

filtering operation can be optimized for one specific mode, both modes, or no mode at all. For example, in a MDM system using this ring resonator at $1.549\ \mu\text{m}$, both modes are coupled to the drop port. This is a unique quality of the ring resonator in a MDM system, as the number of modal channels that are filtered can be designed for by adjusting the radius of the ring or the operating wavelength. The number of applications for the filter grow further when considering an active ring resonator design, such as those demonstrated in the past [7,8]. Channel selective switching then becomes possible simply by adjusting the refractive index of the ring. As well, the switching would be in no way limited to a single channel at a time. Furthermore, the two-mode ring can be extended to support additional modes for MDM systems with larger channel numbers. There are no theoretical limits to the number of modes a MDM system can support, however practical limitations such as large waveguide widths leading to weak coupling for the fundamental mode will likely limit this kind of system to 5-10 modes. Matching the values of κ for many modes would add to the design challenge, however similar Q values may not be essential for every application, which would increase the level of freedom one has in the ring resonator design.

6. Conclusion

We have successfully demonstrated a two-mode division multiplexing ring resonator. From our results we conclude that each mode resonates independent of the other within the ring. Optimization of the ring parameters was performed so that similar responses were observed for each mode. We have compared two variations of the asymmetric directional coupler for use as the multiplexer and demultiplexer for the device. In the fabricated device a tapered design was employed as it demonstrated a resilience to fabrication errors. The interface between straight and bent waveguide sections was identified as a potential source of crosstalk in the design. Simulations and experiments both showed that the introduction of Bezier curves in the ring bends could mitigate the crosstalk. The signal-to-crosstalk ratio in the ring stayed above 18 dB for both modes at the through and drop ports. We conclude that the ring resonator is an excellent channel selective filter for mode-division multiplexing (MDM) systems. Switching is also possible using rings by integrating refractive index tuning in the device.

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