UofT GDS Submission to University of Washington Microfabrication Facility

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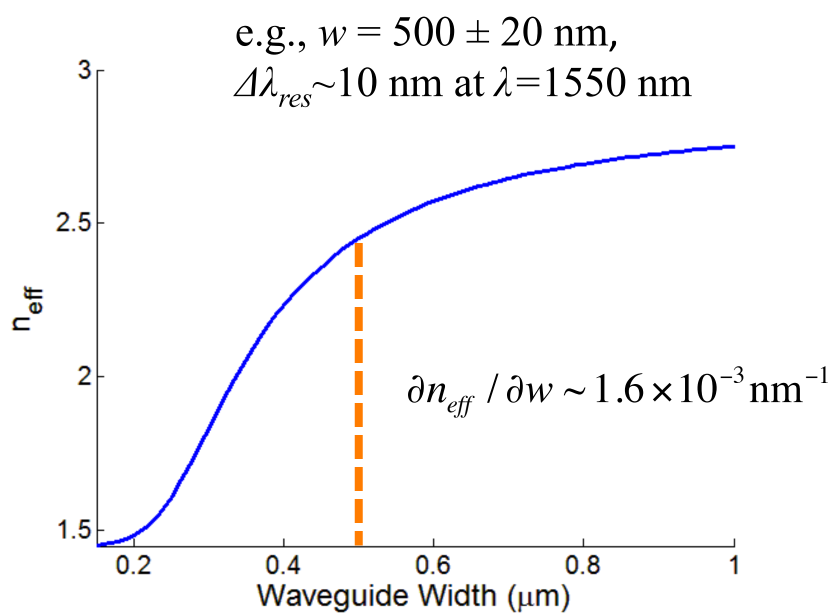
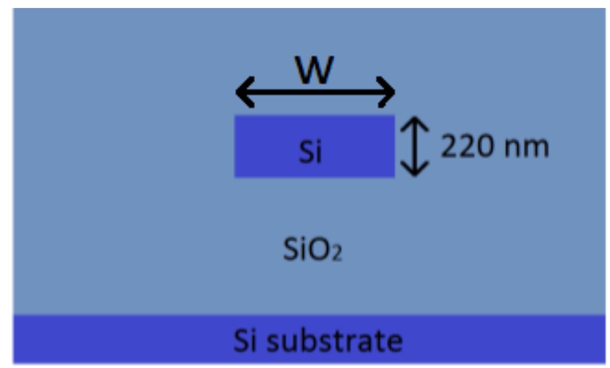
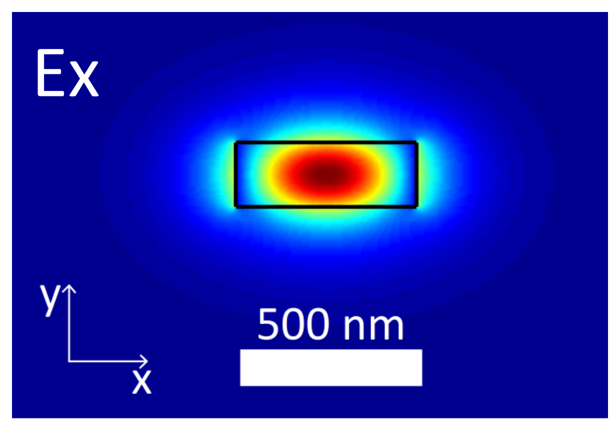
Dimensional Sensitivity in PICs

- High Index contrast for tight optical confinement and compact PICs
- **Problem:** High sensitivity to dimensional variations $\Rightarrow$ Yield? Scalability?

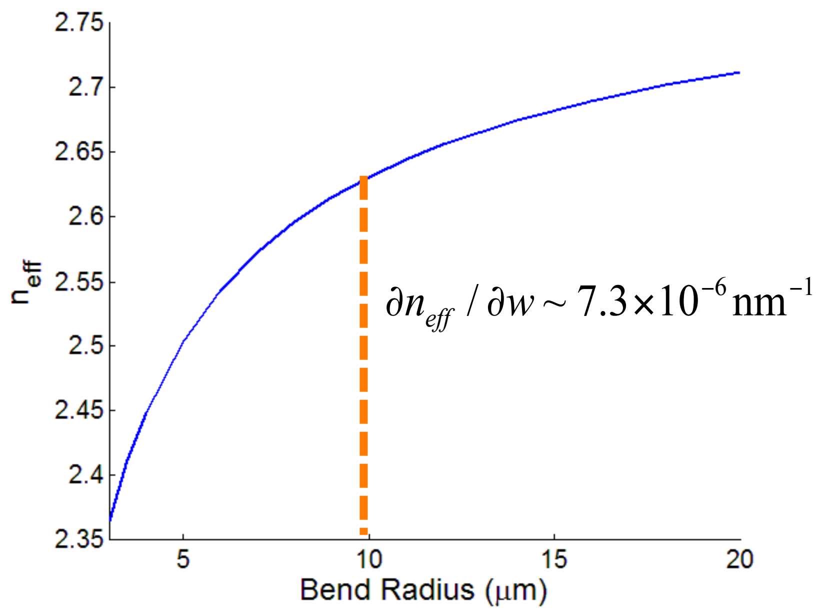


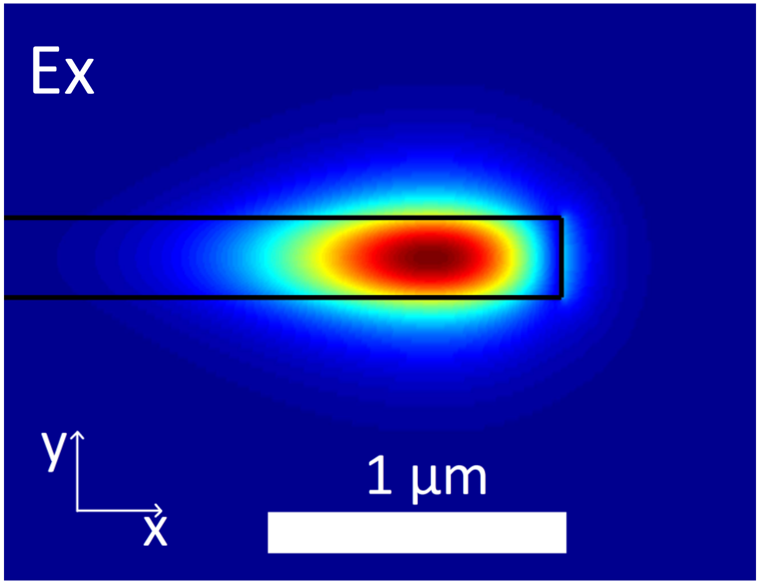




Variation-Tolerant Microrings

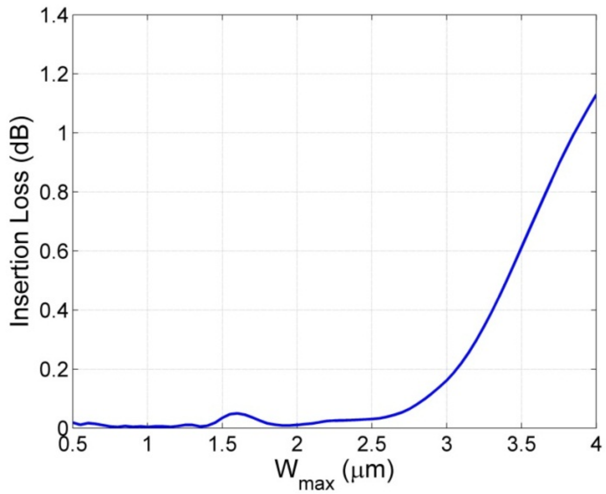
- For sufficiently wide bent waveguides, no modal interaction with inner waveguide wall $\Rightarrow$ Whispering-Gallery Mode (WGM)-like propagation
- WGMs are ~2 orders of magnitude less sensitive to width variations than strip waveguide modes

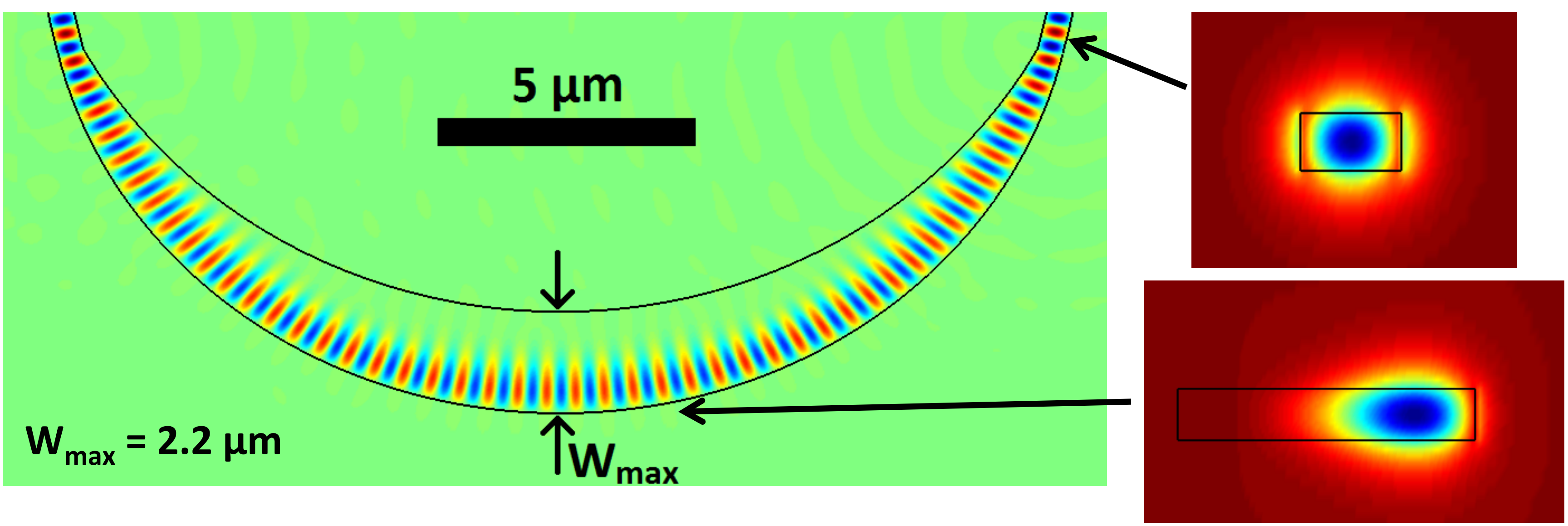




Adiabatically widened microrings

- Adiabatic mode conversion between sensitive 500 nm strip waveguide mode and variation-tolerant WGM
- Design mode converters to be short and maintain low insertion losses (<0.02 dB)

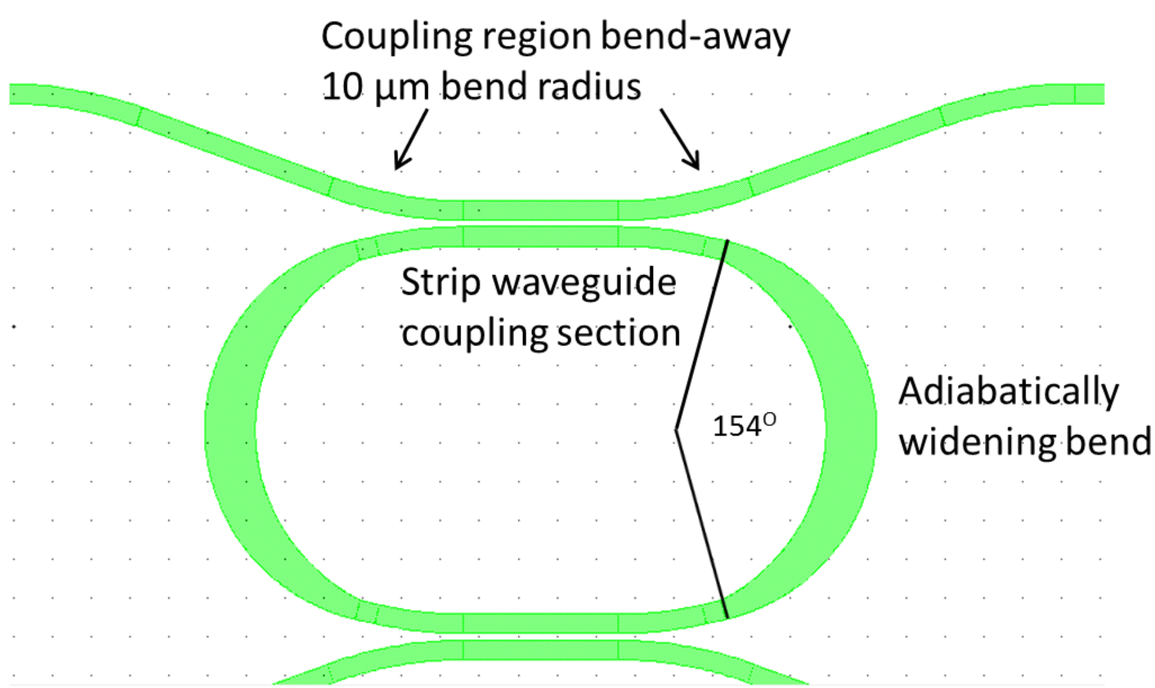




Microring Design

- Coupling region consists of parallel strip waveguides and partial circular arc bends to separate the waveguides.
- Adiabatic bends have an outer wall in the shape of a partial circular arc extending from angle θ_{start} to θ_{stop}.
- For our designs $|\theta_{stop} - \theta_{start}| = 154^o$
- Along the bend, the waveguide width *w* (measured normal to the outer wall) varies parabolically from w_{min} (the strip waveguide width) to w_{max}:

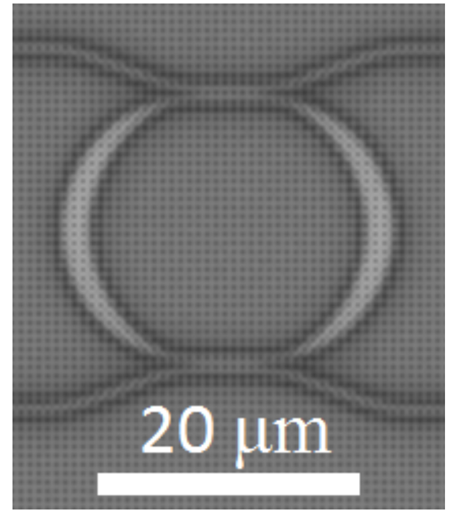
$$w(\theta) = w_{max} - 4\frac{w_{max} - w_{min}}{(\theta_{stop} - \theta_{start})^2}\left(\theta - 0.5*(\theta_{start} + \theta_{stop})\right)^2$$



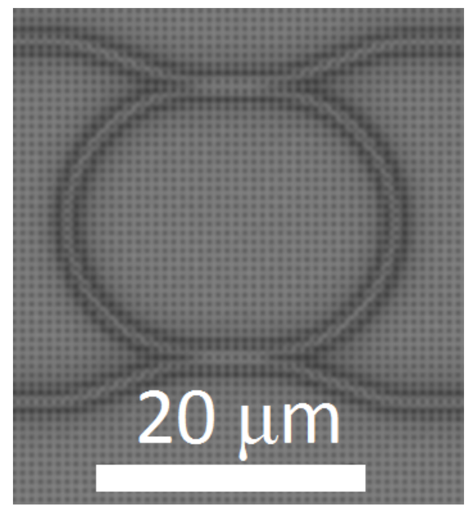
Microring Design

- Two sets of adiabatically widened rings **AR1** and **AR2** fabricated alongside matching sets of standard microrings without widened bends **BR1** and **BR2**

Device family	Adiabatic bend outer wall radius (µm)	W_{max} (µm)
AR1	5	1.3
BR1	5	0.5
AR2	10	2.2
BR2	10	0.5



Microring from AR2 family

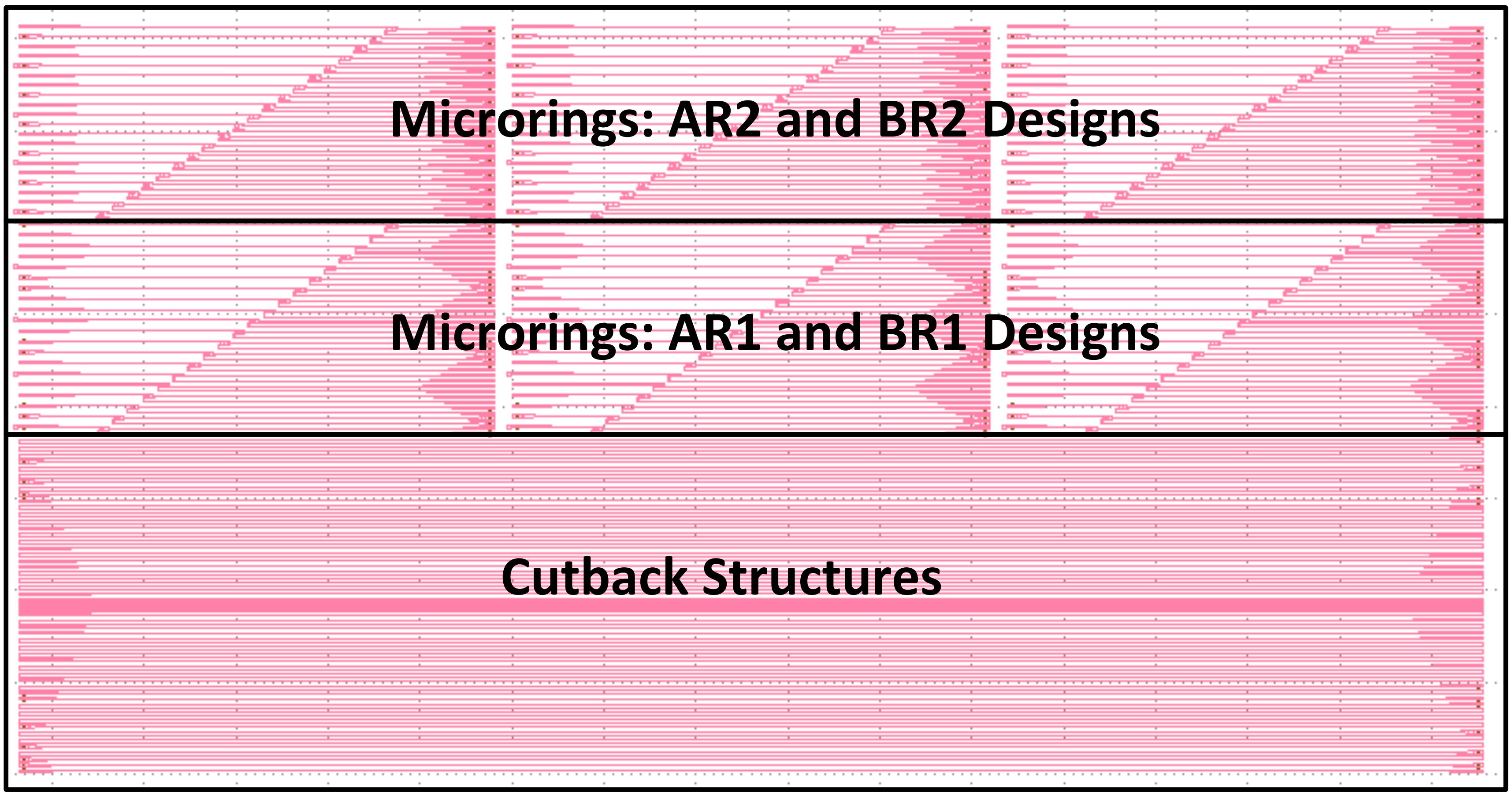


Microring from BR2 family

GDS Organization (Bottom Half)

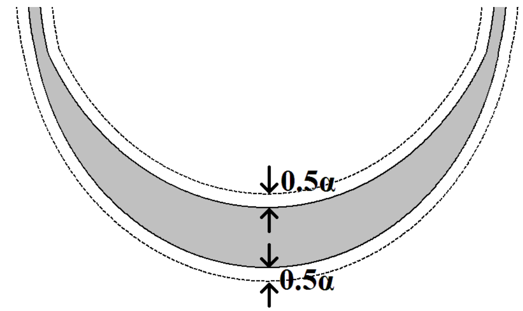
- Parameter sweeps for microring designs:

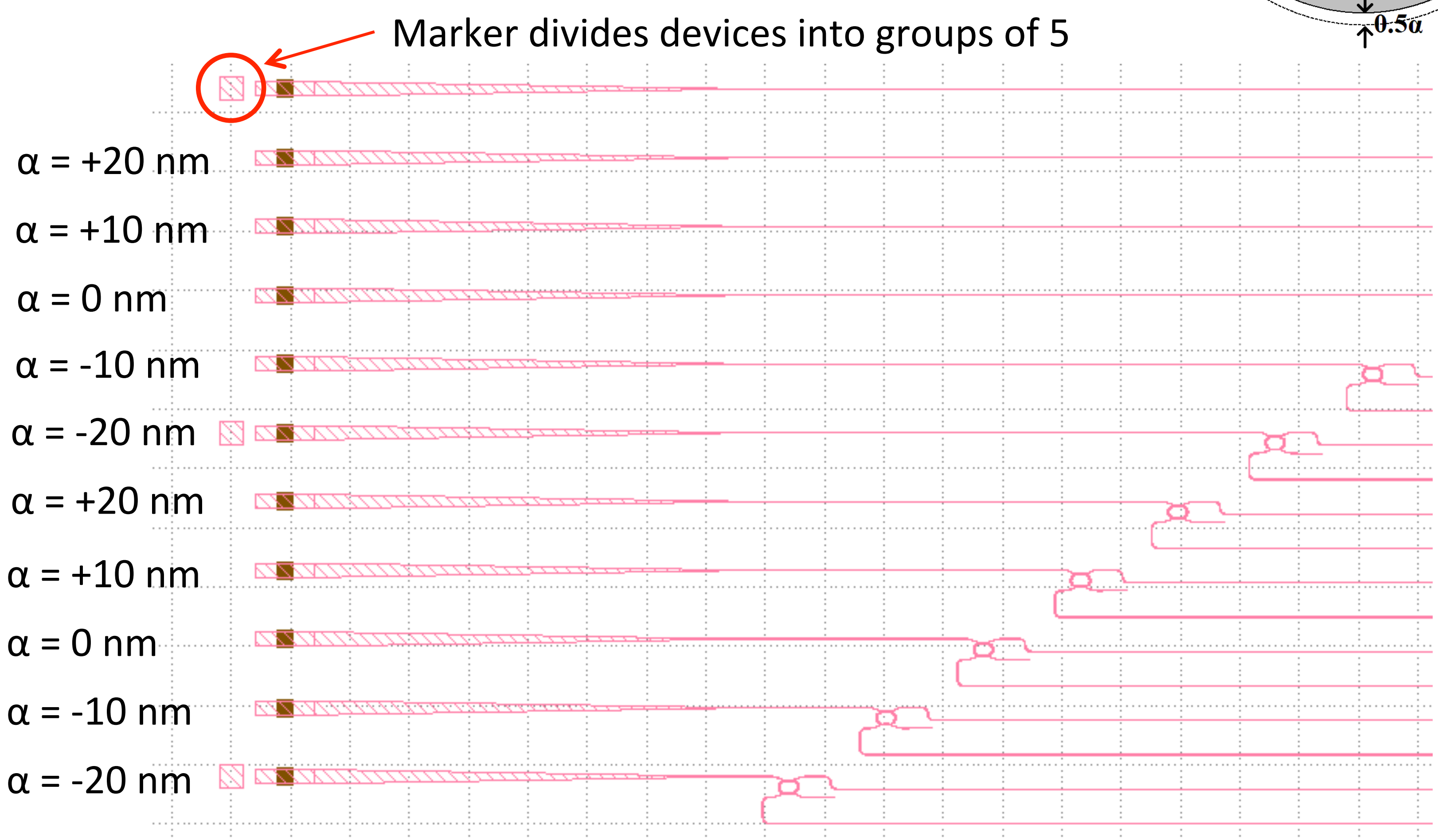
{coupling gap: 180nm,200nm} X {coupling length: 4µm, 6µm, 8µm} X{width offset: -20nm,-10nm,0nm,+10nm,+20nm}



GDS Organization

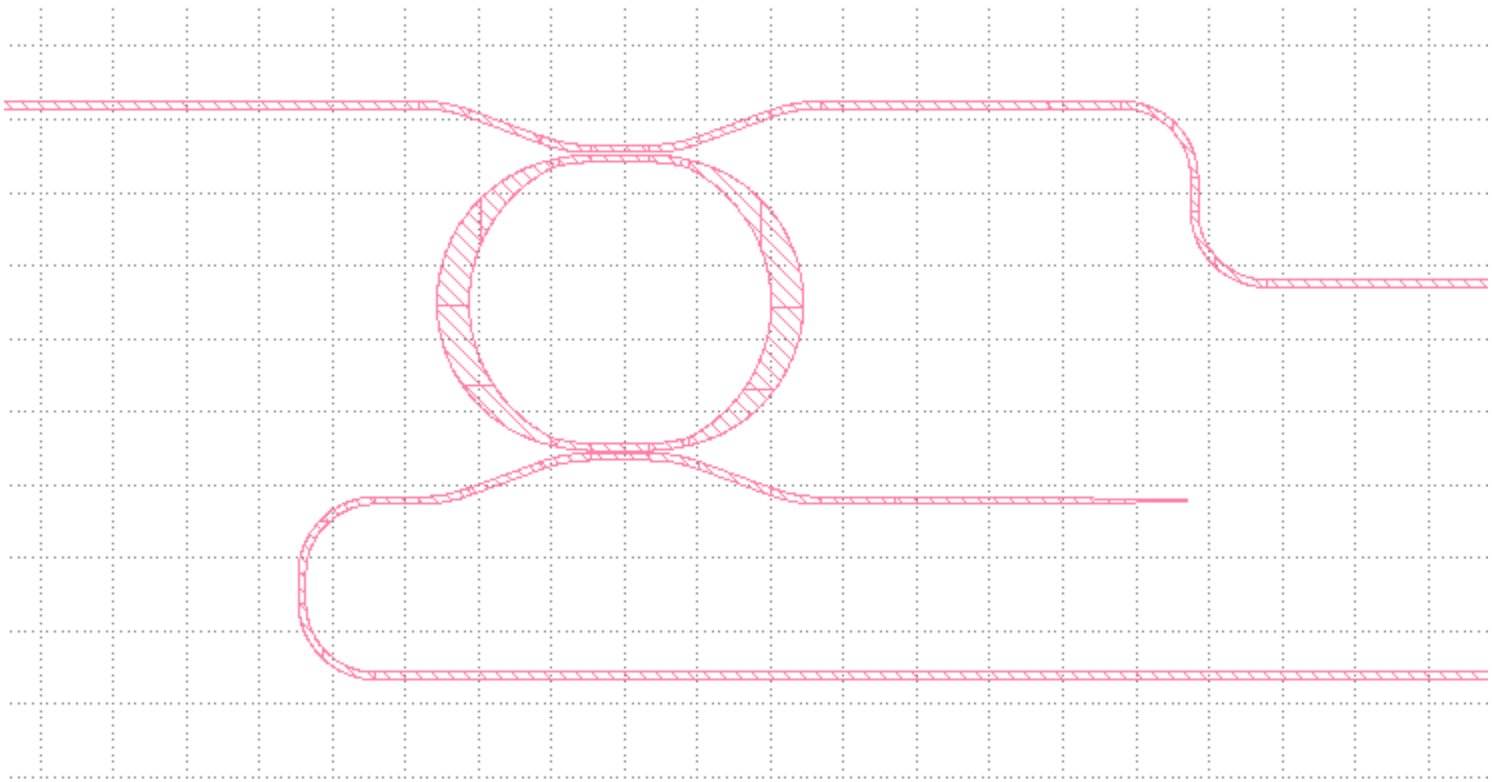
- Uniform width offset α is incorporated into designs at mask level





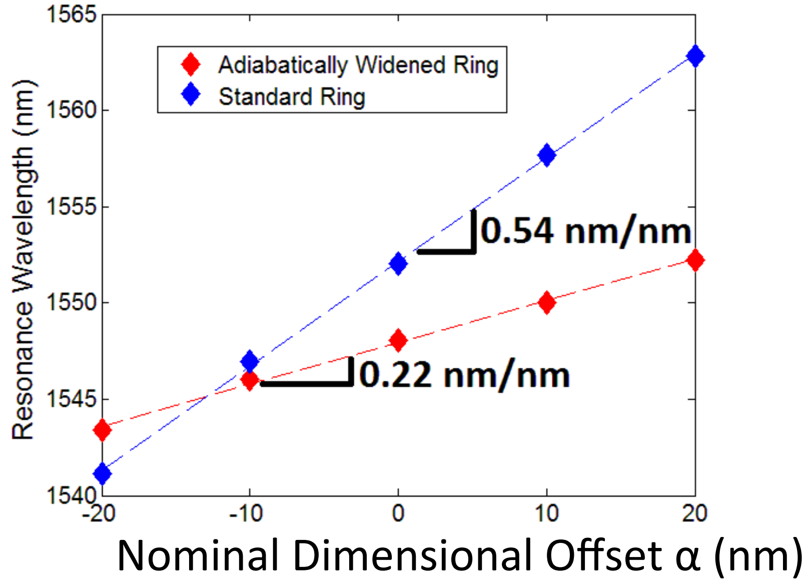
GDS Organization

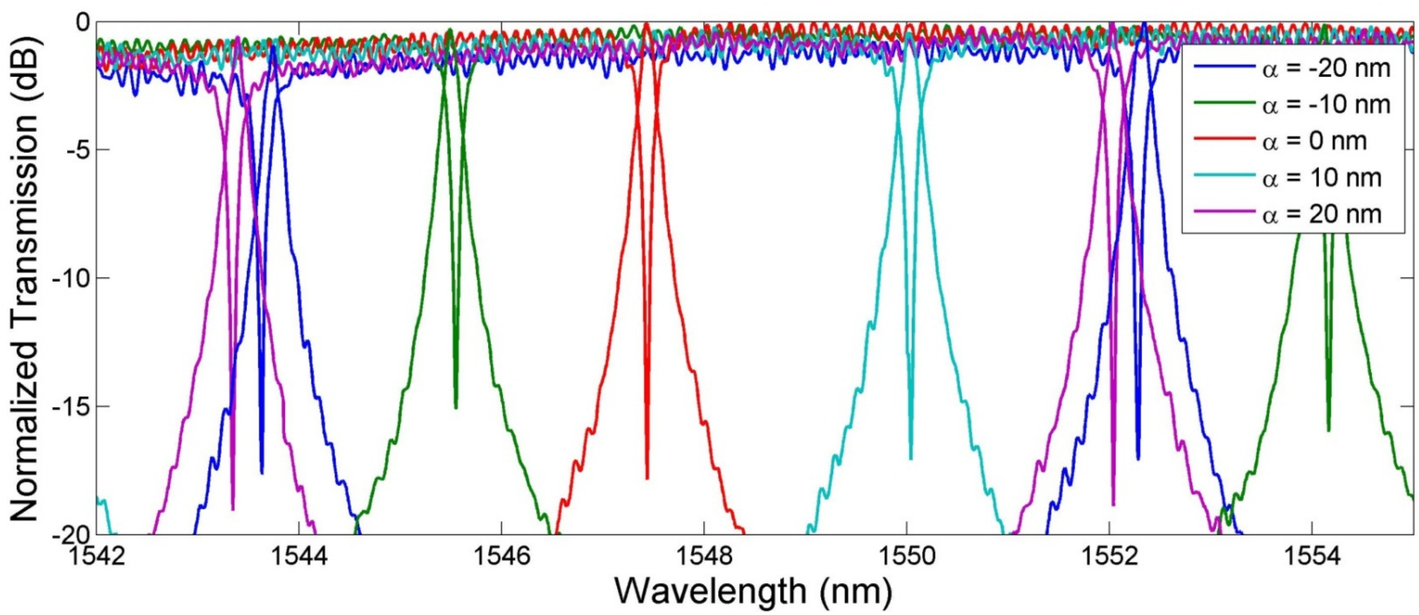
- Best results for family of larger microrings (AR2)



Microring Design

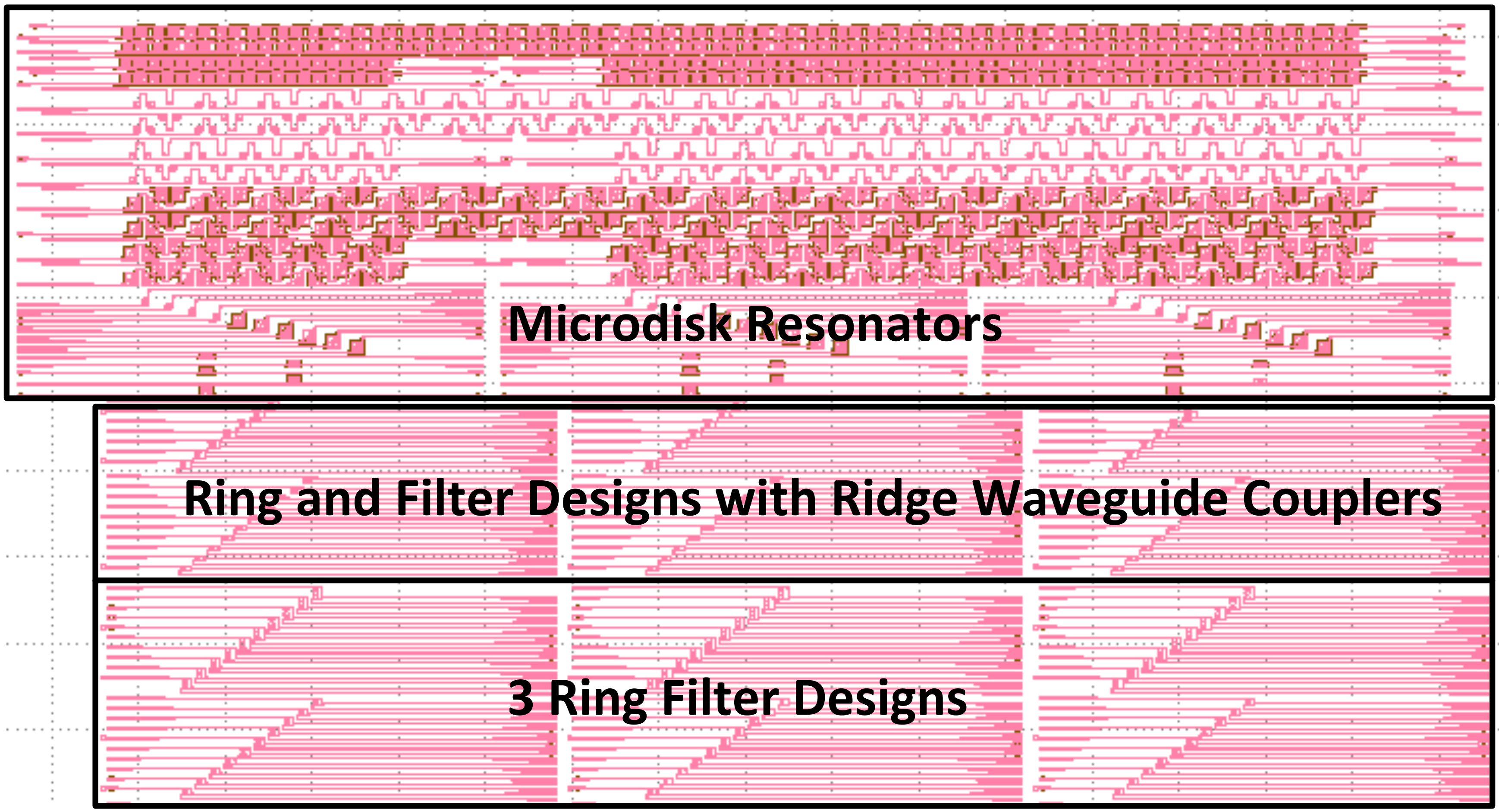
- Published results are for the AR2 and BR2 sets of devices
- 2.5x reduction in sensitivity of resonance wavelength



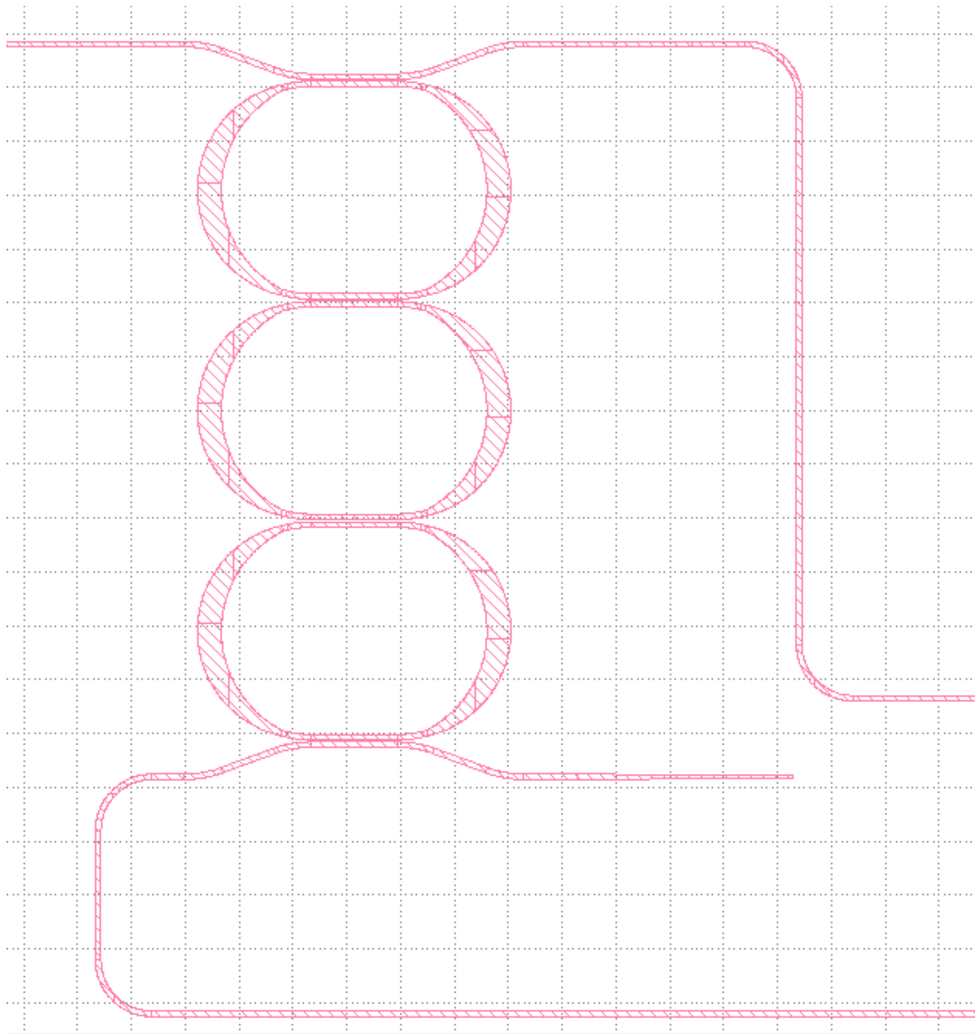


Other Devices on GDS

- Top half of GDS contains devices that we did not publish



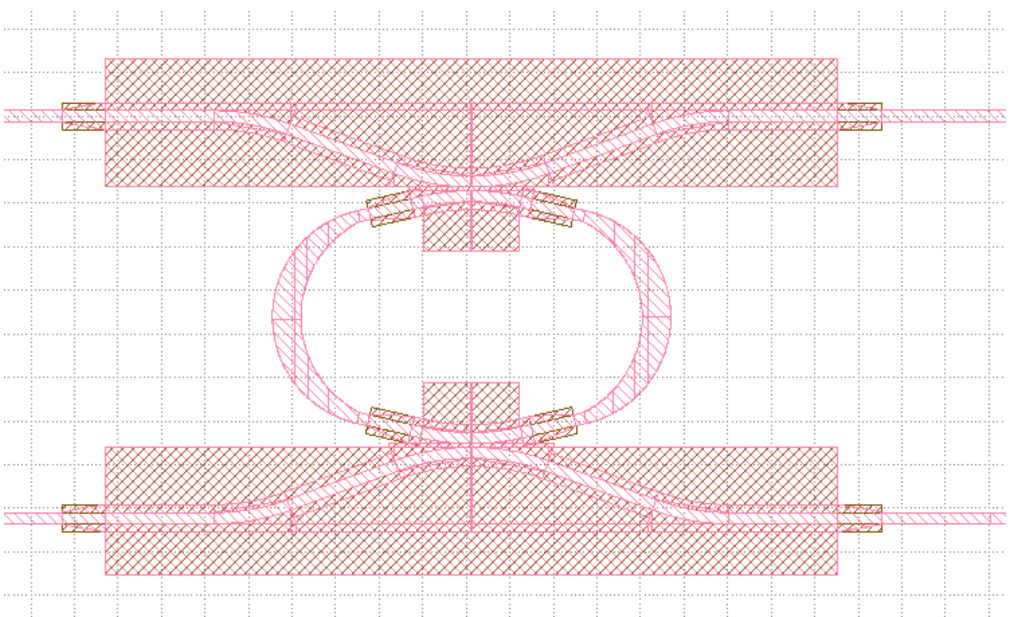
3 Ring Filter Designs

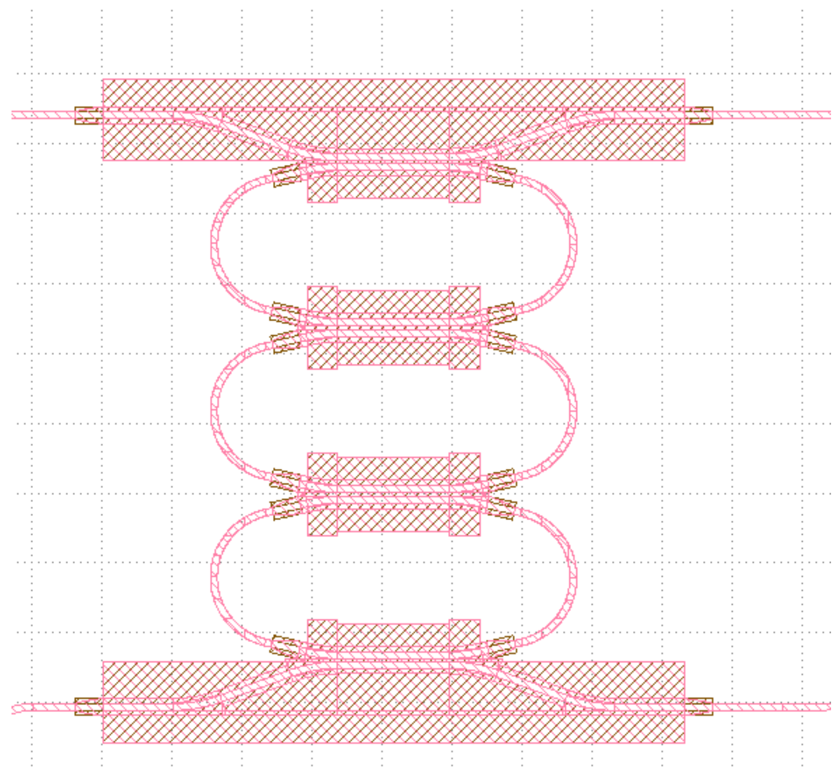


Ring and Filters with Ridge Waveguide Couplers

- We explored incorporating ridge waveguide couplers into microrings for further improvement to variation tolerance:

"J. Mikkelsen, W. Sacher, and J. Poon, "Dimensional variation tolerant silicon-on-insulator directional couplers," Opt. Express 22, 3145-3150 (2014)"





Microdisk Resonators

- We explored “pulley-coupled” microdisk resonators for single-mode excitation:

E. Shah Hosseini, S. Yegnanarayanan, A. Atabaki, M. Soltani, and A. Adibi, "Systematic design and fabrication of high-Q single-mode pulley-coupled planar silicon nitride microdisk resonators at visible wavelengths," Opt. Express 18, 2127-2136 (2010)