High temporal resolution of the ring down of SOI wire racetrack resonators

T.J. Karle[1], F. Raineri[1,3], F. Bordas[1], I. Sivan[1], S. Ali[1], Y. Halioua[1,2], G. Roelkens[2] and R. Raj[1]

[1]Laboratoire de Photonique et de Nanostructures, 91460 Marcoussis, France
[2]IMEC/Ghent University, St-Pietersnieuwstraat 41, 9000 Ghent, Belgium
[3]Universite Paris VII, Denis Diderot
Timothy.Karle@lpn.cnrs.fr

Summary

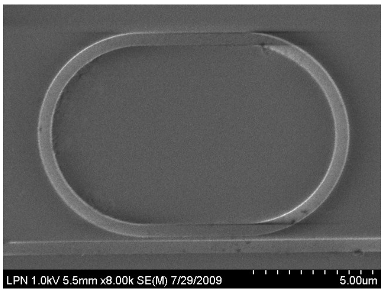
The temporal ringdown of Silicon-on-Insulator racetrack resonators is measured for input pulses of duration 150fs using a parametric amplification technique. This allows us to study the coupling between the bus waveguide and the racetrack. A cavity round trip time of 660fs and Quality Factor of 9500 are determined.

Introduction

The coupling between optical waveguides and All Pass resonator filters has been intensely studied for the promise they hold for device applications in light emission and modulation. One of the important aspects which needs to be understood and controlled is their dynamic response.

Measuring the transmission of the waveguides (for a continuous wave (CW) input), can yield directly the resonant frequencies of the racetrack and their quality factors. In the case of dynamically actuated samples such inferences are not so simple. We therefore investigate the ability of the temporally precise and background free method of optical parametric amplification, to resolve the response of the waveguide coupled racetrack resonators to femtosecond pulses, thereby gaining greater understanding of the coupling and testing our ability to follow dynamic events.

The silicon racetracks consist of wire waveguides (width 526nm) and the bus waveguide (width 536nm), sitting atop a silica cladding. The radius of the curved sections are 4µm and within the set of samples the straight waveguide section is varied between 1 and 8µm. The coupling gap between racetrack and bus waveguide is d=180nm. The silicon waveguides are tapered up to a width of 2µm. The sample is thinned and cleaved in order to allow lens end-fire investigation in free space. CW spectral studies allow us to determine the dispersion of the different resonators. The free spectral range of the resonances decreases as the size of the racetrack is increased as expected.



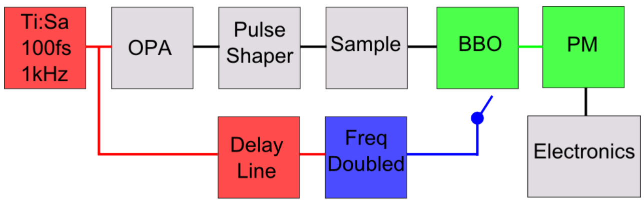


Fig 1.a) SEM image of racetrack resonators b) Block diagram of optical technique

The temporal measurements were performed by launching 150 femtosecond pulses, produced using a 1kHz Optical Parametric Amplifier, pumped at 810nm, generating tunable pulses at around 1540nm, into the silicon waveguide. The input pulses are strongly intensity filtered to avoid non-linearities in the Si such as Two-Photon Absorption and Free Carrier Absorption. The pulse propagates in the guide and is evanescently coupled to the racetrack. Once the light is coupled into the ring it is apparent that for pulses of 150fs duration the spatial extent of the pulse is shorter than the length of the racetrack.

The light coupled into the racetrack circulates for many round trips given the low losses in the high quality Si guides and low bending loss. At each passage though the coupler section, a percentage is recoupled to the bus waveguide. This gives rise to a sequence of output pulses with diminishing intensities. This sequence is coupled out from the Si waveguide to free space. The power levels of these pulse along with their short duration make direct detection and autocorrelation very challenging. We can however gate the pulses by making use of the original 810nm pump pulses.

The intense 810nm pump pulses are firstly converted to 405nm by second harmonic generation in a nonlinear crystal of BBO and then these blue pulses are combined with the output pulse sequence from the racetrack in a second BBO crystal. The interaction parametrically amplifies the pulses at the idler wavelength of 1540nm as well as generating an amplified signal pulse at 540nm. In order to obtain a background free signal we detect the latter using a photomultiplier, boxcar averaging and a lock-in amplifier. By optically delaying the blue gating pulse it is possible to track the temporal response of the pulses coming out of the waveguide-racetrack coupled system.

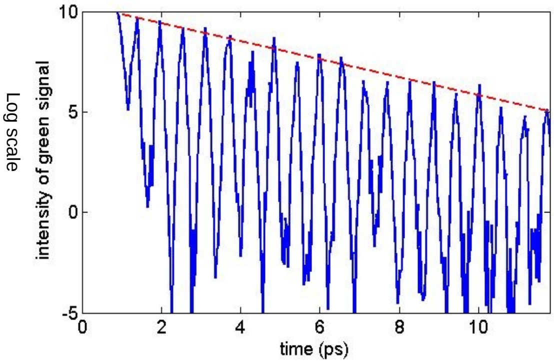


Fig 2. The intensity of the signal measured at 540nm (log scale) vs the delay time of the pump. The temporal ring-down of the racetrack shown as a sequence of diminishing peaks.

As seen above the racetrack gives rise to a train of pulses exiting the waveguide spaced by the round trip time of 660fs. We can deduce loaded cavity Q from the exponential decay of the peaks as 9500.

Conclusions

Temporal measurements have been performed on very low intensity pulses transmitted through Si wire waveguides, having interacted with a micron scale All Pass Filter. Extending the technique to look at non-linear and active devices is now in progress.

References

The SOI racetrack samples were fabricated by CEA-LETI as part of the ePIXfab platform. The authors acknowledge FP7 ICT project HISTORIC for funding.