drop Multiplexer in Silicon Photonics

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Abstract: We report a silicon photonic tunable add/drop multiplexer based on thermally tuned grating Fabry-Perot etalons embedded in a Mach-Zehnder interferometer. A filter bandwidth of 100GHz is achieved within a broad 60nm wide stopband.

I. Introduction

Silicon photonics enables dense integration of WDM functions. Previously, wavelength-tunable add/drop multiplexers have been demonstrated using thermally tuned micro-ring resonators [1]. However, the ring fabrication tolerance is very tight. Grating-based devices have also been demonstrated [2], but a long (500µm) weak grating is needed to achieve narrow channel bandwidths. Using a Fabry-Perot (FP) cavity with waveguide width-modulated grating [3] or photonic crystal [4] mirrors, a narrow passband within a wide stopband was achieved with a compact device. However, these 2-port devices send the reflected light back along the input waveguide. Here, we report on a 4-port, silicon photonic tunable add/drop multiplexer with compact FP etalons (8µm grating length) embedded in a Mach-Zehnder interferometer (MZI). A narrow passband (100GHz) within a wide stopband (60nm) and an electro-thermal tuning rate of 18pm/mW have been achieved.

II. Principle of Operation

The schematic of the add-drop filter is shown in Fig. 1. Two identical, thermally tuned FP cavities are integrated with the two arms of the MZI. For signals that fall within the resonance bandwidth of the FP cavity (~100GHz), both paths transmit and the light recombines into the lower (Drop) port at the second directional coupler due to the phase offset introduced by the first coupler (Fig. 1a). For signals outside the resonance bandwidth but within the stopband of the grating reflector (~60nm), both paths reflect and the phase offset is maintained. The light recombines in the lower (Through) port, allowing the reflected light to be further routed, rather than sent back along the input waveguide (Fig. 1b). The use of a strong grating with FP etalons significantly reduces the grating length (to 8µm) compared with that of a weak, long grating (500µm).

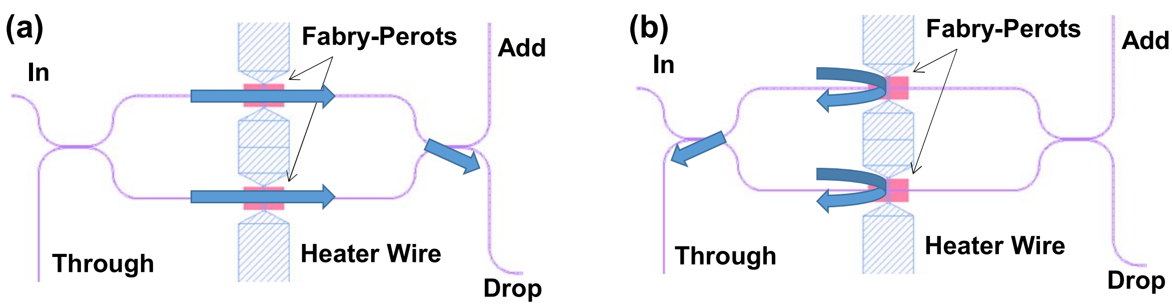

Figure 1 Schematic and operating principle of the tunable wavelength add-drop filter. Two compact grating Fabry-Perot etalons are embedded in a Mach-Zehnder interferometer. (a) For resonant wavelengths, the signal goes to the Drop port. (b) For all non-resonant wavelengths within the stopband, light is reflected by the grating FP and sent to the Through port.

III. Design and Fabrication

The device was fabricated through the ePIXfab/LETI silicon photonics multi-project wafer service, and required no post-processing. The waveguide is 220nm thick and 500nm wide. The FP etalon consists of a $\lambda/2$ cavity (330nm) between two 8µm long strong gratings (23 periods of 159nm line and 184nm space). The grating is made by partial etch (70nm) of the silicon waveguide. The micro-heater (AlCu) is 1µm wide and 10µm long, and insulated from the silicon waveguide by a 0.7µm thick oxide. The required minimum feature size of the first-order waveguide grating is 159nm. Fig. 2a shows the fabricated device. The area inside the annotation box is enlarged in Fig. 2b to show the resistive heater crossing over the Fabry-Perot cavity between the two Bragg mirrors.

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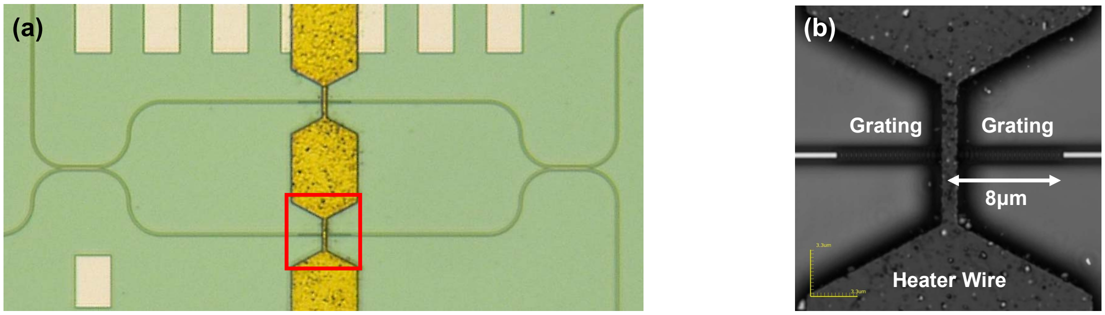

Figure 2 (a) Micrograph of overall add-drop structure. (b) Confocal micrograph enlargement of the area in the red box from (a) showing the compact grating length of 8μm each.

IV. Experimental Results

The measured optical spectra at the Through port are shown in Fig. 3 at various thermal tuning power. The device transmits a 100GHz passband from the Input to the Drop port. The rest of the broad 60nm wide stopband is reflected and sent to the Through port where it can be routed independently from the input (Fig. 3a). The center wavelength of the passband can be tuned by injecting current into the integrated metal heater. Tuning of 2nm is achieved with 113mW heater power (Fig. 3b), demonstrating a tuning slope of 18pm/mW as compared with 8.25pm/mW for the long weak grating [2]. The tuning response time is 5 microseconds, due to the small effective cavity size.

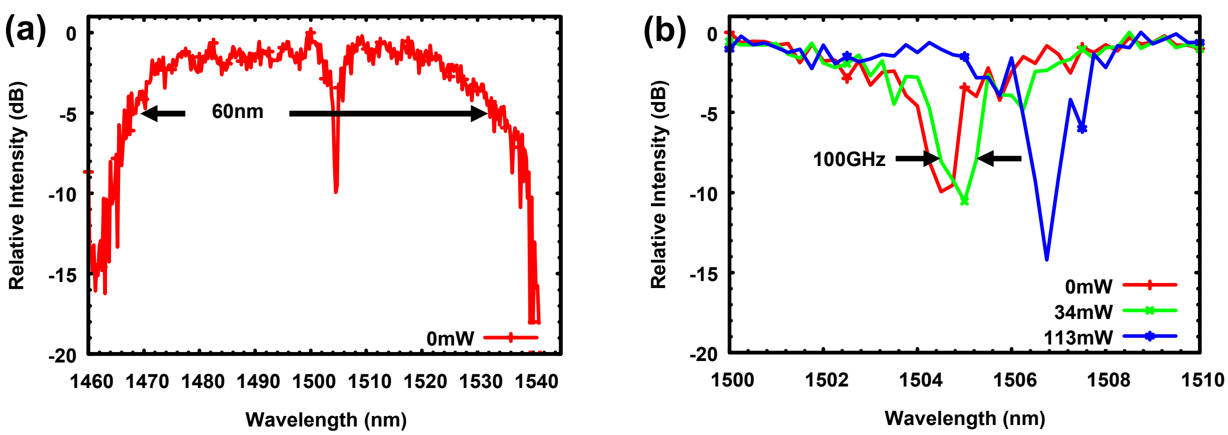

Figure 3 Measured reflection spectra of the FP-based add/drop. (a) The stopband of the Bragg mirrors is 60nm wide, allowing a broad range of wavelengths to bypass the filter and exit at the Through port. (b) The passband of the FP cavity is 100GHz, transmitting only a narrow band to the Drop port. The wavelength of the FP passband can be tuned with the integrated metal heater.

V. Conclusion

We have demonstrated a 4-port, compact tunable grating-based add/drop multiplexer in a foundry-compatible silicon photonics process having a 100GHz passband within a 60nm stopband. By tuning the resonance on or off of a given wavelength with the integrated heater, that wavelength can be selectively routed, forming a 2x2 wavelength switch with a reconfiguration time of 5 microseconds.

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