# Fast Wavelength Locking of a Microring Resonator

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***Abstract*—We experimentally investigate the latency for wavelength locking and thermally stabilizing a microring resonator to its operating wavelength, showing that the integrated-heater bandwidth is the limiting factor.**

## I. INTRODUCTION

Due to advantages such as small footprint, power efficiency, and wavelength division multiplexing (WDM) capability, microring resonator devices are promising components for use in future silicon photonic enabled optical interconnects. However, fabrication variations create an inherent offset between the resonant wavelength of the microring resonators and their desired operating wavelengths [1]. Integrated heaters can thermally tune microring resonators to desired operating wavelengths, but an automated, scalable, and energy efficient initialization process must be implemented for commercial applications.

Efforts to initialize microrings automatically have involved measuring optical power then using digitally implemented search algorithms [2, 3]. While successful, these systems are limited in their wavelength locking speed and range by optical power measurement sensitivity. They are also susceptible to power fluctuations in the optical path. An alternative wavelength locking technique has been demonstrated based on the generation of anti-symmetric error signals using thermal dithering [4]. This method offers implementation using simple, low-cost, and low-power analog electronics, and is immune to fluctuations in optical power.

In this work we characterize how fast the dithering based initialization and control system can lock a microring filter device to its operating wavelength. The speed of initialization is a very important parameter for designing future microring-based optical interconnect architectures.

## II. EXPERIMENTAL SETUP

The device used in the experiment is a 10 µm diameter microring demultiplexing filter fabricated using a standard CMOS-compatible process on a 250 nm SOI wafer with 3 µm of buried oxide. It has 450×250 nm waveguide channels and a nickel-chromium heater deposited on top of a 1 µm thick oxide cladding. With a small 1 µm separation from the microring, the 1.8 kOhm heater offers a tuning efficiency of 0.56 nm/mW (70 GHz/mW).

The experimental setup is shown in Fig. 1. A tunable laser is coupled onto the chip using tapered fiber, and DC probes are used to contact the heater. A 100 kHz, 40 mVpp sinusoidal dither signal is driven onto the heater, which imprints a small modulation on the light reaching the drop port. The output at the drop port is detected by a commercial off-chip low-speed photodiode and mixed with the original dither signal to generate the error signal used for feedback.

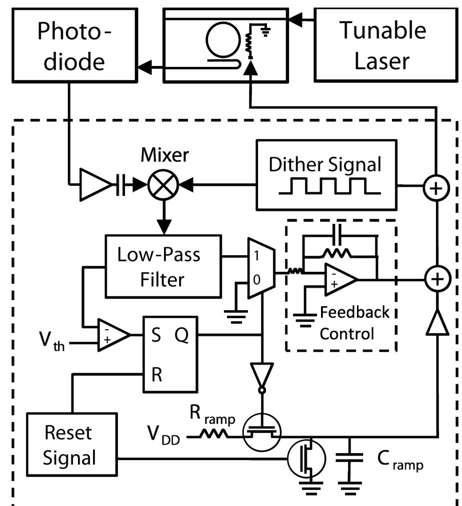


Fig. 1. Schematic of the experimental setup and the wavelength initialization circuitry, with configuration of the chip indicated in top-center of the diagram.

## III. RESULTS

At reset, the output heater voltage starts to ramp up from 0 V, and the microring resonance starts to shift toward the fixed laser wavelength. When the resonance approaches the laser, the asymmetric error signal is detected, at which point the system stops ramping and activates the feedback circuitry to lock the microring to the laser wavelength. Fig. 2 shows the heater voltage during initialization. The voltage ramps up from 0 to 1.5 V, which equates to a 2.1 nm resonance shift to reach the laser wavelength.

The speed of initialization can be approximated as: $t \approx (\Delta\lambda / \delta\lambda/\delta t) + t_{circuit} + t_{feedback}$, where $\Delta\lambda$ is the offset between resonance and laser wavelength, $\delta\lambda/\delta t$ is the heater ramp speed, $t_{circuit}$ is the delay from the circuit logic, and $t_{feedback}$ is the time it takes for the feedback system to stabilize. $t_{circuit}$ is measured in 10s of nanoseconds, sufficiently small that it be can ignored when approximating the aggregate initialization time.

While an arbitrarily fast heater ramp can be generated, we found that there was a limit to the speed useable for initialization. Fig. 3a shows the fastest usable ramp speed achieved, corresponding to a resonance shift of 0.012 nm/µs

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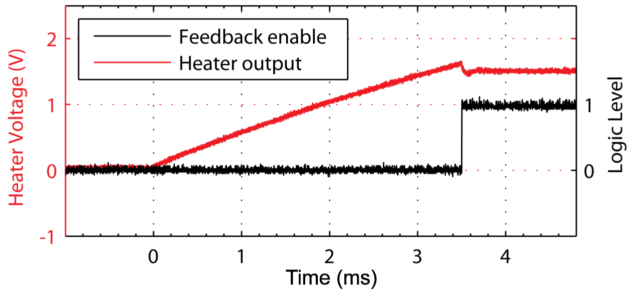


Fig. 2. Voltage applied to heater during the initialization process.

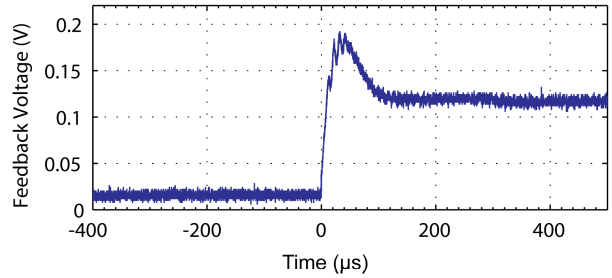


Fig. 4. Feedback circuit output during initialization, inverted for clarity.

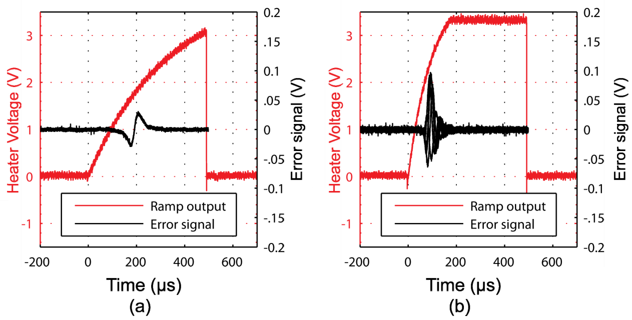


Fig. 3 (a) A fast heater ramp signal generating a usable error signal. (b) A ramp signal that is too fast and generating an unstable error signal.

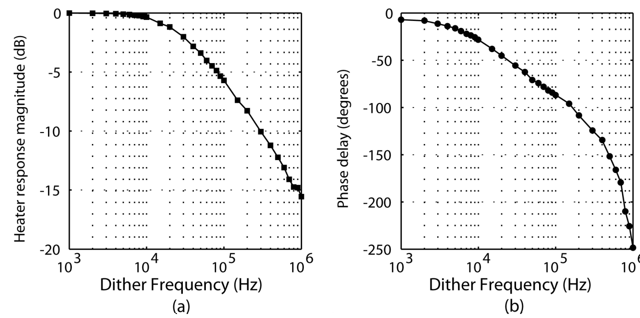


Fig. 5. (a) Heater modulation magnitude and (b) phase response as dithering frequency is increased.

(1.5 Ghz/µs), and the corresponding recovered error signal. A faster ramp generates an unstable error signal (Fig. 3b). This instability arises because the ramp signal has frequency components on the same order as the dither signal itself, which interferes with the mixing process used to generate the error signal. The faster heater ramp also overshoots the actual device thermal response, making it impossible for the feedback system to lock at the resonance and stabilize the system.

The fastest achieved feedback circuit stabilization time is shown in Fig. 4. The circuit overshoots then settles back to a steady state after 100 µs, 10 times the dither signal period. The settling time must be longer than the dither signal period because the dither signal generates the error input to the feedback system.

The dither frequency is key to system locking speed, and this choice is governed by the thermal bandwidth of the microring. Fig. 5 shows the magnitude and phase of the optical modulation from the heater as the frequency of the dithering signal is increased. The 100 kHz dithering signal is chosen to minimize the latency of the feedback system while maintaining SNR at the output of the mixer. A convenient way to represent thermal bandwidth is using the thermal time constant, which we measure to be 7 µs for the microring, consistent with other devices found in the literature [5].

## IV. Conclusion

We have demonstrated that the initialization speed of the microring resonator is limited by the fundamental thermal time constant of the device. The dithering signal used cannot be faster than the microring thermal response, and the heater ramping and feedback settling times are slower still. However, the thermal time constant will be an issue for any implementable control system for wavelength locking microring resonators. We have experimentally shown that the use of the dithering mechanism can achieve wavelength locking with a latency on the order of one magnitude larger than the thermal time constant. These latency characteristics, when combined with the prior advantages in ease of implementation and scalability, make the dithering mechanism an ideal solution for wavelength locking microring-based devices in future silicon photonic interconnects.

The experimental results and analysis we provide must be leveraged by future photonic architectures to ensure that latencies associated with reinitializing microring links can be resolved. Additionally, these results motivate further investigation into reducing the thermal time constants of integrated heaters, which notably, have been experimentally demonstrated in the sub-microsecond regime [6].

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