

Design and control of NxN microphotronics switch array based on non-adiabatic theory

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The development of linear programmable nanophotonics processors requires large number of couplers to route light through the photonic chip. This number scales nonlinearly with the number of inputs and outputs [1], making the device increasingly complex to control, and bulky. Regarding the latter aspects, densely packed array of waveguides would be an elegant solution. In order to couple selectively the different –at first isolated- waveguides, we rely on the analogy between the equations governing the unidirectional propagation in optics and the time evolution in quantum physics [2]. Namely, as seen in fig.1-a, if each waveguide can be considered as a photonic energy level, then a transition between discrete levels could be obtained providing the array is excited by the right spatial modulation. Such a strategy greatly differs from current design techniques that assume either adiabatic or diabatic transformations, hence without any transition between eigenstates. To the best of our knowledge, non-diabatic transition has been demonstrated in two-waveguide systems such as grating assisted contra-propagating couplers (subwavelength modulation), and PPLN (modulation caused by optical Kerr nonlinearity), and in long period gratings in fibers; but with little control and has never been generalized to waveguides array. Proper mathematical description involves the adiabatic theory which can be easily extended to the non-diabatic regime: it requires not only a modulation of the right periodicity [3], but the parameters that are modulated must obey some symmetry rules.

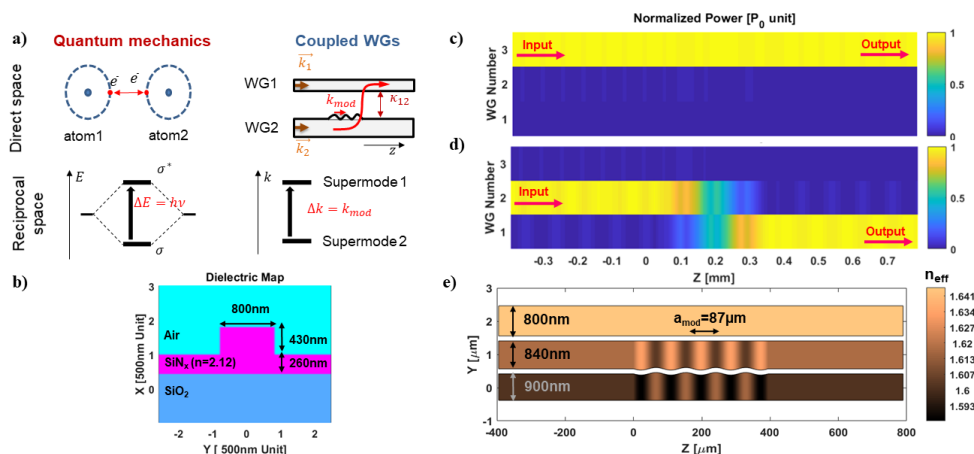


Figure 1: a) Schematic analogy between optics and Quantum Mechanics. b) Side view of the partially etched SiN waveguide whose parameters are considered for simulations. c-d) Propagation when injection of light in the first (resp. second) waveguide: coupling is only enabled by the modulation. e) Corresponding sample geometry (top view). Effective index is here modulated by change of the waveguides' widths. Maximal change of waveguide's width is about 75nm.

To put numbers, we considered waveguides made of SiN (fig.1-b,e) : the required interaction length of $400\mu\text{m}$. Remarkably the transfer of light is obtained here through a $87\mu\text{m}$ -period modulation of the waveguides' effective index by $\Delta n_{eff} = 0.05$ (2% relative variation, $n_{eff} = 1.65$). This relaxes numerous design and material constraints because weak control effects can be strong enough to switch the array. While small perturbations are enough to control the array, making it quite sensitive; the requirement for a precise periodicity makes such a technic still very robust to random perturbations. Finally, the technics we present here as a standalone solution, can also of course be combined with any others (adiabatic) design strategies to provide better and more advanced functionality.

References

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- [3] G. Griffel, et al, "Coupled mode formulation for directional couplers with longitudinal perturbation," *IEEE J. of Quant. Elec.* **27**, 985–994 (1991).