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ABSTRACT

We summarize the results of a European Project entitled **WAPITI** (**W**aferbonding and **A**ctive **P**assive **I**ntegration **T**echnology and **I**mplementation) dealing with the fabrication and investigation of active/passive vertically coupled ring resonators, wafer bonded on GaAs, and based on full wafer technology. The concept allows for the integration of an active ring laser vertically coupled to a transparent bus waveguide. All necessary layers are grown in a single epitaxial run so that the critical coupling gap can be precisely controlled with the high degree of accuracy of epitaxial growth.

One key challenge of the project was to establish a reliable wafer bonding technique using BCB as an intermediate layer. In intensive tests we investigated and quantified the effect of unavoidable shrinkage of the BCB on the overall device performance. Results on cw-operation, low threshold currents of about 8 mA, high side-mode suppression ratios in the range of 40 dB and large signal modulation bandwidths of up to 5 GHz for a radius of 40 µm shows the viability of the integration process.

Keywords: InP, photonic integration, vertical coupler, wafer bonding, ring laser

1. INTRODUCTION

Photonic Integration is considered a key technology for providing low cost reliable devices suitable for large scale integration. Typically photonic integrated circuits comprise standard basic building blocks such as lasers, waveguides and detectors.

Microring waveguide resonators are expected to take over a crucial role in the future large scale monolithic integration of photonic integrated circuits as they do not require either cleaving to form edge mirrors nor integrated Bragg gratings. For resonant devices, filter quality and power enhancement are sensitive to resonator losses. A strong optical confinement in higher index contrast waveguides allows the design of compact devices, however, limited by increased scattering losses due to waveguide roughness. While other material systems like Silicon-On-Insulator (SOI) or SiON are particularly suitable for the cost effective fabrication of passive ring resonators, GaAs or InP offer the advantage of optical amplification for loss compensation. Microring resonators are particularly suited for the monolithic integration with other components forming compact integrated devices.

Especially active ring resonators are becoming more and more attractive since they can be used as wavelength division (de)multiplexers, single- or multi wavelength light sources, filters, sensors, or wavelength converters. Here, miniaturization is not only a prerequisite for low costs but also to assure high bit-rate capability due to the photonic lifetime in the resonator. This demand necessitates the realization of rings with small diameters in the range of several tens of micrometers but also requires ultra small couplers with well controlled coupling conditions.

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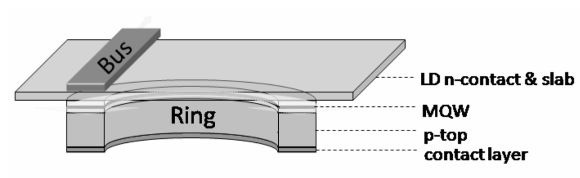
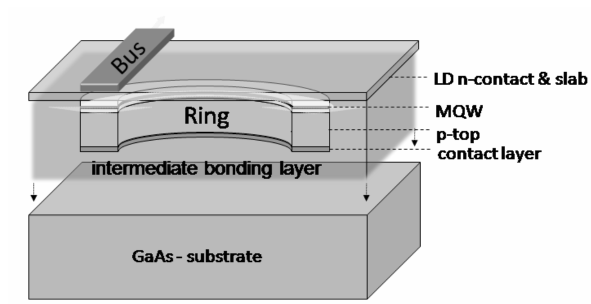
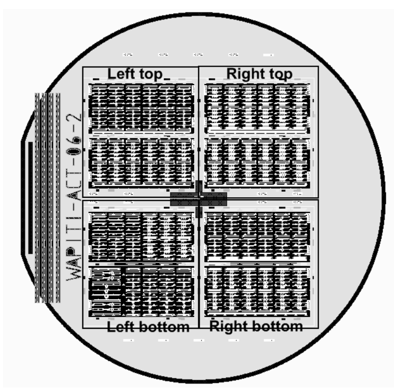
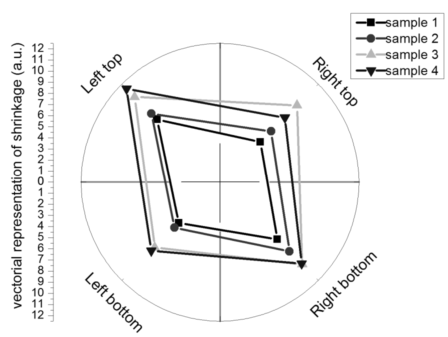
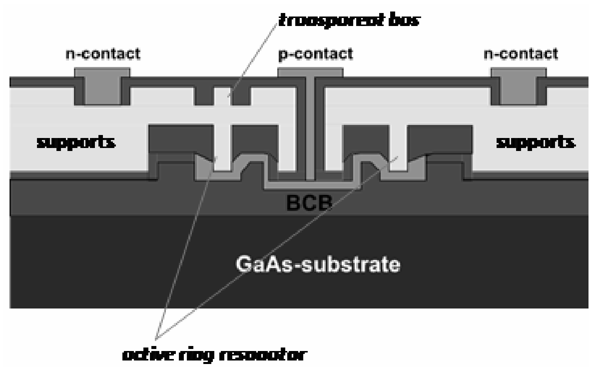

Bus
Ring
LD n-contact & slab
MQW
p-top
contact layer

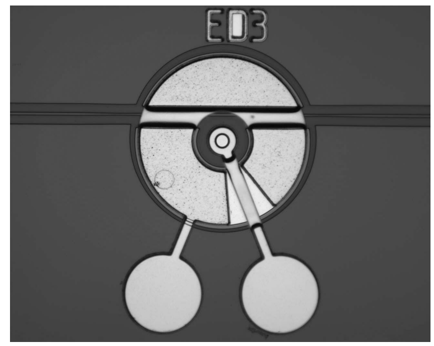

Bus
Ring
LD n-contact & slab
MQW
p-top
contact layer
intermediate bonding layer
GaAs - substrate

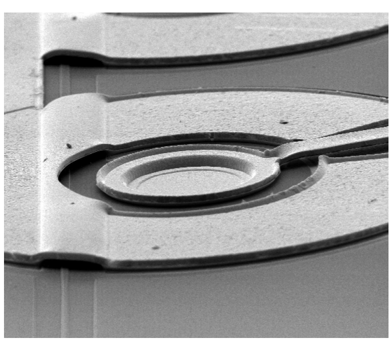
$$\sqrt{(X_1 + X_2)^2 + (Y_1 + Y_2)^2}$$

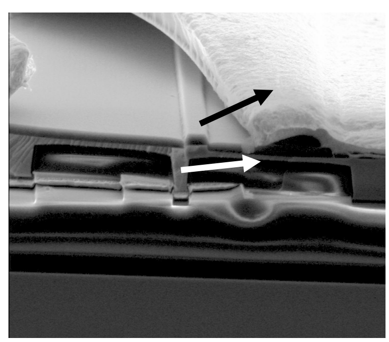


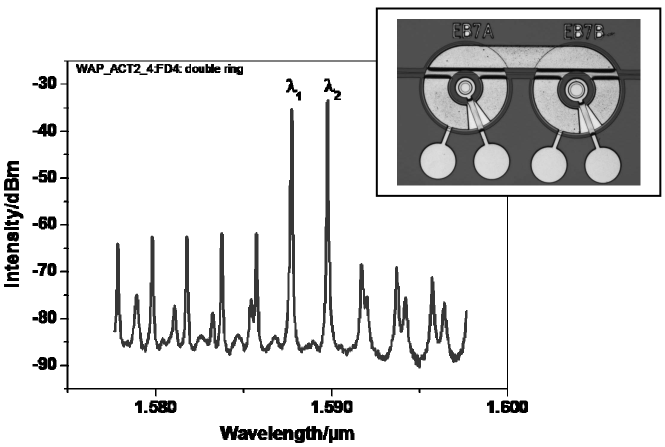


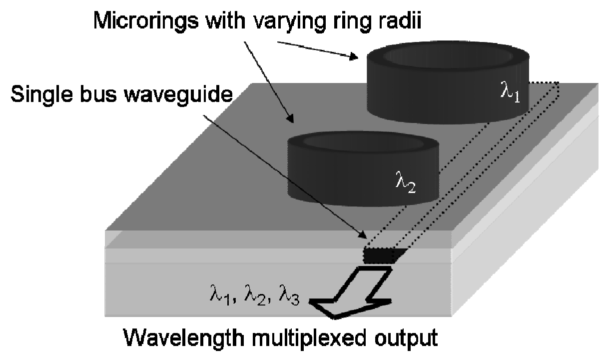

n-contact
p-contact
n-contact
supports
supports
BCB
GaAs-substrate

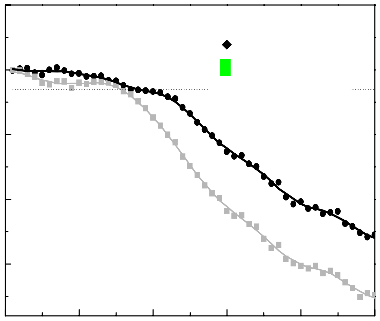

ED3

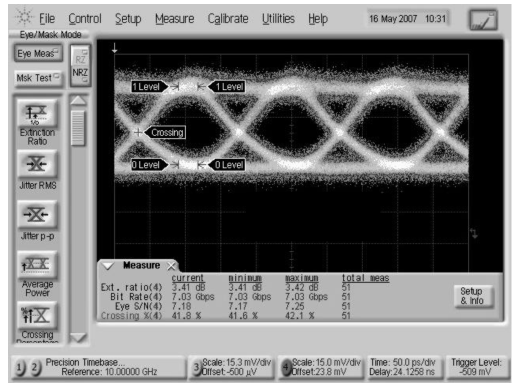




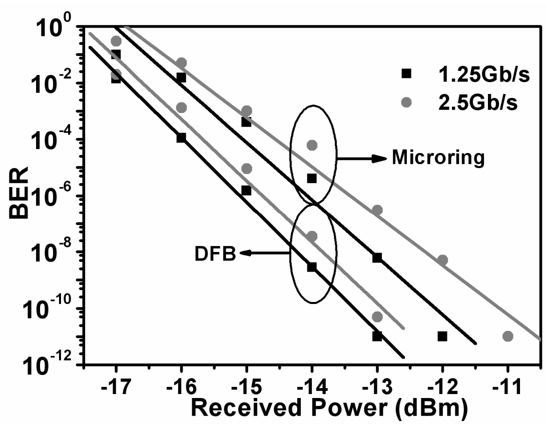

WAP_ACT2_4:FD4: double ring
λ1
λ2
EB7A
EB7B
Intensity/dBm
-30
-40
-50
-60
-70
-80
-90
1.580
1.590
1.600
Wavelength/µm


Microrings with varying ring radii
Single bus waveguide
λ1
λ2
λ1, λ2, λ3
Wavelength multiplexed output

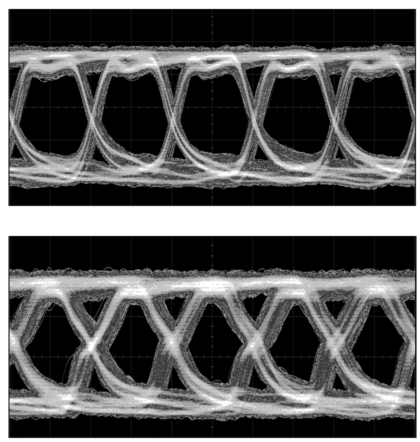




File
Control
Setup
Measure
Calibrate
Utilities
Help
16 May 2007 10:31
Eye/Mask Mode
Eye Meas
Msk Test
RZ
NRZ
Extinction Ratio
Jitter RMS
Jitter p-p
Average Power
1 Level
1 Level
Crossing
0 Level
0 Level
Measure
current
minimum
maximum
total meas
Ext. ratio(4) 3.41 dB 3.41 dB 3.42 dB 51
Bit Rate(4) 7.03 Gbps 7.03 Gbps 7.03 Gbps 51
Eye S/N(4) 7.18 7.17 7.25 51
Crossing %(4) 41.8 % 41.6 % 42.1 % 51
Setup & Info
Precision Timebase...
Reference: 10.00000 GHz
Scale: 15.3 mV/div
Offset: -500 µV
Scale: 15.0 mV/div
Offset: 23.8 mV
Time: 50.0 ps/div
Delay: 24.1258 ns
Trigger Level:
-509 mV



BER
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
1.25Gb/s
2.5Gb/s
Microring
DFB
-17
-16
-15
-14
-13
-12
-11
Received Power (dBm)



Integration Technology and Implementation/ WAPITI (FP6-IST-004073).

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