Tutorial on Photon-phonon Interaction in Highly Confined Silicon and Silicon nitride Photonic Wires

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Abstract: In this tutorial the fundamentals and the state-of-the-art of spontaneous and stimulated Raman and Brillouin scattering in highly confined silicon and silicon nitride waveguides are reviewed. Applications in spectroscopy and in microwave photonics are discussed.
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1. Introduction

The high optical confinement in silicon or silicon nitride photonic wires give rise to strong coupling of light fields with vibrations of matter, both with molecular vibrations (optical phonons) in the THz range as well as with acoustic vibrations (acoustic phonons) in the GHz range. In the past 5-10 years this has led to a myriad of experimental demonstrations of a broad variety of phenomena and functionalities, with a rich potential for applications.
In this tutorial this field will be reviewed, whereby both the basics, the state-of-the-art and the applications will be covered.

2. Outline of the tutorial

The tutorial will start with an introduction to highly confined waveguides and to the major CMOS-compatible technology platforms for such photonic wires, in particular silicon photonics based on either silicon-on-insulator (SOI) or on silicon-nitride-on-silica-on-silicon.
Then the basic physical processes of inelastic scattering or photon-phonon interaction – Brillouin and Raman scattering – will be introduced, both in their spontaneous linear variant as well as in their stimulated nonlinear variant, which leads to optical gain.
We will then focus on the Raman case and discuss how tight optical confinement helps to induce efficient interaction between waveguide modes and molecular vibrations, either of the waveguide material itself or of molecules present in the cladding of the waveguide. We will give examples of the use of this mechanism for evanescent Raman spectroscopy on a chip.
Then we will segue into the Brillouin case and discuss once more how tight optical confinement is instrumental for efficient interaction of the optical and the acoustic waves. The challenge of confining the acoustic fields is discussed. Finally, we will give examples of the use of these mechanisms in the field of microwave photonics.