

Internship subject

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Emission and nonlinear optical properties in carbon nanotubes-on-silicon nanostructures

On-chip light sources and nonlinear optical functionalities in silicon photonics platform are still a big challenge for many applications including quantum technology, optical communications, and sensing. Most approaches considered today, rely on a wide variety of materials deposited or grown on silicon. These include III/V, Germanium, colloidal quantum dots, graphene, chalcogenides (for their nonlinear properties), etc. These approaches have advantages to offer a range of physical effects to emit, modulate and detect light on chip. However, none has the capability to exhibit efficient emission, modulation, detection as well positive and negative Kerr effect (third-order nonlinearity) at the same time. In this context, we are carrying out ground-breaking approach aimed at exploiting the optoelectronic and nonlinear optical properties of single-walled semiconducting carbon nanotubes (s-SWNTs) as active optical material for Si photonics platform. Indeed, s-SWNT is a direct bandgap semiconductor exhibiting room-temperature electro- and photo-luminescence, strong Kerr effect and absorption from the visible to the mid-infrared wavelength range. Recent advances in solution processing and wafer-scale selective deposition have opened a new route towards the realization of on-chip devices for the Si photonics platform, based on the use of s-SWNTs.

Recent experiments have shown the demonstration of resonant-enhancement of the photoluminescence emission from a s-SWNT network from 2-D hollow-core Si photonics microcavities, ring resonators, nanobeam cavities and micro-disks and a negative and positive Kerr effect. The purpose was to exploit the strong evanescent field, the small mode volume and the high-quality factors of the cavities to yield narrowband light emission with high off-resonance rejection and to develop versatile all-optical photonic devices.

In this context, the objective of the internship work will be first to experimentally study the emission and nonlinear optical properties from s-SWNTs coupled to Si waveguide. Secondly, the student will participate to develop a new type of electrical-pumped circuits based on carbon nanotubes integrated in silicon and silicon nitride photonics platforms. The candidate will be fully involved in the optical and electrical simulations and in the characterization using integrated optical benches, linear and nonlinear pulse benches and Raman spectrometers.

The research activities will include:

- **Theoretical study and electro/optical/nonlinear simulations** to evaluate the key metrics for tuning the optical properties of the waveguide modes
- **Experimental characterizations** of optoelectronic and nonlinear nanostructures based on carbon nanotubes

During the internship, the student will be actively involved in the current research activity of the group, collaborating also with CEA Saclay (Arianna Filoramo).

VALUED QUALITIES IN THE STUDENT

- Curiosity for novel research experiences and fields.
- Creativity and pro-activity in the search for innovative solutions and approaches.
- Attractiveness in experiments and simulations.
- Capability to communicate and share results in a multidisciplinary and multi-nationality environment.

BIBLIOGRAPHY RELATED TO THE TOPIC

- M. Balestrieri et al., Polarization-sensitive single-wall carbon nanotubes all-in-one photodetecting and emitting device working at 1.55 μ m, *Adv. Funct. Mater.*, 1702341 (2017)
- Thi Hong Cam Hoang et al. Narrow-linewidth carbon nanotube emission in silicon hollow-core photonic crystal cavity, *Optics Letters* Vol. 42, Issue 11, pp. 2228-2231 (2017)
- E. Durán-Valdeiglesias et al., Integration of carbon nanotubes in silicon strip and slot waveguide micro-ring resonators, *IEEE Transactions on Nanotechnology* 15(4), 583-589 (2016).
- F. La China et al., Near-field imaging of single walled carbon nanotubes emitting in the telecom wavelength range, *J. Appl. Phys.* 120(12), 123110 (2016).
- E. Durán-Valdeiglesias, W. Zhang, C. Alonso-Ramos, S. Serna, X. Le Roux, D. Maris-Morini, N. Caselli, F. Biccari, M. Gurioli, A. Filoramo, E. Cassan, L. Vivien, "Tailoring carbon nanotubes optical properties through chirality-wise silicon ring resonators," *Nature Sci. Rep.*, 8, 11252 (2018).
- W. Zhang et al., Integration of Semiconducting Carbon Nanotubes Within a Silicon Photonic Molecule, *IEEE Photonics Journal* 12 (2020)

This project can be continued and expanded within the frame of a PhD.