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Abstract: We report on the strong photoluminescence enhancement from carbon nanotubes integrated in silicon microring resonators under two pumping configuration: surface-illuminated pumping and collinear pumping. Extremely efficient rejection of non-resonant photoluminescence is observed.

1. Introduction

Nanophotonics is an emerging field where researchers look for potential application of carbon nanotubes (SWNT) in the framework of silicon photonics technology, due to SWNT ability to emit, modulate and detect light in the wavelength range of silicon transparency.

In this field of nanotube photonics, a first milestone was to couple light emission from SWNT into silicon waveguides [1,2]. Current researches focus on coupling SWNT with optical cavities [3-7], either for enhancing nanotube photoluminescence (PL) or nonlinear optical phenomena at the nanoscale, using microdisk resonators, or photonic crystal cavities. However, these kinds of cavities could not be easily coupled to silicon waveguides, hindering subsequent integration into more complex photonic devices.

Building up on our previous work [8-10], we propose to couple SWNT PL with silicon microring resonators in a fully integrated configuration, with an access waveguide. PL coupled to microring modes could be collected from the access waveguide, with efficient rejection on non-resonant photons. Emission quality factor up to 8000 were observed.

This design allow for collinear excitation of SWNT through the access waveguide, leading to efficient excitation and collection of SWNT PL at different wavelengths. The requirement for out-of-the-plane SWNT excitation is lifted, underlining the pertinence of this approach for realistic carbon nanotube based photonic devices.

2. Experimental setup

Silicon microring are fabricated from silicon-on-inulator (SOI) wafers with a 220 nm thick top Si layer and a 2 µm thick buried oxide layer. E-beam lithography is used to define pattern which arethen transferred into the top Si layer by dry etching. A typical microring width is 340 nm, and a local cladding of 900 nm was added on top of access waveguide using Hydrogen Silses-Quioxane (HSQ). (cf. Fig. 1(b))

Semiconducting carbon nanotubes (s-SWNT) are extracted from HiPCO nanotubes using a polyfluorene (PFO) process, known to yield high-purity material, without remaining amount of metallic nanotubes [11], and where spin-casted on top of photonic structures.

The characterization setup presented in figure 1(a) is a home-made micro-photoluminescence setup coupled to a integrated optics fibered test benche. It allow both external and collinear excitation of s-SWNT photoluminescence.

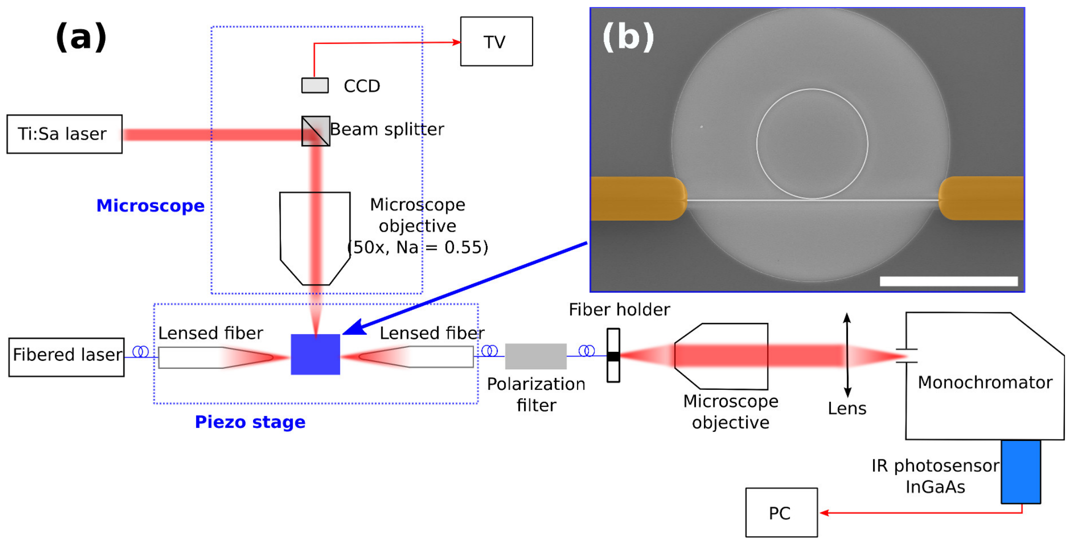

Fig1. (a) Characterization set-up for the microring resonators covered with s-SWNT, allowing measurement in two different configuration: externally excited photoluminescence and collinearly excited photoluminescence. (b) Typical SEM picture of a microring resonator, with HSQ cladding indicated in false yellow color. Scale bar 50 µm. (Adapted from [10]).

3. Results

A typical photoluminescence spectrum, obtained after pumping with an external excitation at 735 nm is displayed in figure 2 (a). Evenly spaced narrow peaks are observed, corresponding to ring resonance modes excited by s-SWNT PL in TE polarization.

The full potential of SWNT in integrated configuration is demonstrated while using collinear excitation through the access waveguide and is displayed in figure 2 (b). Wavelength of interest for integrated pumping were identified looking at the external excitation PL spectrum. Two wavelength were chosen in resonance with the microring mode, while one was chosen out of resonance.

When the pumping wavelength match a microring resonance, output PL spectra displayed evenly spaced peaks, in agreement with the externally excited reference spectra, as highlighted by the dotted lines. Those peaks are absent in the case of the non-resonant pump and give some insight of the mechanism occurring here.

Light input through the waveguide evanescently couples in the microring, and excite nanotubes PL. If the pump wavelength match a resonance of the ring resonator, this excitation is much more efficient. Nanotubes PL is then coupled back to the bus waveguide, and collected at the sample output.

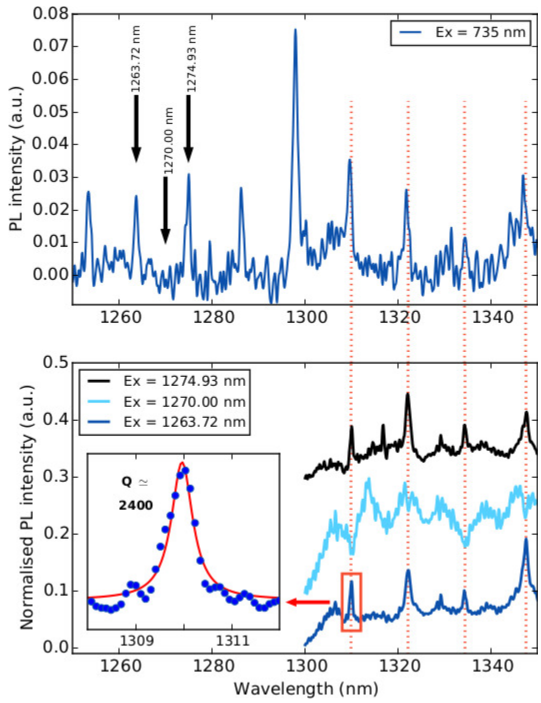

Fig2. (top) Externally excited s-SWNT PL spectrum recorded in TE polarization at the waveguide output. (bottom) PL spectra recorded after collinear excitation of s-SWNT through the access waveguide (adapted from [10]).

4. Conclusion

We have demonstrated the coupling of carbon nanotube PL with silicon microring resonators in a fully integrated configuration, with efficient rejection of the non-resonant photoluminescence. This demonstration paves the way for the development of integrated light sources in silicon based on carbon nanotubes.

5. References

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