

Design and Control of Photonic Neural Networks Applied to High Bandwidth Classification

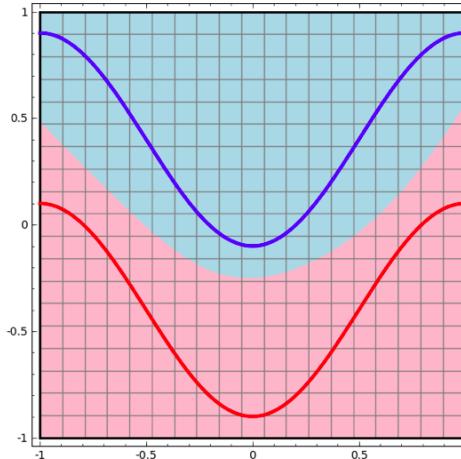
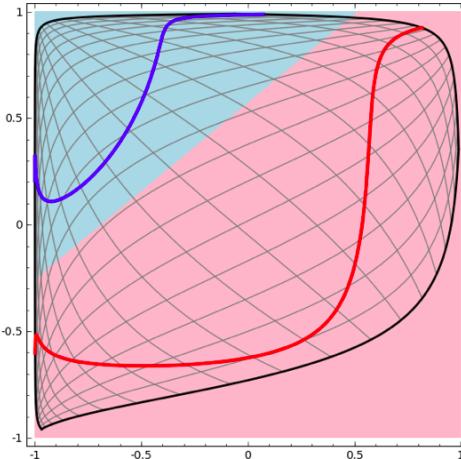
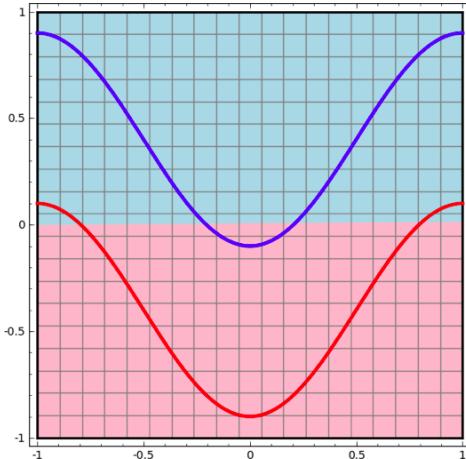
Ethan Gordon '17

May 9, 2017

Neural Networks, Briefly

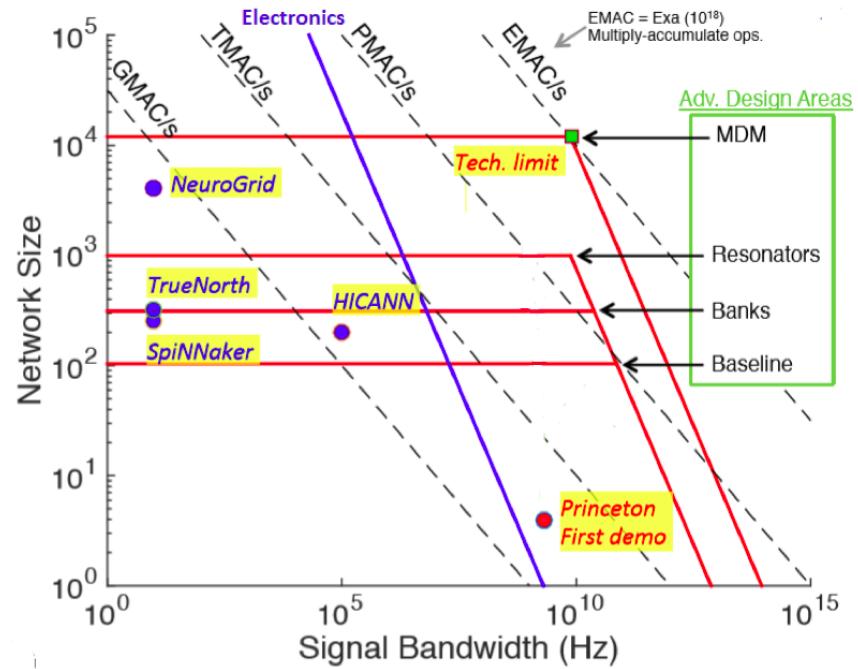
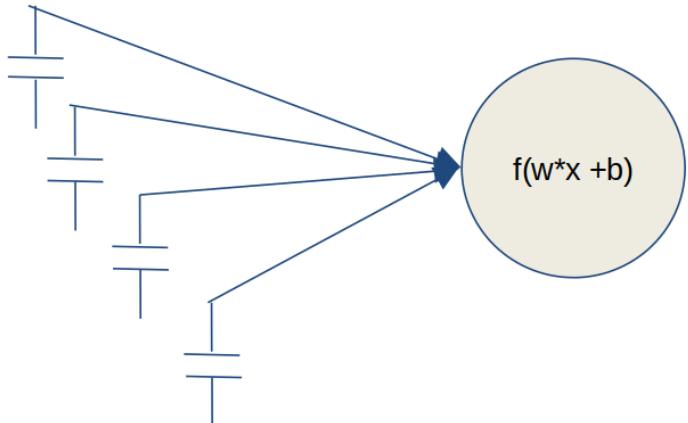
Nonlinearity and Weighted Addition:

$$\vec{x}_{i+1} = f(\vec{w} \cdot \vec{x}_i + b)$$

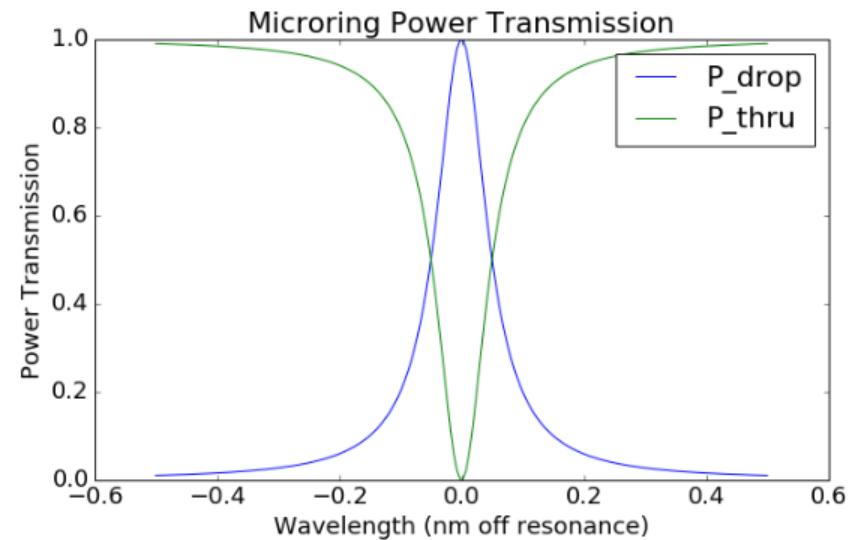
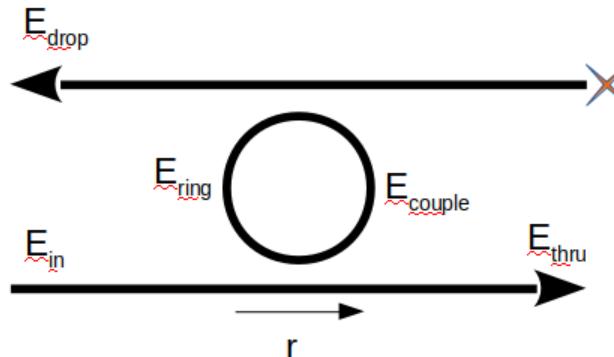


A Case for Photonics

Throughput = Bandwidth * Layer Size

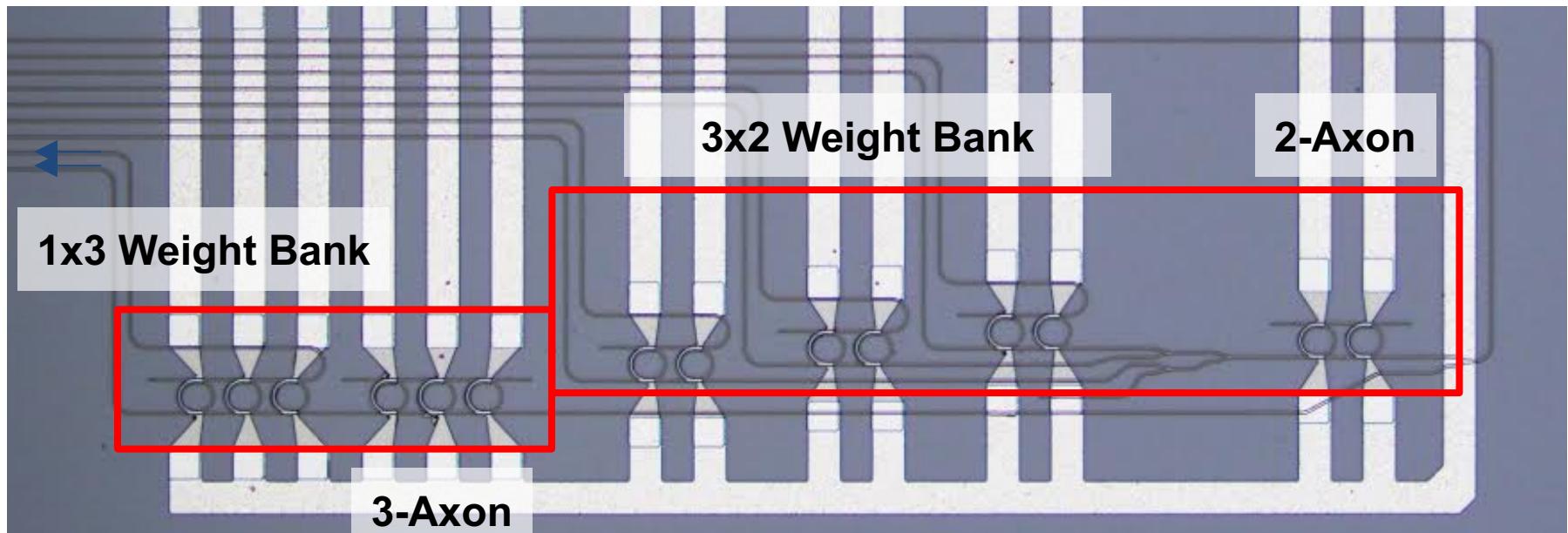


Microring Resonators: Operating Principle

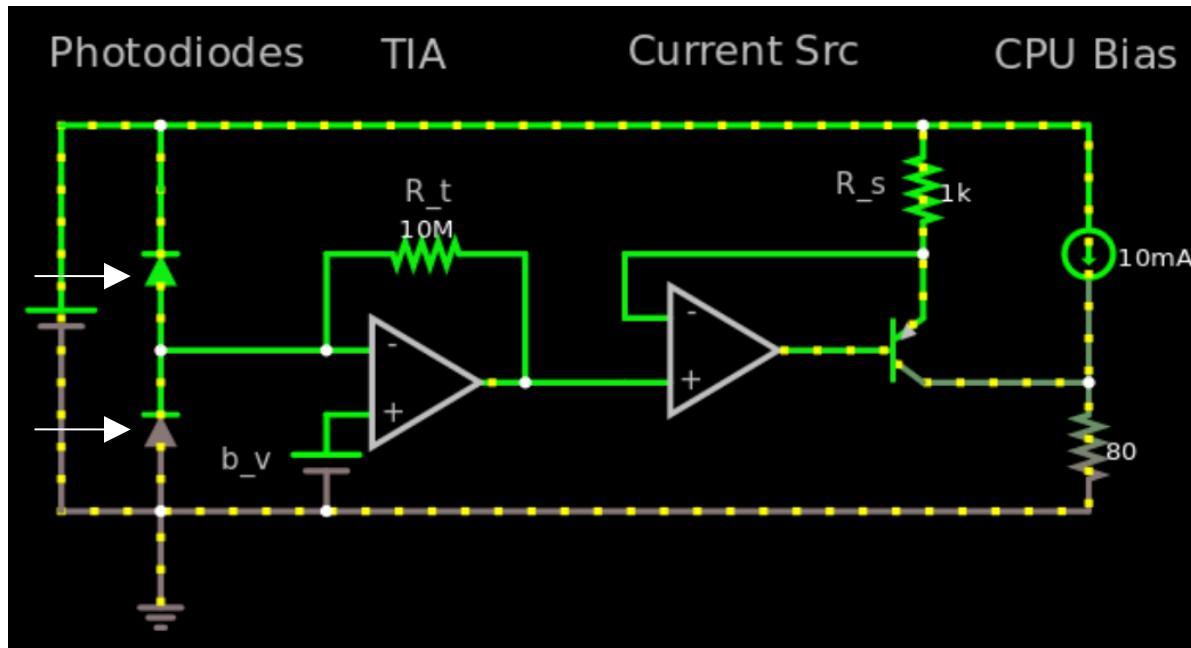


Resonant Frequency is Temperature-Dependent

Putting it Together: A 2-3-1 Feed-Forward Network



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Thermal Calibration: Basic Procedure

Goal: Map electrical state and optical weights and biases.

1. Ascription

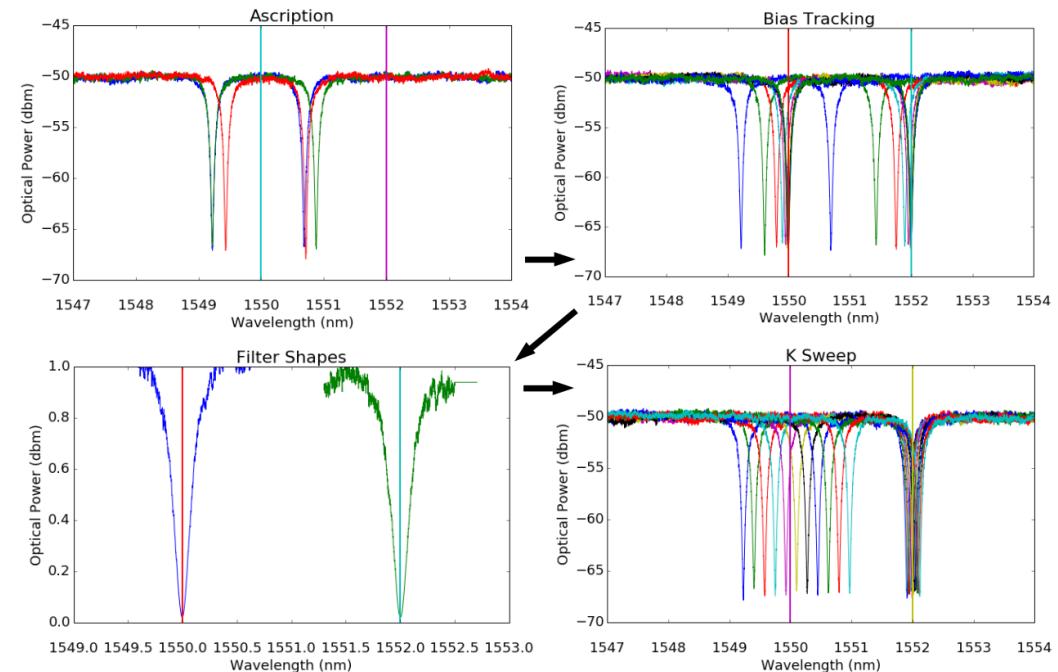
2. Background Removal

3. Track to Bias

4. Pull Filter Shapes

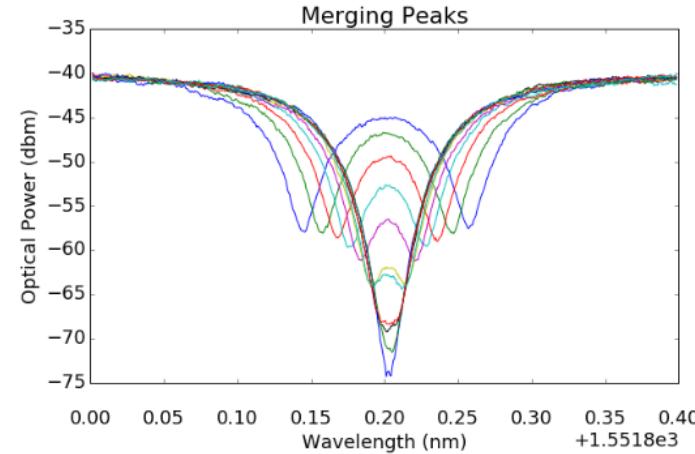
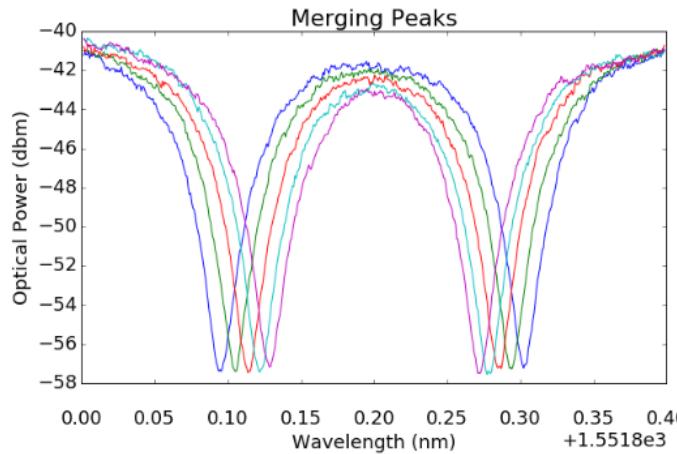
5. Determine K Matrix

$$\lambda - \lambda_0 = K((i + i_0)^2 - i_0^2)$$



Thermal Calibration: Cascaded Calibration

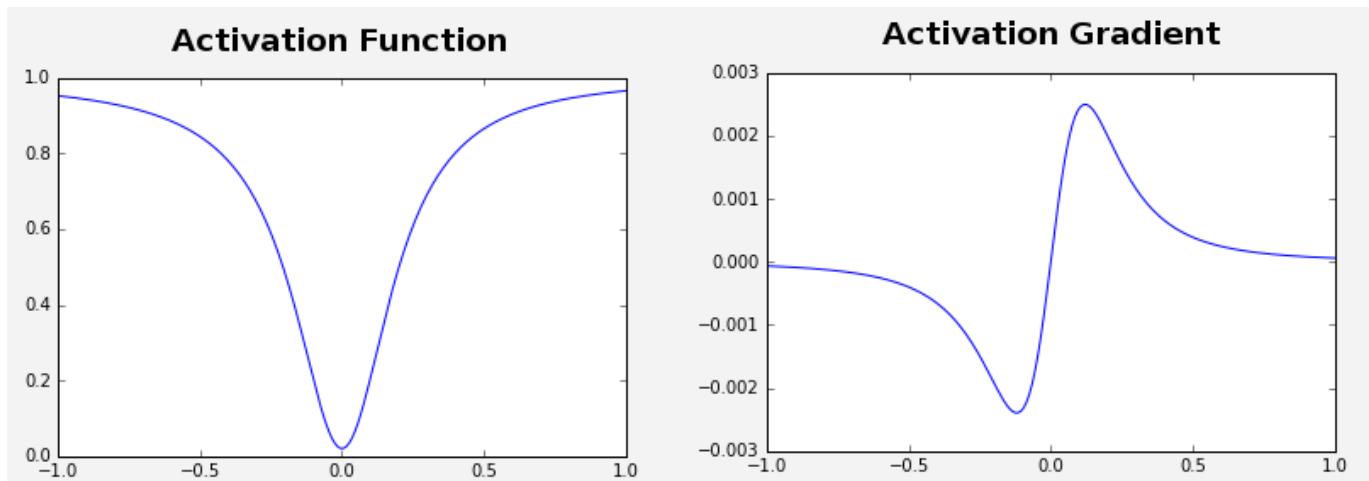
Goal: Map electrical state and optical weights and biases.



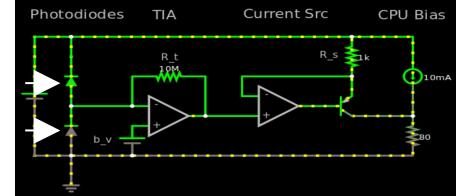
$$\Delta i^2 = \pm k_p * K * (\text{err}_{fwhm} + \text{err}_\lambda)$$

Network Training: Model

Activation Function: Current \rightarrow Power \rightarrow Wavelength Shift



Network Training: Model

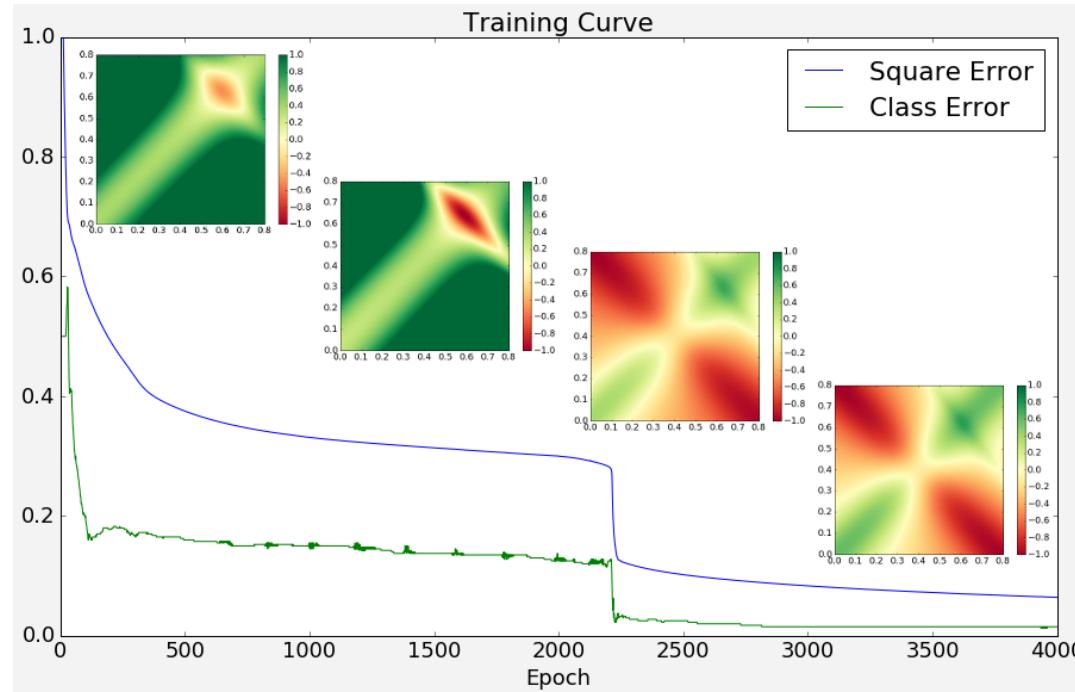


$$\vec{x}_1 = f\left(\frac{R_t * (\vec{w} \cdot \vec{x}_0 + b_p) + b_v}{R_s} + b_c\right)$$

$$\rightarrow \vec{x}_1 = f(W_0 \vec{x}_0 + B_0)$$

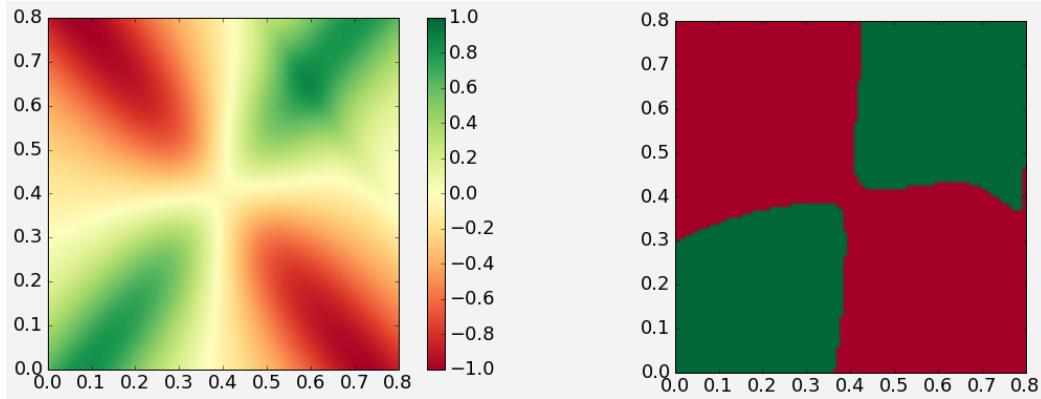
$$\vec{x}_2 = W_1 \cdot \vec{x}_1 + B_1$$

Network Training: Backpropagation

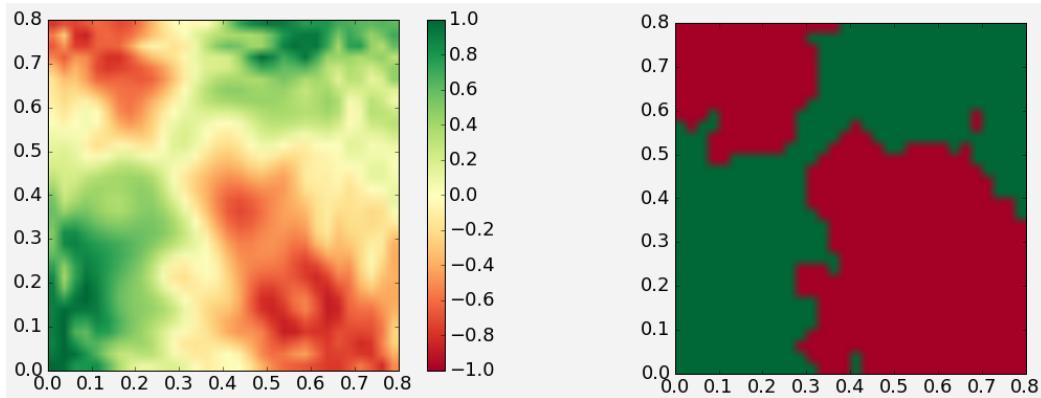


Network Training: Simulation

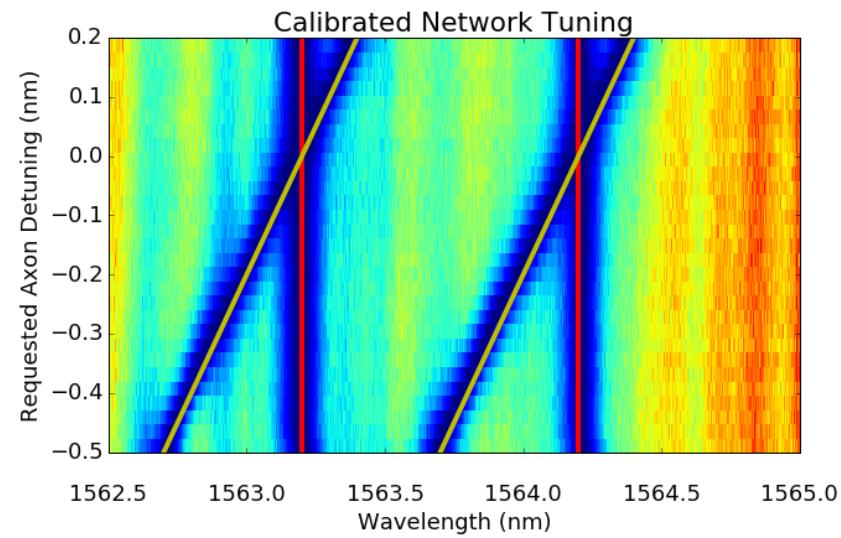
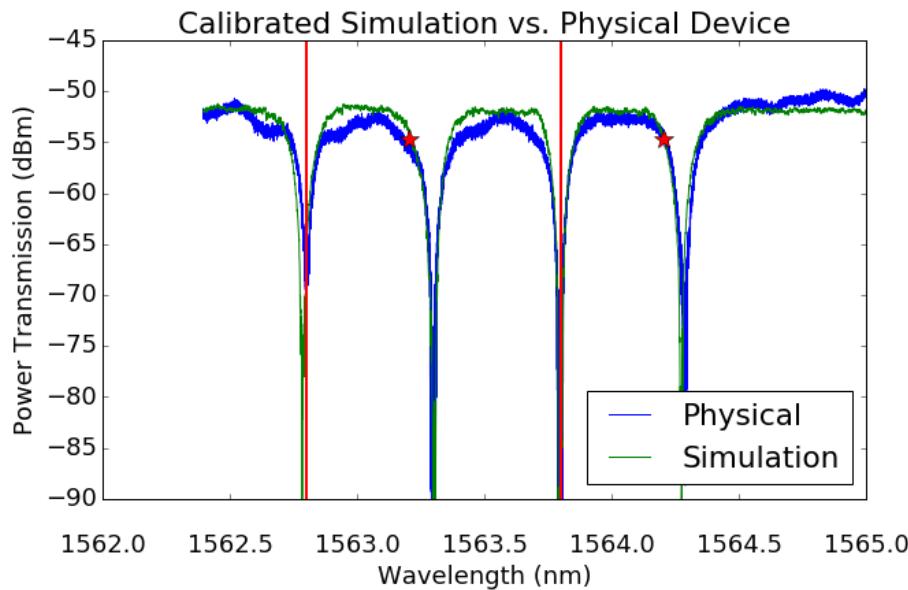
Backprop Output:



Network Simulation:

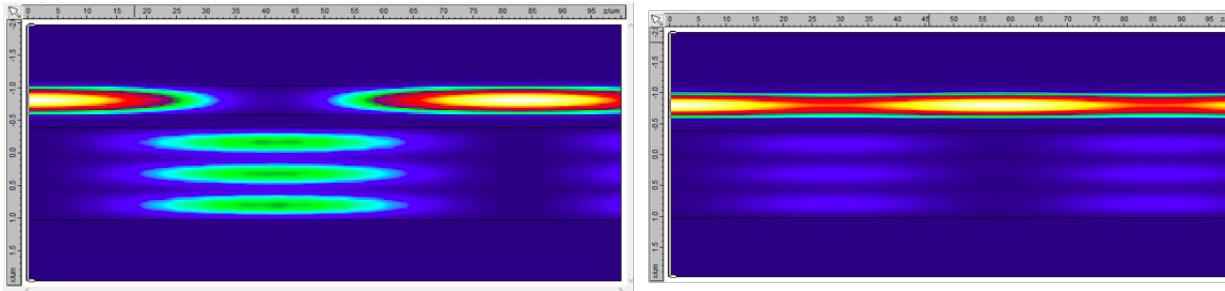
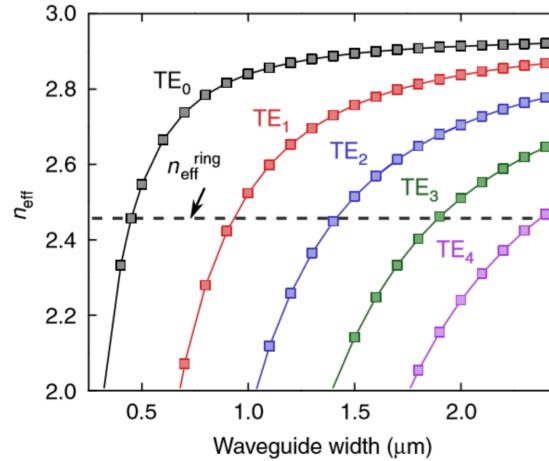


Experimental Validation: Calibration

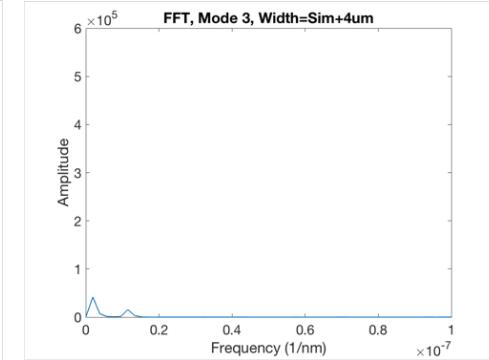
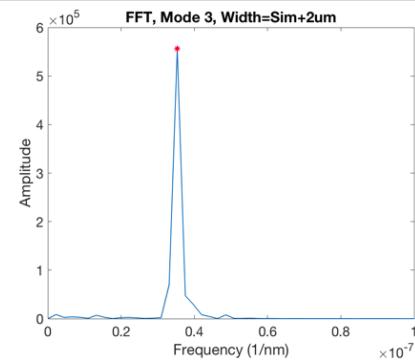
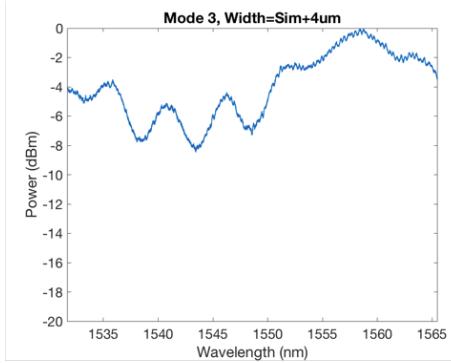
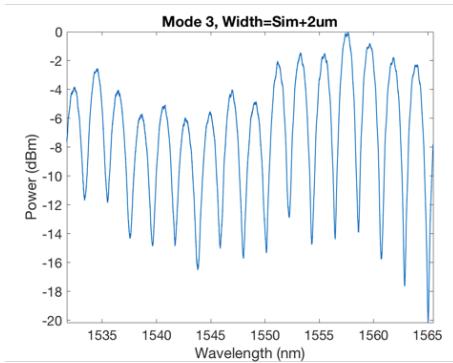
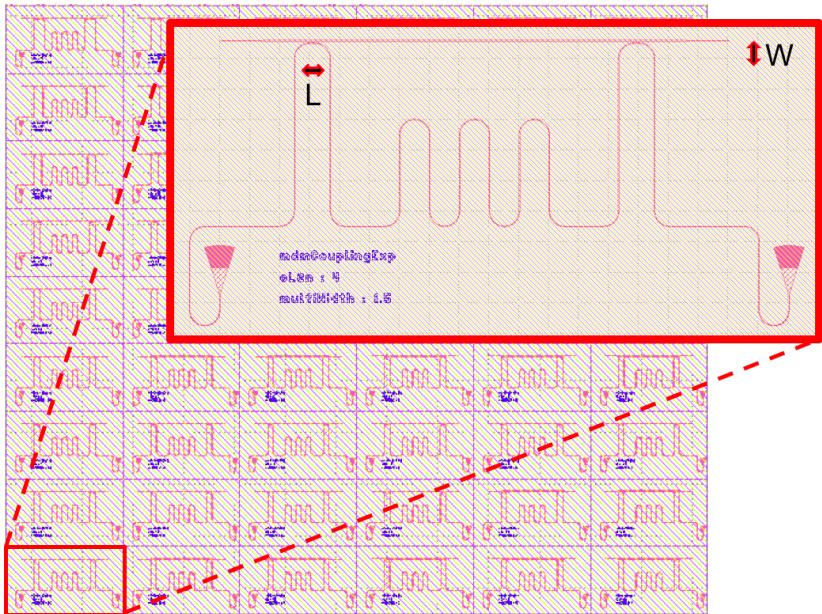


Questions?

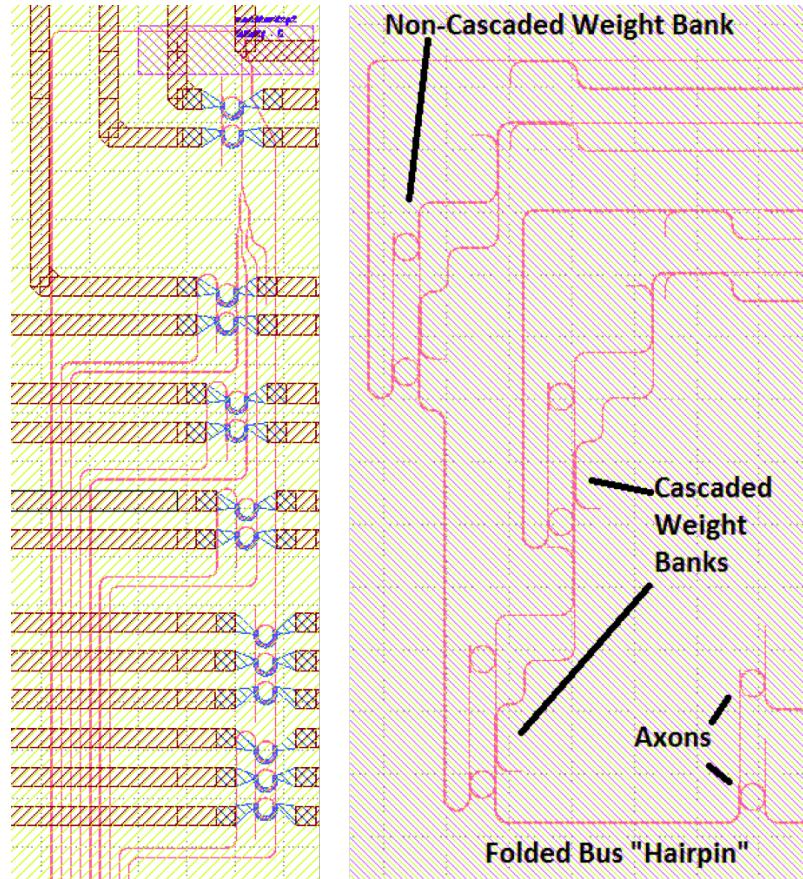
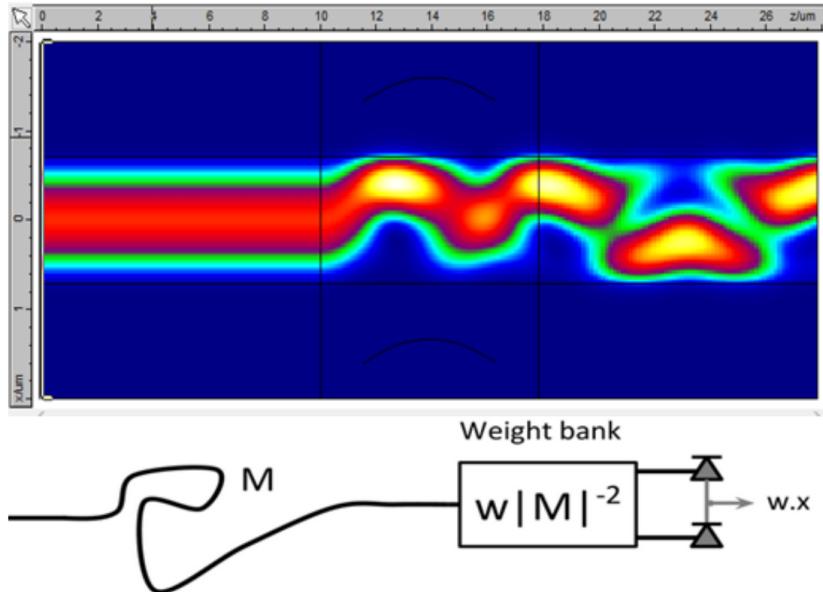
Future Work: Multi-Mode Waveguides



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Calibrated Network Tuning

Requested Axon Detuning (nm)

0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5

1562.5 1563.0 1563.5 1564.0 1564.5 1565.0

Wavelength (nm)

