<http://www.diva-portal.org>

Postprint

This is the accepted version of a paper presented at *CLEO: Science and Innovations, 2017*.

Citation for the original published paper:

Errando-Herranz, C., Edinger, P., Gylfason, K B. (2017)

Dynamic dispersion tuning of silicon photonic waveguides by microelectromechanical actuation.

In: (pp. SW1N. 3-).

N.B. When citing this work, cite the original published paper.

Permanent link to this version:

<http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-207815>

Dynamic dispersion tuning of silicon photonic waveguides by microelectromechanical actuation

Carlos Errando-Herranz^{*1}, Pierre Edinger^{1,2}, and Kristinn B. Gylfason¹

¹*Micro and Nanosystems, KTH Royal Institute of Technology, Osquldas väg 10, SE-100 44 Stockholm, Sweden*

²*Grenoble Institute of Technology - INP Phelma, 3 Parvis Louis Neel, 38000 Grenoble, France*

**carloseh@kth.se*

Abstract: Efficient nonlinear silicon photonics rely on phase-matching through fine waveguide dispersion engineering. We experimentally demonstrate dynamic dispersion tuning of 800 ps/nm/km in a silicon waveguide ring resonator, by using microelectromechanical actuation of an adjacent suspended waveguide rim.

OCIS codes: 130.0130, 230.4685.

1. Introduction

In recent years, silicon photonics has emerged as a low cost and large scale platform for on-chip optical networks. However, most of these advances are based on linear optics, and lack important functionalities arising from nonlinearity such as wavelength conversion and all-optical signal processing. Despite silicon's high third-order nonlinearity, devices have shown low nonlinear efficiency, due to phase mismatch caused by material dispersion. Recently, advances in waveguide fabrication have enabled waveguide geometries with anomalous dispersion, resulting in compensation of material dispersion, phase matching, and higher nonlinear efficiency. However, the nanometric tolerances required for waveguide dispersion tailoring make fabrication challenging. Providing dynamic tuning of waveguide dispersion is key to increasing the efficiency of nonlinear effects in silicon based devices, through post-fabrication tuning of waveguide dispersion. This approach has the potential to enable important new device functionalities [1].

In previous work, piezoelectric actuation of a thin film on top of a silicon waveguide was used to increase wavelength conversion efficiency [2]. However, the demonstrated dispersion tuning, limited by the piezoelectric breakdown voltage, was far from achieving phase-matching.

2. Description of our device

An effective strategy to tune the dispersion of a waveguide is to change its geometry. In previous work, we presented microelectromechanical tuning of the effective mode index of a ring resonator waveguide with an integrated cantilever, and its application as a low-power tunable add-drop filter [3]. In this work, by optimizing the waveguide to achieve low anomalous dispersion, and the cantilever for large dispersion tuning, we demonstrate dynamic tuning of waveguide dispersion. Our waveguide dispersion tuning, combined with the tunable waveguide being in a ring resonator configuration, makes our device a promising building block for integrated silicon photonic wavelength conversion devices such as frequency comb generators [4].

The device consists of a 10 μm radius ring resonator formed by a suspended silicon waveguide with a 480×220 nm cross-section. The ring resonator waveguide is surrounded, with a separation of 100 nm, by a waveguide rim with a 220×220 nm cross-section. The waveguide rim is part of a suspended cantilever, and the ring waveguide is attached by a 110×350 nm cross-section silicon slab to a bus waveguide, leaving the ring coupling unaffected by actuation.

Application of an actuation voltage between the cantilever and the substrate changes the waveguide geometry, by vertically displacing the rim. Waveguide simulations using an eigenmode solver show the effect of displacement of the waveguide rim on the waveguide quasi-TE mode group index and the dispersion coefficient (Fig. 1a, b, and c).

3. Results

A scanning electron microscope image of our device is shown in Fig. 1d. From the measured ring resonator free spectral ranges (FSRs, about 9 nm) in the wavelength range between 1.46 and 1.58 μm , we extract the waveguide group index (Fig. 1e). Then, the dispersion coefficient (Fig. 1f) and the group velocity dispersion (GVD) are extracted. The

scatter in our data is caused by fitting errors due to background ripple, and the offsets between simulation and experiment in group index and dispersion are most likely due to a deviation of the fabricated waveguide cross-section from the design. Our results show a 800 ps/nm/km tuning of the dispersion coefficient, i.e. from 1500 to 2300 ps/nm/km, which, in combination with our measured GVD values at $\lambda = 1.55 \mu\text{m}$, from -1.9 to $-3 \text{ ps}^2/\text{m}$, are in the range of static dispersion-engineered waveguides enabling phase matching and efficient silicon nonlinear optics [1].

Fig. 1. a) Eigenmode simulations of our waveguide cross-section show the effect of the displacement of the rim due to tuning voltage V on the quasi-TE mode field distribution (here for $\lambda = 1.55 \mu\text{m}$), b) the waveguide group index, and c) the dispersion coefficient. d) Colored scanning electron microscope image of our device showing the cantilever (green), ring and bus waveguide (purple), and rim (orange). e) Measured group index tuning with increasing voltage, with a linear fit. f) Measured tuning of the dispersion coefficient, showing the fit to our simulations.

4. Conclusions

We have experimentally demonstrated, for the first time, dynamic dispersion tuning of 800 ps/nm/km in a silicon photonic ring resonator waveguide with anomalous dispersion by using microelectromechanical actuation on-chip. These results show the potential of our device for nonlinear integrated silicon photonics.

References

1. R. M. Osgood, N. C. Panoiu, J. I. Dadap, X. Liu, X. Chen, I.-W. Hsieh, E. Dulkeith, W. M. J. Green, and Y. A. Vlasov, "Engineering nonlinearities in nanoscale optical systems: physics and applications in dispersion-engineered silicon nanophotonic wires," *AOP* **1**, 162–235 (2009).
2. K. K. Tsia, S. Fathpour, and B. Jalali, "Electrical control of parametric processes in silicon waveguides," *Opt. Express* **16**, 9838–9843 (2008).
3. C. Errando-Herranz, F. Niklaus, G. Stemme, and K. B. Gylfason, "Low-power microelectromechanically tunable silicon photonic ring resonator add-drop filter," *Opt. Lett.* **40**, 3556 (2015).
4. A. G. Griffith, R. K. W. Lau, J. Cardenas, Y. Okawachi, A. Mohanty, R. Fain, Y. H. D. Lee, M. Yu, C. T. Phare, C. B. Poitras, A. L. Gaeta, and M. Lipson, "Silicon-chip mid-infrared frequency comb generation," *Nat. Commun.* **6**, 6299 (2015).