Centre de Nanosciences et de Nanotechnologies

Soutenance de thèse

Samedi 19 octobre 2019

14h00

Center for Optical and Electromagnetic Research, East Building No.5, Conference room
Zijingang Campus, Zhejiang University
388 Yuhangtang Road, Hangzhou, China.

Jianhao ZHANG

"Subwavelength engineering of silicon waveguides and cavities for nonlinear photonics"

Jury members:

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Abstract :

econd-order Pockels and the third-order Kerr effects are among the important effects exploited for light modulation and light generation in integrated photonic platforms. To take advantage of these nonlinearities in silicon photonics, especially due to the lack of second order effect in bulk Si, the use of subwavelength optical structures is explored. In this context, this thesis work has focused on two main aspects, including: 1) Exploration of a novel photonic cavity scheme to take benefit of the electro-optical Pockels effect in strained Si structures for the realization of ultra-fast lower-consumption compact silicon modulators; 2) Exploration of a new family of waveguides leading to an automatic satisfaction of energy/momentum conservation for the purpose of Kerr frequency comb generation in integrated photonic platforms.

For improving the performances of integrated silicon resonant optical modulators, we have developed a novel Fano cavity resonator enabled by sub-wavelength engineering, leading simultaneously to high extinction ratio (23 dB) with a small Q factor of only 5600, and characterized by an ultra-low power consumption of less than 5 fj/bit when relying on the free carrier plasma dispersion effect. We have further extended the method to design a strained silicon Fano modulation structure which performances traditionally suffer from the weak amplitude of the exploited strain-induced Pockels effect and from considerable microwave losses due to large footprint components. By means of the proposed ultra-compact subwavelength structured Fano resonator, around 200-fold/60-fold (Q factor of 32000/5600) improvement on the modulation extinction ratio with the same driven voltage was theoretically predicted.

For improving the exploitation of silicon Kerr nonlinearities, we have proposed a novel family of graded index optical waveguides intending to automatically fulfill the energy and momentum conservation laws of four-wave mixing processes. The design of the waveguide section is based on a principle inherited from quantum wells of wave mechanics and concepts inherited from subwavelength structures for the practical realization of the rather particular index profiles. Standing on these specific waveguides in term of light dispersion, we have applied them to the modeling of frequency micro-combs (e.g. frequency combs generated using micro-ring resonators and a CW light source) by solving the nonlinear relevant equations (Lugiato-Lefever) to dynamically analyze the soliton comb spectrum generation process in various configurations. On top of this model, the specifically automatically phase-matched sub-wavelength-enabled graded-index waveguides were considered to trim and extend the bandwidth of silicon soliton frequency combs, demonstrating enlarged bandwidth and improved spectrum design flexibility with respect to previous works.

Overall, one of the dominant features of our study was to contribute to showing that sub-long wavelength photonic structures could provide concrete solutions to problems useful for the realization of on-chip non-linear functions. Subwavelength/nano structures not only benefit to passive photonic circuits which have been intensively developed in the past ten years, but also show strong potentials in the realization of active functions. This subwavelength toolbox is decisive in practice for the concrete achievement of the objectives pursued.

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