

Chapter 2

Silicon Photonics

Lorenzo Pavesi

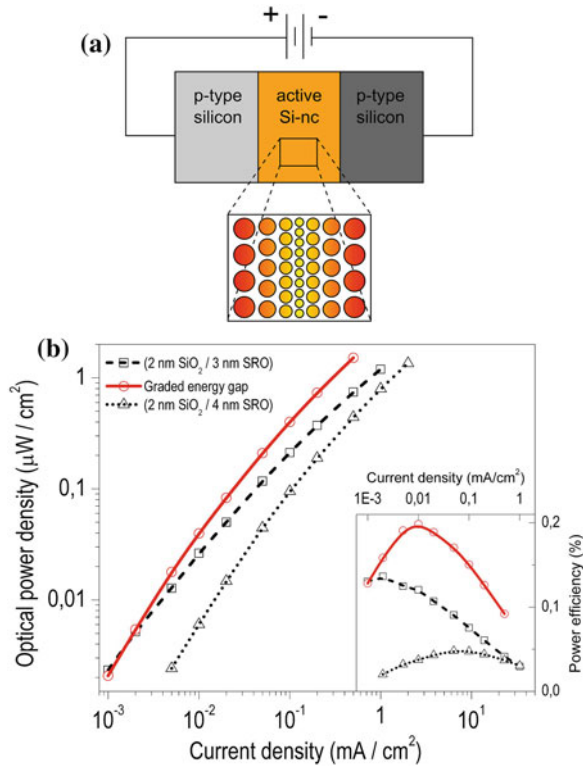
Abstract Silicon Photonics is no more an emerging research topic but is an actual technology with commercial products already available on the market. Quantum confinement of carriers or spatial localization of photons allows enhancing dramatically and widening the scope and potential of silicon photonics.

The tremendous evolution of internet has urged the microelectronic and telecommunication industries to look at technologies to face the bandwidth, speed and power consumptions that internet requires. One technology which is emerging as a comprehensive solution to this is integrated photonics where complexity, reconfigurability and intelligence are thrusts. An ideal platform for such integration is to use the same material that has permitted the success of microelectronics in the last century, i.e., silicon. Silicon photonics is a technology where photonics devices are fabricated by using standard silicon technologies [1–4]. In this way it is possible to leverage on the capabilities of the silicon industry to mass manufacture cheap photonics devices. A key ingredient to achieve this goal is to exploit the high level of integration that parallel and planar processing allows. Still, integration in photonics is limited to few hundreds of different components in a single chip due to the complexity of integrated photonic circuits and to the needs of hybrid integration technologies to face all the different functionalities needed. Nowadays, all the different functions have been generated and integrated in silicon photonics by using silicon based materials or, when they are not possible, hybrid integration [4]. An example of this is the signal source which in silicon photonics is provided by a hybrid III–V on silicon laser.

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Fig. 2.1 **a** Scheme of graded band-gap LED. **b** Electro-optical characterization of LED with different Si-nc sizes (*black curves*) and multilayer structure (*red curve*). The *inset* shows the power efficiency



Alternatively one can try to change the properties of silicon: the use of nano-silicon is one of such an attempt [5]. The use of nano-Si in silicon photonics (waveguides, modulators, switches, sources and detectors) is reviewed and discussed in [6, 7]. Recent advances of nano-Si devices such as bio-imagers, optical resonators (linear, rings, and disks) are treated in [5, 8]. High efficiency light emitting diodes (Fig. 2.1, [9]) can be used for interchip bidirectional optical transceiver [10]. Silicon nanocrystals improve silicon solar cells [11]. In addition, third order nonlinearities in silicon nanocrystals allow fast all-optical switches (Fig. 2.2, [12]). On the other hand, confinement of photons to small microresonators allows tuning the photon properties [13]. Here also novel effects are found. Ultra high bandwidth robust optical switches for UDWDM [14], active suspended microdisk bistable devices [15], nonlinear optical generations [16] are only few applications where nanophotonics can be appreciated.

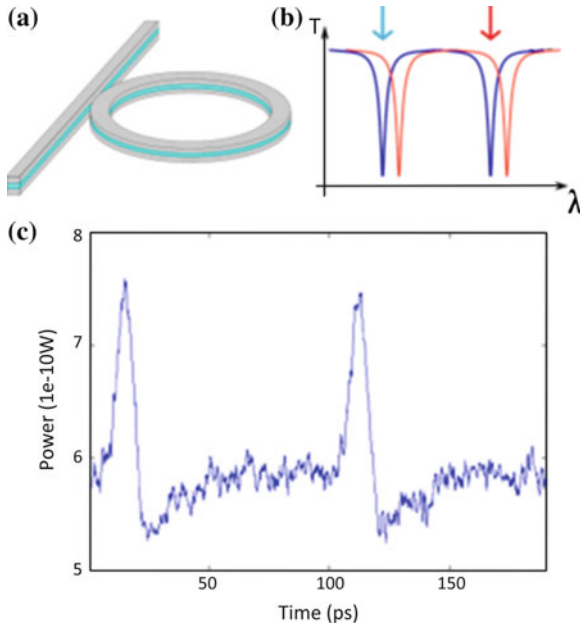


Fig. 2.2 **a** Scheme of the waveguide and the microring. The cyan layer indicates the nanosilicon layer. **b** Switching mechanism: *red arrow* indicates the pump beam, *cyan arrow* the CW signal beam. In the unperturbed state (*blue line*) the transmission of the probe is low, due to the intrinsic ring losses. While pumping (*red line*), a red shift is achieved and the probe beam is temporarily out of resonance and completely transmitted along the WG. **c** Experimental data of the optical switching achieved. FWHM of the pulses is about 20 ps

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