All-optical silicon-nitride-based nonlinear switch

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Abstract

All-optical control of signals is attracting a huge interest in the last years due to the possibility to increase the speed of the operation and new functionalities in several applications ranging from wavelength converters, optical switches, logic gates for high-speed opticl processing and optical interconnections.
In this work, we have investigated the behaviour of a nonlinear Mach-Zehnder (NMZ) interferometer devoted to all-optical switching. It is worth highlighting that most of the examples reported in literature uses only one nonlinear arm in the Mach-Zehneder configuration [1]. Therefore, this strongly limits the options for the experimental realization and fabrication of such configurations. In our work, we have considered a fully non-linear configuration as sketched in Figure 1. In particular, a common NMZ is made-up of two 3-dB directional couplers (at both input and output waveguides) and two nonlinear arms. The arms are designed so that the overlap of the mode with the nonlinear material is different in each. The input power is equally distributed into two nonlinear arms and then constructively/distructively interfere again at the output waveguide. We have developed an analytical model which considers both nonlinear arms. The device is desgined in order to get a 0 (π) phase shift, when the control signal (high power) is off (on).
In the analytical treatment, we considered the main parameters which have more effect on the performances of the NMZ: the differences in linear refractive indexes ($\Delta neff_L$) and nonlinear refractive indexes ($\Delta neff_{NL}(P_1)$) of the two arms.
The analytical model allows to retrieve several maps (Figure 2) which helps to design the NMZ when the geometrical parameters of the waveguides (i.e. thickness, width and length) are set. This general model allows also to introduce an asymmetry or waveguides with different cross-section(e.g. nanowires and slot waveguides [2-4]). The numerical model is supported by numerical simulations where Si-rich Silicon Nitride waveguides are considered. In Ref. [5] the authors have demonstrated that this material exhibits considerable Kerr response with respect to the stoichiometric Si_3N_4 material.
In conclusion our analisys is of fundamental importance for the design and fabrication of innovative and compact all-optical integrated switches.

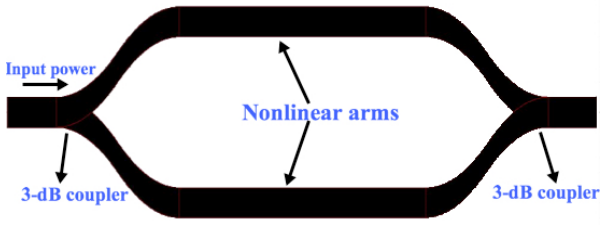


Figure 1 - Nonlinear Mach-Zehnder

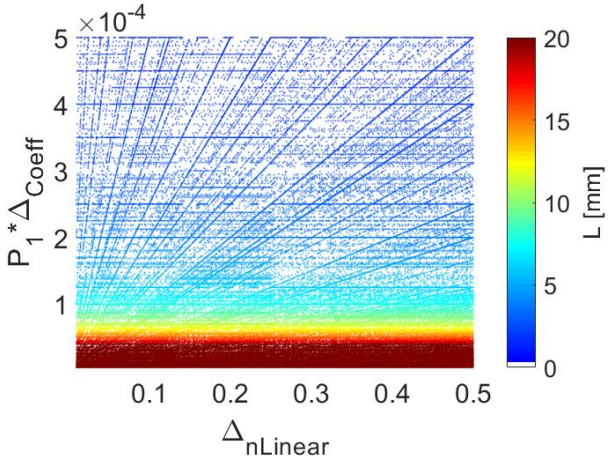


Figure 2 - Example map of device length function of $\Delta neff_L$ and $\Delta neff_{NL}(P_1)$

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