



Optical Filter and Laser Applications using Micro Ring Resonators

Dominik G. Rabus and Michael Hamacher

rabus@hhi.de, hamacher@hhi.de

Heinrich-Hertz-Institut fuer Nachrichtentechnik Berlin GmbH

Einsteinufer 37

10587 Berlin

Germany

Abstract

The characteristic response of single and double multimode interference (MMI) coupled GaInAsP/InP microring resonators in the form of racetracks with a radius of 100 μm and 200 μm and a free spectral range (FSR) of 100 GHz and 50 GHz, respectively, is presented.

1 Introduction

Active and passive ring resonator devices are suited for wavelength filtering, routing, switching, modulation, and multiplexing / demultiplexing applications. Wavelength filters require a high channel contrast, steep roll-off and a rectangular filter shape is also desirable. Ring resonators do not require facets or gratings for optical feedback and are thus particularly suited for monolithic integration with other components, in addition they are rather robust with respect to back reflections. Devices in the AlGaAs/GaAs, Si-SiO₂ and GaInAsP/InP material system have already been reported in the past. The structures under investigation in this paper are shown in Fig. 1.

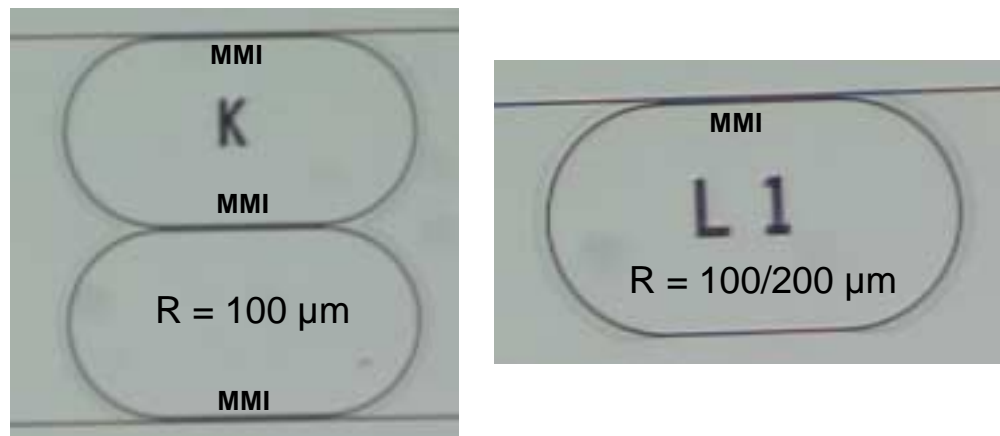


Figure 1. Single and double ring resonators with MMI couplers.

2 Design

The layer sequence of the device is as follows: InP substrate, GaInAsP ($\lambda_{\text{gap}}=1.06 \mu\text{m}$, 0.38 μm), InP etch stop layer (0.020 μm), GaInAsP ($\lambda_{\text{gap}}=1.06 \mu\text{m}$, 0.84 μm), InP cap (0.2 μm). The design assures both, a monomodal propagation of the light in the waveguide and, due to a good confinement, very low bending losses. The structure and the mode profile of the straight waveguide, which is calculated using BPM, is shown in Fig. 2.

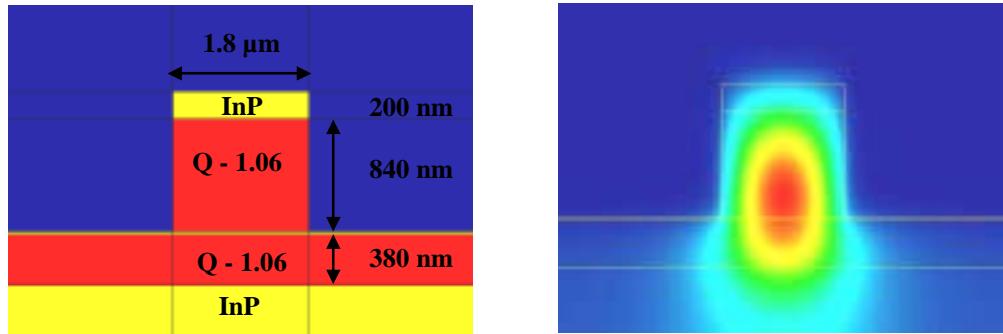


Figure 2. Structure and mode profile of the waveguide.

Additionally, the waveguide was etched down on the outer side of the waveguide in the curvatures. The width of the waveguide is 1.8 μm . The structure of the waveguide in the curved region and the mode profile for a radius of 100 μm are shown in Fig. 3.

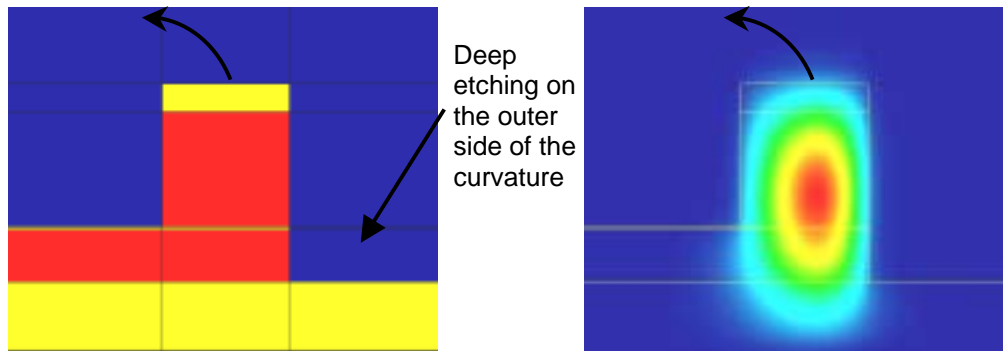


Figure 3. Structure and mode profile of the waveguide in the curved sections.

In order to couple light into the resonator multimode interference (MMI) couplers are used. Multimode interference couplers are well known and are widely used in photonic integrated circuits. In the ring resonators we use them as power splitters with a ratio of 50:50 (3 dB). The coupler has two input and two output ports. The splitting ratio is mainly defined by the length of the MMI. Fig. 4 shows the intensity at the two output ports as a function of the length. The dashed line corresponds to output port 1 and the solid line corresponds to output port 2. At a length of approximately 160 μm the two curves meet and have an intensity of 0.5 each.

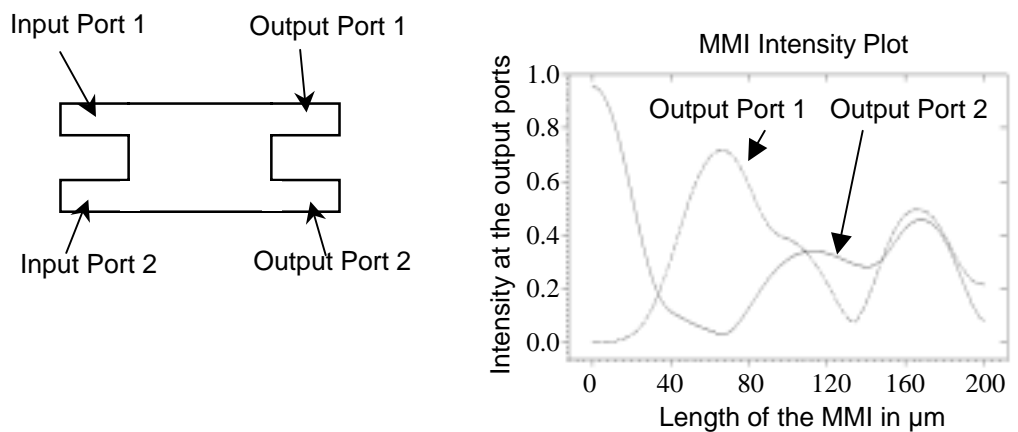


Figure 4. The multimode interference coupler.

3 Fabrication

The ring resonators were structured using standard photolithography and a CH_4/H_2 reactive ion etching (RIE) technique. SiN_x was used as etching mask, which also served as the mask for the deep etching process. In order to reduce the formation of polymers during dry etching and so to minimize the sidewall roughness a small fraction of oxygen was added.

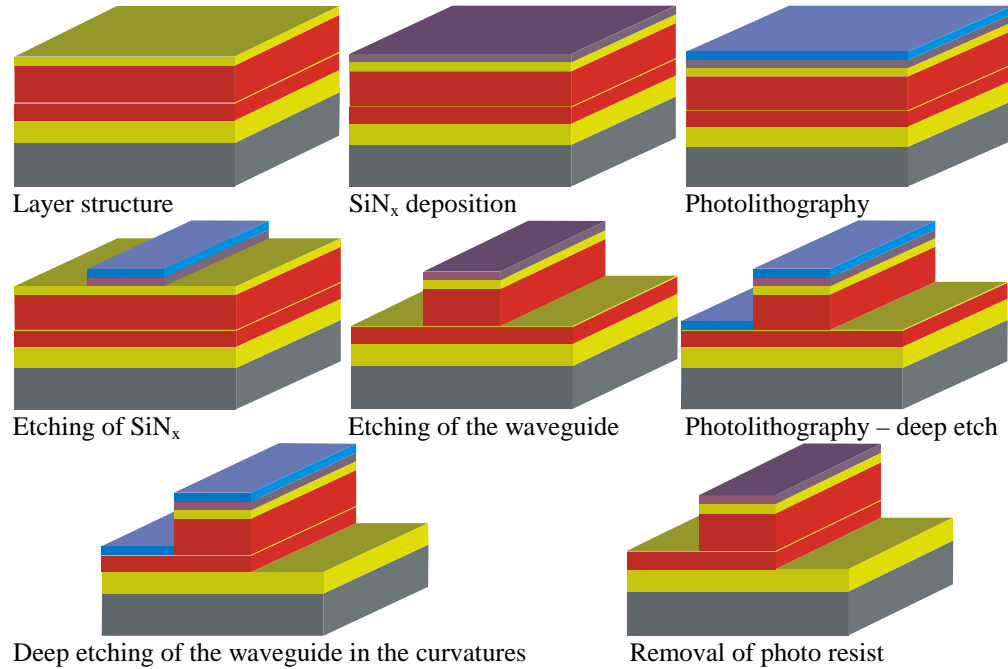


Figure 5. The fabrication process.

The facets of the input and output waveguides have been antireflection coated in order to avoid Fabry-Perot resonances in the straight waveguide section.

4 Measurement and simulation

The ring resonators were characterized using a tapered fiber and an external cavity laser. The ring resonators under investigation here are polarization dependent due to waveguide asymmetry. This is of no relevance, if the ring resonators comprise an active section and act as a laser. Polarization dependent filter characteristics can be eliminated by a polarization diversity architecture, which has already been developed in the past [6, 7]. The measurements (Fig. 6) reported here have been performed for TE polarization. As designed, a FSR of approximately 0.8 nm (100 GHz) for the 100 μm ring devices and 0.4 nm (50 GHz) for the 200 μm devices are observed near $\lambda = 1.55 \mu\text{m}$. The insertion losses of the devices are between 7-8 dB (including coupling losses of approximately 5 dB). The transmission difference between the minima and the off-resonant values for the single micro ring resonators with $R = 100 \mu\text{m}$ and $R = 200 \mu\text{m}$ is more than 13 dB. The FWHM (full width at half maximum) was observed to be approximately 0.14 nm and 0.08 nm, respectively. The single ring resonators are suitable for laser applications due to the small FWHM. For optical filters, multiple, cascaded ring resonators have to be used. The contrast of the throughput port and of the drop port of the double micro ring resonator with $R=100 \mu\text{m}$ are around 3.5 dB and 7.5 dB, respectively. The expected broadening of the FWHM for the throughput port was measured to be 0.25 nm and that of the drop port 0.4 nm. The low contrast is in agreement with theoretical calculations [5], and it can be improved considerably by the implementation of gain sections. These gain sections offer the additional benefit to enable loss less devices.

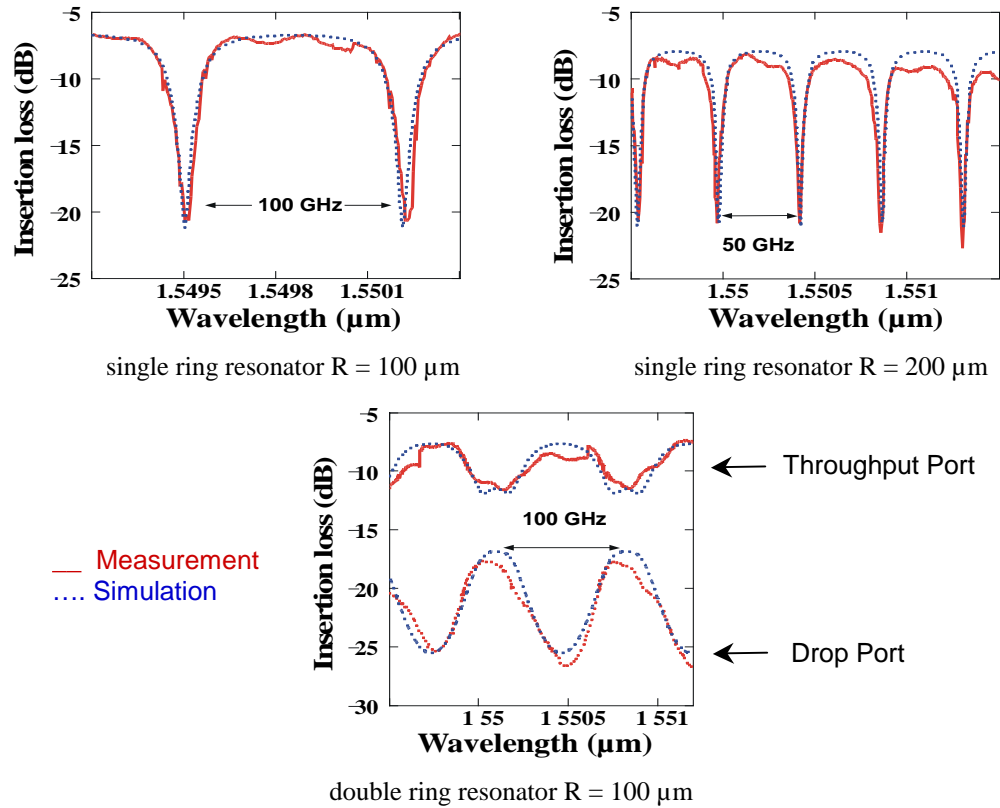


Figure 6. The results for the measured and simulated ring resonators.

5 Conclusions

In conclusion, passive single and double MMI coupled ring resonators with a free spectral range of 50 GHz and 100 GHz were fabricated and characterized. The simulated results coincide very well with experimental values. In order to achieve high channel contrast, steep roll-off and a rectangular filter shape, gain sections will have to be implemented in a next step. We believe that ring resonators will become an important component family.

References

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