Microring Weight Bank Designs with Improved Channel Density and Tolerance

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***Abstract*—Microring weight banks enable reconfiguration in analog photonic networks and multi-channel RF front-ends. We demonstrate 2-ring weight banks and show that they are tolerant to fabrication and thermal effects. Weights consisting of two microrings can potentially increase channel capacity by a factor of 2.72-fold.**

Microring resonator (MRR) weight banks could enable novel signal processing approaches in integrated photonics. The accelerating demands on spectrum resources are pushing radio operations into new regimes of bandwidth, efficiency, and reconfigurability. Multivarite RF photonics is the application of wavelength-division multiplexed (WDM) multi-channel photonic devices to RF signal processing [1]. When WDM signals are detected, the electronic output represents their sum. In analog and/or neural networks, reconfiguration is performed by changing weight values. In these systems, N distinct wavelengths of light carry N signals from N antennas or N analog network elements [2]. Recent acceleration of high-performance, CMOS-compatible photonic integrated circuit (PIC) platforms promise to greatly expand the possibilities for large scale systems.

MRR weight banks allow for reconfigurable functionality in analog photonic networks to be integrated on a silicon photonic chip. By tuning filters on and off resonance with their respective signals, an MRR weight bank can individually weight each WDM channel. MRR weight banks are the key photonic subcircuit associated with interconnection and network configuration in integrated analog photonic networks and multivariate RF photonics. Their scaling potential is therefore closely tied to the performance limits of these overall systems, which must be better understood to allow the construction of larger systems.

In conventional analyses of MRR devices for multiplexing, demultiplexing, and modulating WDM signals, the tradeoff that limits channel spacing is inter-channel cross-talk [3]. As shown in Ref. [4], this analysis can not be applied to MRR weight banks. Weight banks have a metric of effective insertion loss that trades off with channel density, and this tradeoff depends on phase accumulated on the bus waveguides between MRR weights (Fig. 1). Multi-MRR coherent interactions are especially relevant when resonances are closely spaced, so it is essential to account for them in channel density analysis. In a 1-pole bank, a channel partially coupled through a neighboring MRR – instead of causing inter-channel cross-talk – can return through the opposite bus waveguide to complete a coherent feedback path involving multiple MRRs [5]. 2-pole banks instead have coherent feedforward paths that behave like interferometers.

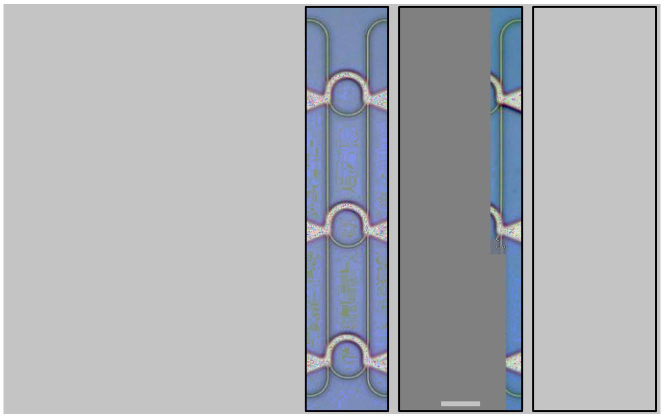

Fig. 1. 1-pole weight banks showing coherent feedback path when a wavelenth channel (pink) couples through a neighboring MRR. 2-pole weight banks showing coherent *feedforward* path when a wavelenth channel (pink) couples through a neighboring MRR. Device A: fabricated 1-pole weight bank with 3 weights. Device B-C: fabricated 2-pole weight bank with 3 weights. Device C also contains a bus length difference in order to alter the interference condition. Due to their symmetry, tuning MRR resonances will heat bus waveguides equally, changing their summed length, but keeping the length difference consistent.

Here, we demonstrate 2-pole MRR weight banks and analyze their impact on WDM weight bank channel scaling limits, tunability, and fabrication tolerance. Using the simulation tools developed in [4], we estimate a factor of 2.72 improvement in channel scalability as compared to 1-pole weight banks. The advantages of 2-pole banks stem from steeper filter rolloff but also, crucially, their interferometer-like interaction between neighboring weights, which depends on a phase difference in two bus waveguides, rather than a phase sum. Therefore, element (Fig. 1A-C). Device A is a 1-pole bank. Device B is 2-pole. Device C is also 2-pole, but with a lithographically defined bus waveguide length difference.

The procedure for assessing how MRR tuning affects the bus phase condition is as follows. Initially, the resonances are distributed based on fabrication variation. Analyzing their peak locations with a spectrum analyzer, the resonances are tuned to a separation of 1.0 nm. Then, all rings are tuned collectively such that their center wavelengths traverse 3.0 nm, while their separation from one another remains constant at 1.0 nm. In this way, thermal cross-talk affects the bus waveguides as the MRRs are tuned.

Fig. 2 shows the results of tracking and tuning each weight bank. Inter-resonator interference can be observed in the dips between peaks. For device A (black), the dips between resonance peaks varies strongly as a function of tuning. The 2-pole devices B (blue) and C (red) maintain a constant transmission profile. This is because thermal cross-talk from MRRs to bus WGs cancel out, making the interference condition stay relatively constant with dynamic tuning. Device C, which introduced a bus path length difference exhibits deeper isolation between filters. This means that the interference can be *designed* in order to hit an optimal interference point, which is advantageous for independent weighting of neighboring channels.

Scaling analysis