Internship subject

Laboratory: Centre de Nanosciences et de Nanotechnologies (UMR 9001)
Address : 10 Boulevard Thomas Gobert, 91120, Palaiseau

Contact: Daniele MELATI

phone number: +33 (0)1 70 27 06 16 // email: daniele.melati@universite-paris-saclay.fr
https://minaphot.c2n.universite-paris-saclay.fr

Artificial intelligence for advanced photonic devices

The development of nanofabrication technologies has opened the door to the possibility of **precisely controlling the behaviour of light using nano-scale devices realized on chip**. In particular, **silicon-based photonics is widely considered the platform of choice for the realization of miniaturized devices** in a wide variety of application fields, including optical communications, sensors, machine learning computation, and imaging. Additionally, due to its compatibility with CMOS fabrication processes, silicon photonics holds the promise of providing ultra-compact devices that could be fabricated at large-volumes and low cost and offers the unique potential for the integration of photonic and microelectronic functionalities in a single chip.

Classical photonic devices exploit relatively simple geometries that are designed by hand (e.g., waveguides, rectangles, rings, etc.), resulting in relatively large components and limited scale of integration. On the contrary, one of the most active research topics in the field focuses on the possibility to use non-intuitive shapes, complex material distributions, and metamaterials to achieve extremely compact devices capable of integrating multiple functions with footprints of few square microns.

The way light interact with matters in such devices cannot be described with commonly available models and their design requires **developing innovative design methodologies**. **These challenges stimulated a large research effort in the direction of artificial intelligence and data-driven methodologies which have been demonstrated as a viable solution to handle thousands of design variables simultaneously**. Machine learning algorithms can build complex physical models directly from a set of training data, models that can then be used to very efficiently design novel photonic structures with desired optical properties. In this context, **our group has pioneered the use of dimensionality reduction techniques, demonstrating devices with unprecedented performance.**

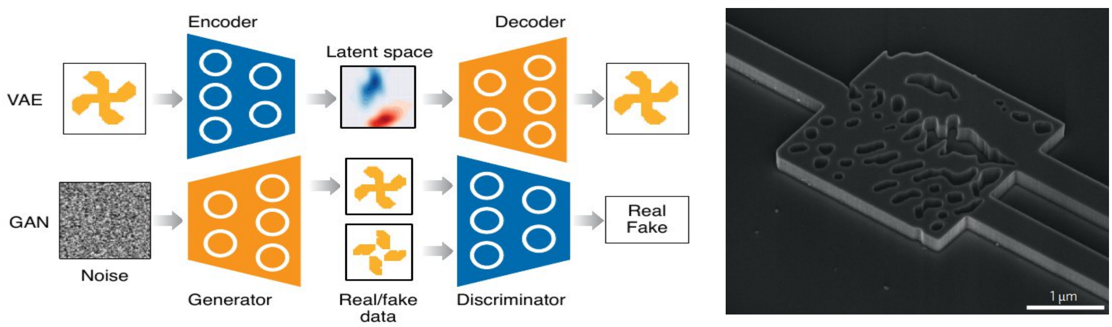

Fig.1: (left) Schematic representation of a Variational Autoencoder and a Generative Adversarial Neural Network [3]. (right) Metamaterial-based photonic device [4]

The goal of this internship is the exploration of machine learning algorithms for the development of silicon photonic devices with improved performance and advanced functionalities. Deep learning methodologies (e.g. variational autoencoders) will be combined with optimizaiton techniques to both alleviate the large amount of input data required by classical algorithms and to efficiently optimize device designs. Devices will then be fabricated in the C2N cleanroom and tested to demonstrate their performance.

The research activity will include:

- **Bibliography study** to familiarize with machine-learning-based algorithms, optimization techniques, their use in the field of integrated photonics, and unresolved challenges.

- **Set-up of machine learning models** linked to optical simulators (using available software and packages) capable of generating new device designs and evaluation of their performance compared to other available design techniques.

- **Comparison of expected performance and experimental measurements** of key performance metrics performed on fabricated devices (efficiency, bandwidth, reflections...) and integration of experimental data in the machine learning models.

During the internship, the student will be actively involved in the current research activity of the group, collaborating with PhD students, postdocs and researchers of different research backgrounds and nationalities. **This project can be continued and expanded as a PhD thesis within the framework of the project BEAMS funded by the European Research Council (ERC)** .

What we expect from you:

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

Relevant bibliography

[1] P. R. Wiecha et al., 'Deep learning in nano-photonics: inverse design and beyond', Photon. Res., PRJ, vol. 9, no. 5, pp. B182–B200, May 2021, doi: 10.1364/PRJ.415960.

[2] Z. Liu et al., 'Tackling Photonic Inverse Design with Machine Learning', Advanced Science, vol. 8, no. 5, p. 2002923, 2021, doi: 10.1002/advs.202002923.

[3] W. Ma et al., 'Deep learning for the design of photonic structures', Nature Photonics, pp. 1–14, Oct. 2020, doi: 10.1038/s41566-020-0685-y.

[4] D. Melati et al. 'Mapping the global design space of nanophotonic components using machine learning pattern recognition', Nat Commun, vol. 10, no. 1, pp. 1–9, Oct. 2019, doi: 10.1038/s41467-019-12698-1.

[5] D. Melati et al., 'Design of Compact and Efficient Silicon Photonic Micro Antennas with Perfectly Vertical Emission', IEEE J. Select. Topics Quantum Electron., vol. 27, no. 1, pp. 1–10, Jul. 2020, doi: 10.1109/JSTQE.2020.3013532.