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Design Considerations for Spatial Monomode Operation of InP-based Passive Vertically Coupled Microring Resonators

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Outline

- ④ Motivation
- ④ Introducing microring resonators
 - Vertical coupling scheme – motivation and benefits
 - Requirement for monomode operation
- ④ Design Scheme
 - ④ Rational of the scheme
 - ④ Design maps
- ④ Proposed Structure
- ④ Results
- ④ Discussion and Conclusions





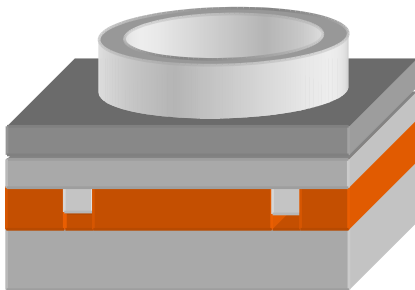
WAPITI - Objectives



WAPITI's Aims

- Development of μ ring cavity devices of compact footprint with high performance and novel functionalities
- Implementation using InGaAsP/InP – GaAs active/passive waferbonding technology

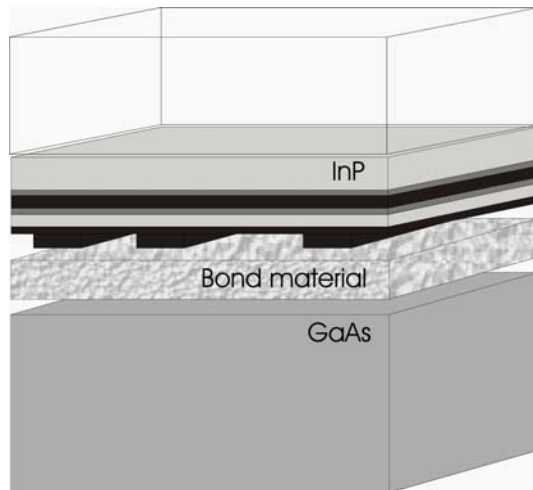
Ring Laser Features



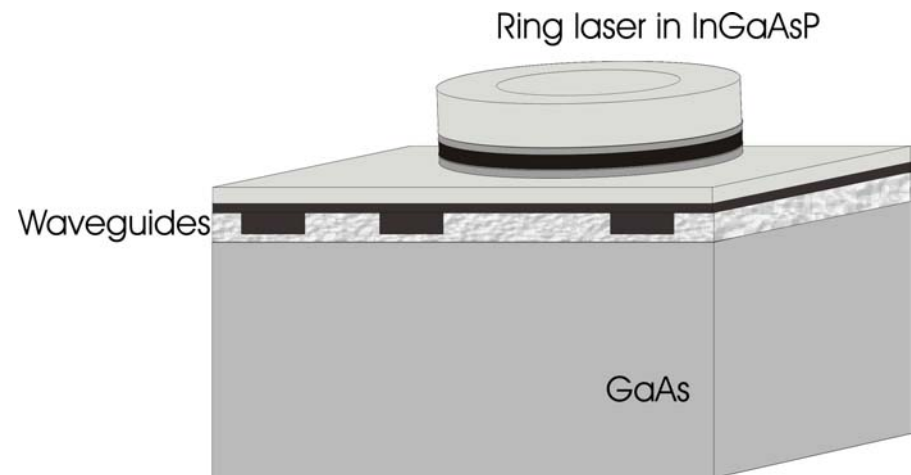
- Material composition and pattern of the passive and active waveguides can be optimised independently
 - Optical I/O ports in passive waveguide layer
 - Vertically coupled to active waveguide layer via **compact couplers of few 10 μ m length**
 - Accurate coupling strength control due to layer thickness tolerances with epitaxial growth accuracy



Waferbonding of ring resonator components



Wafer bonding of GaInAsP layer stack on GaAs



Nanofabricated vertically coupled compact ring resonator devices

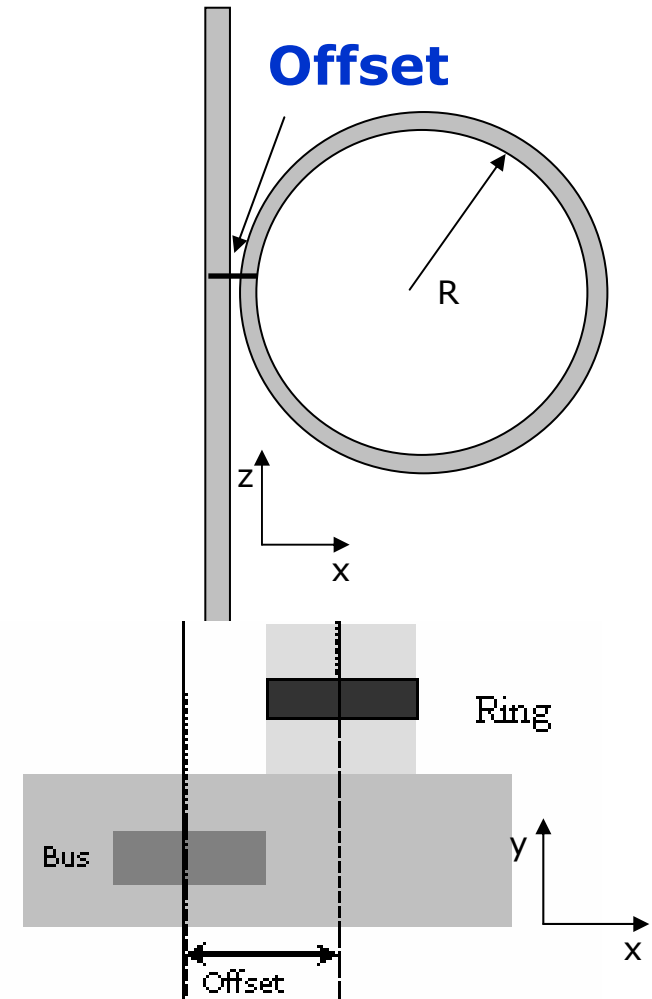
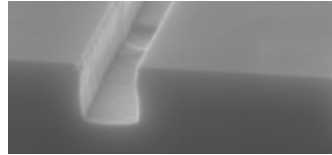


Microring resonators

- ④ Microring resonators ideal for integration
- ④ Versatility demonstrated (lasers, filters, wavelength converters, logic gates)

Passive/active integration:

- ④ Lateral coupling
 - ④ bus and ring waveguides on the same wafer level
 - ④ Restrictive in design
 - ④ Additional growth steps for active/passive coupling
- ④ Vertical coupling
 - ④ Ring placed on top of the bus waveguide - wafer bonding
 - ④ Tailoring of the characteristics of the two separately
 - ④ Advantages for active/passive coupling
- ④ Need for monomode operation.
 - ④ Higher order modes radiate and contribute to losses.
 - ④ A monomode device is more predictable.



Design scheme: Rational for suppressing higher order modes

- ➞ Maximum of coupling between modes with same propagation constant
- ➞ Straight/bent waveguide coupler: we propose selective excitation of the fundamental mode of the ring
- ➞ By tailoring the material and geometrical properties of the bus and ring waveguides the effective indices n_{eff} can be leveled
- ➞ Facilitated by the vertical geometry



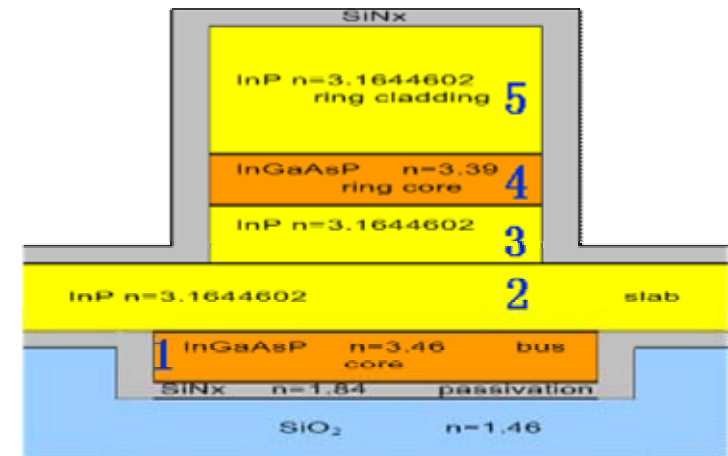
Passive Devices: Proposed Structure

TABLE 1
DETAILS OF THE STRUCTURE

Layer	Description	Height (μm)	Width (μm)	n
1	Bus	0.35	defined in table 2	3.46
2	InP slab & coupling	0.35	100	3.16
3	InP ring rib	0.35	1.8	3.16
4	Ring	0.17	1.8	3.39
5	InP ring rib	1.5	1.8	3.16

TABLE 2
LIST OF STRUCTURES USED IN THE SIMULATION

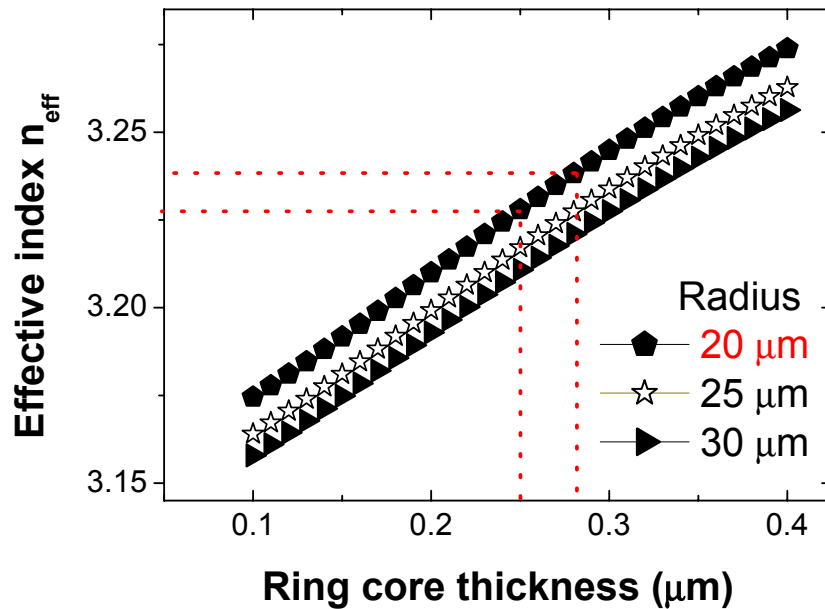
Structure	Bus		Ring		Radius (μm)
	Width (μm)	Width (μm)	height (μm)	height (μm)	
1	2	1.8	0.25	0.25	20
2	3	1.8	0.28	0.28	20



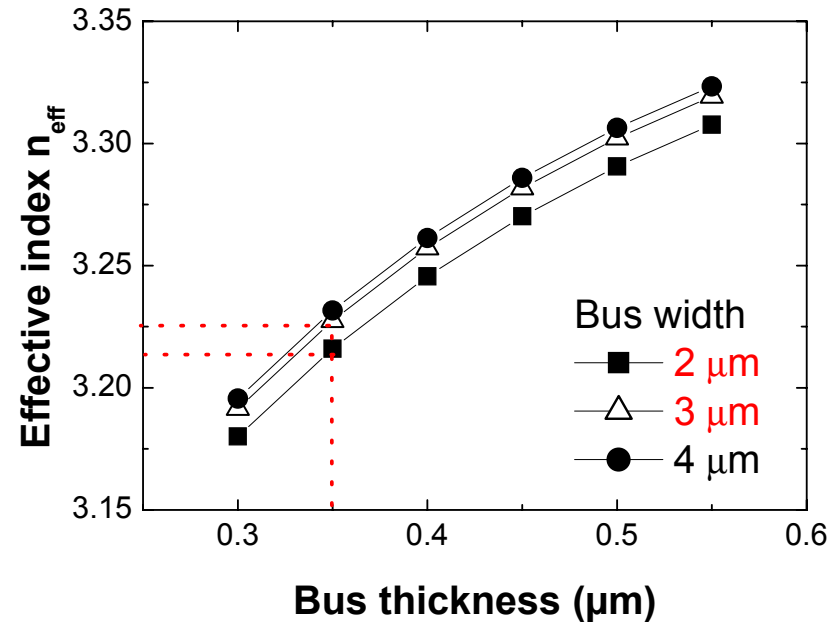
- ⊗ The values of ring core thickness and bus width are chosen from the design maps
- ⊗ For these values the n_{eff} of the ring and bus is approximately the same



Design maps



TE fundamental mode
Ring waveguide width: 1.8 μm

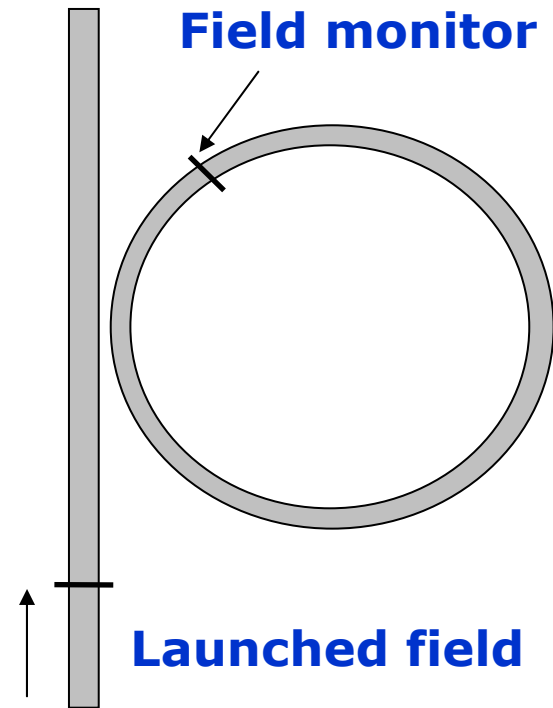


TE fundamental mode



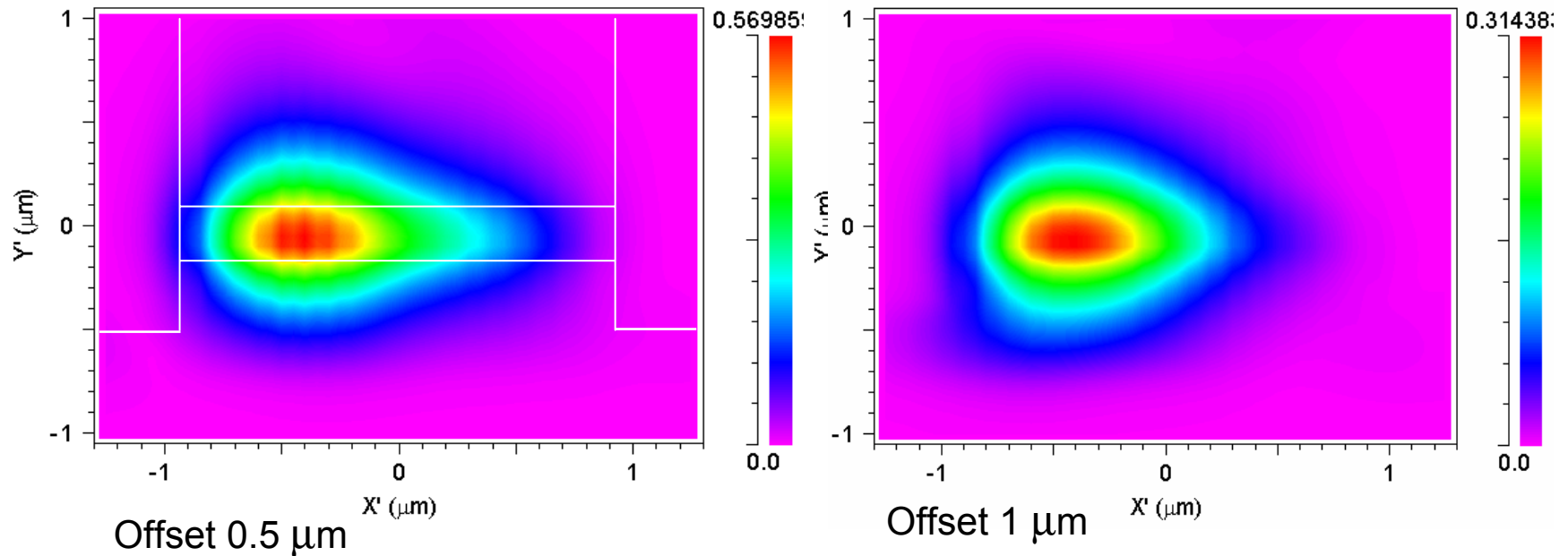
Results – simulation details

- ☞ Simulation performed using FULLWAVE, RSOFTEs FDTD simulation package
- ☞ Field launched in fundamental mode (TE polarization at wavelength $\lambda=1.55\mu\text{m}$) of the bus and then collected in the ring
- ☞ Discretisation of grid is set to $\lambda_{\text{eff}}/10$
- ☞ Calculation performed for **two offsets**, changes intentionally or unintentionally perturb modal properties of structure
- ☞ Wider bus study is motivated by need to relax fabrication uncertainties
- ☞ Bus waveguides will be multimode - use of taper structure to restore monomodal operation



Results – Structure 1

$R = 20 \mu\text{m}$



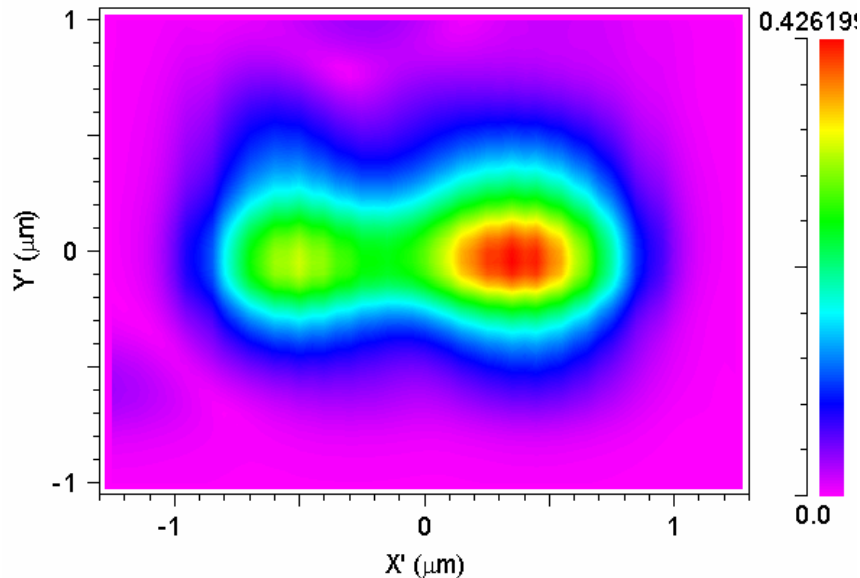
Bus width 2.0 μm
Ring width 1.8 μm
Ring core: 0.25 μm

- Field maximum of mode shifts towards outer surface of ring which is typical for ring geometry
- Monomode operation for both offsets

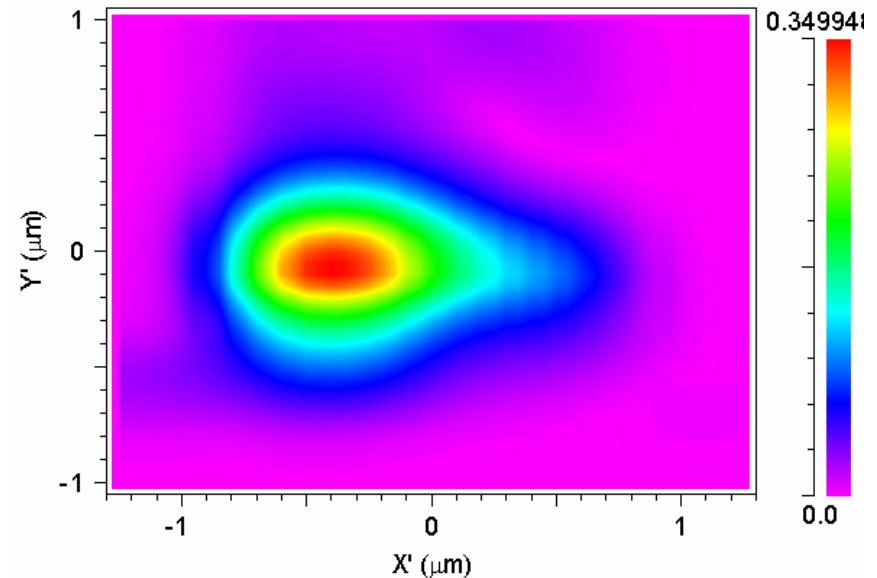


Results – Structure 2

$R = 20 \mu\text{m}$



Offset $0.5 \mu\text{m}$



Offset $1 \mu\text{m}$

Bus width $3.0 \mu\text{m}$
Ring width $1.8 \mu\text{m}$
Ring core: $0.28 \mu\text{m}$

- ☞ Monomode operation for $1 \mu\text{m}$ offset
- ☞ Excitation of higher order modes for $0.5 \mu\text{m}$ offset



Features

- ④ Simple design strategy: efficient for high offset values
- ④ Small offset values and relatively wide waveguide dimensions result in multimode operation
- ④ Offset: additional degree of freedom for coupler design
- ④ Proposed scheme of selective excitation of the ring fundamental mode



Conclusions

Vertical coupling

- ☞ flexibility in tailoring the properties of the waveguides independently from one another ☺
- ☞ Waferbonding – novel fabrication technology with potential of innovative small footprint devices, but also challenges



First realised couplers

