Temporal measurements of SOI wire racetrack resonators

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Abstract—**The temporal response of Silicon-on-Insulator racetrack resonators is measured using parametric up conversion for input pulses of duration 150fs. This allows us to study the dynamics of the coupling between the bus waveguide and the racetrack. The cavities exhibit a round trip time 660fs and a Quality Factor of 9500.**

Keywords- Racetrack Resonators, SOI, Temporal Measurements

I. Introduction

Coupling between optical waveguides and racetrack resonators has been widely studied for the promise they hold for device applications in light emission and modulation. For this, one of the important aspects which needs to be understood and controlled is their dynamic response.

We first focus on the continuous wave characteristics of the system, measuring the transmission of the waveguides, which gives the resonant frequencies of the racetrack and their quality factors. We then use the extremely temporally precise and background free method of optical parametric amplification to resolve the passage of the femtosecond pulses through the waveguide coupled racetrack resonators.

II. Samples

The silicon racetracks consist of wire waveguides with a width of 526nm and the bus waveguide have a width of 536nm, sitting atop a silica cladding. The radius of curvature 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. In this way we avoid fibre nonlinearities which would be incurred by the short pulses. Continuous wave spectral studies show each racetrack displaying several resonances dips within the 150nm bandwidth of our tunable laser. The free spectral range of the resonances decreases as the size of the racetrack is increased as expected.

III. Measurements

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. The coupling section of the racetrack resonator is longer than that of a circular ring resonator, allowing a larger coupling gap between the resonator and guide, for an equivalent coupling factor. 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.

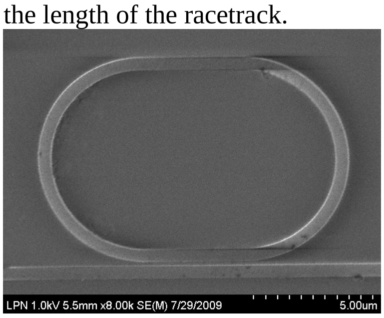

Figure 1. SEM image of racetrack resonators

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 (which is the wavelength of operation of our system) 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 "map" the temporal response of the pulses coming out of the waveguide-racetrack coupled system.

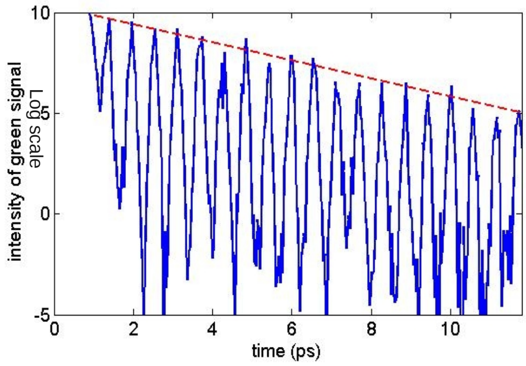

Figure 2. The intensity of the signal measured at 540nm (log scale) vs the delay time of the pump. The temporal ring-down of the racetrack shown as a sequence of diminishing peaks.

Figure 2 displays the train of pulses exiting the resonator. 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.

IV. Conclusion

In conclusion 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.

Acknowledgment

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