Enhancing SOI Waveguide Nonlinearities via Microring Resonators

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Abstract: All-optical devices can exploit a suite of nonlinearities in silicon photonics. We study how microring resonators (MRRs) harness these nonlinearities, with theoretical model and experimental validation. Free-carrier effects will practically always dominate Kerr in MRRs.

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1. Introduction

Microring resonators (MRRs) are ubiquitously used in silicon photonic integrated circuits (PICs) in a variety of devices: modulators, filters, and multiplexers. Recent improvements in fabrication and packaging of silicon PICS are decreasing coupling- and waveguide loss. This allows the cavity energy inside each resonator to easily reach levels that trigger optical nonlinearities, such as Kerr effect and two-photon absorption [1]. These effects can be exploited to engineer devices for all-optical switching [2], thresholding [3] or self-pulsations [4].

All nonlinear optical effects in single waveguides must be taken into account to correctly model the experimental behavior of MRRs built on silicon-on-insulator (SOI) platforms. These include thermo-optic, free-carrier absorption (FCA), free-carrier dispersion (FCD), two-photon absorption (TPA), and the Kerr effect. Here, we study their relative strengths in a typical SOI electron beam foundry platform. We match a constructed model with coupled-mode theory (CMT) to experimental measurements. Our results suggest that all these effects, except for the thermo-optic, play an important role in altering ultrafast dynamics.

An all-pass MRR (Fig. 1A) with nonlinearities can be modeled via a CMT method [4]. Its normalized complex amplitude, a, and normalized carrier density, n, evolve with

$$¶a=¶t = i(dw \quad n_{Kerr}jaj^2 + s_{fcd}a_{tpa}n)a \quad (1 + a_{tpa}jaj^2 + g_{fca}a_{tpa}n)a + \quad q\overline{g_p P_{in}(t)} \tag{1a}$$

$$¶n=¶t = jaj^4 \quad n=t; \tag{1b}$$

where dw

[redacted]