Internship subject (2026-2027)

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Antennas and metasurfaces for optical wireless systems

The development of nanofabrication technologies has opened the door to the possibility of **precisely controlling the behaviour of light using nano-scale devices integrated 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.

Optical communications has been the first application of optical integration technologies, and remains an area of great importance today. Whereas in the past the focus was mainly on fiber-optic communication networks, interest in **optical wireless** (or free-space optical communications) has grown again in recent years. Similarly to common radio-frequency wireless, **these systems aims at connecting two terminals using laser beams propagating in free-space**. Wireless systems can be installed more easily and at lower cost than fibres and are also compatible with mobile equipment, such as satellites (the main application of optical wireless today is inter-satellite communication). However, many of the devices required for free-space systems are not yet integrated and often rely on conventional optical components (e.g. lenses and mirrors) and mechanical assemblies, particularly for generating and receiving optical beams. This makes them bulky, slow and costly.

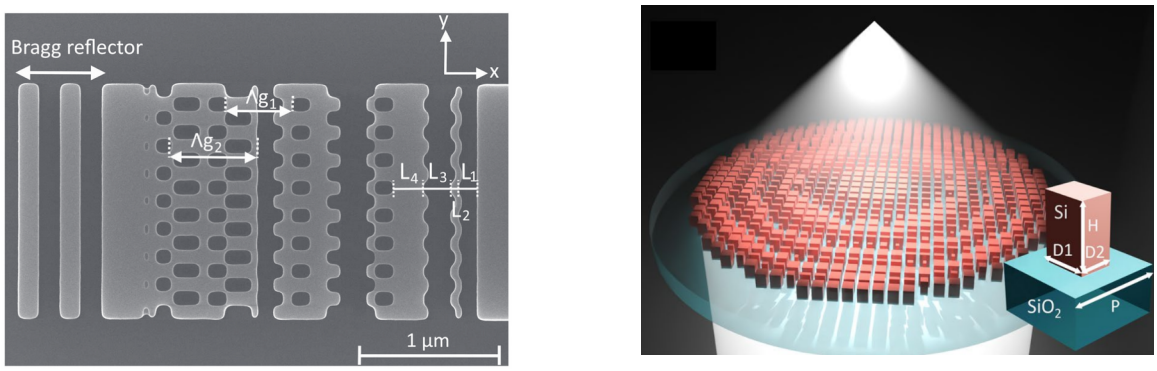


Fig.1: (left) An example of a fabricated optical antenna with a complex metamaterial structure. (right) An ultra-thin optical lens realized with metamaterials (meta-lens).

The internship will focus on two fundamental elements of an optical wireless system. The first one is the optical antenna that is used to couple light from an on-chip waveguide to the free-space. The second is the optical elements that are used to chape and point the generated free space wavefront (e.g., lenes or deflectors). The goal will be exploiting metamaterials to develop highly efficient antennas and meta-lenses with the final objective of integrating them in a single, on-chip device. Machine learning technics and optimization algorithms will be

exploited to assist in the design of the components. Depending on the results of the design phase, the devices could be fabricated in the C2N cleanroom and tested to demonstrate their performance.

The research activity will include:

- **Bibliography study** to familiarize with optical wireless systems, optical antennas, and optical metasurfaces

- Evaluate performance of different antenna arrangements (phased arrays, focal plane arrays) through **optical simulations** (using available software and packages)

- Study the performance of a combined system including an array of antennas and metamaterial-based optical elements (e.g., meta-lenses)

- **Optimize the design** of the selected geometries using advanced algorithms for inverse design (optimization, machine learning tools)

- Prepare the final design files for fabrication in the C2N cleanroom and **optical characterization** of the fabricated antennas.

During the internship, the student will be actively involved in the on-going research activity in the described topic, collaborating with PhD students, postdocs and researchers of different research backgrounds and nationalities.

Additional information:

- The internship proposal is dedicated to **Master student (M2 or equivalent)** in photonics, physics, micro/nanoelectronics, or applied physics.

- A solid background in electromagnetism/optics is required. Prior experience with numerical simulation, clean-room practice, or optical characterizations is appreciated but not mandatory.

- **Duration**: 6 months, full-time

Relevant bibliography

[1] J. Cao, S. Salhi, J. Peltier, J.-R. Coudevylle, S. Edmond, C. Villebasse, E. Herth, L. Vivien, C. Alonso-Ramos, and D. Melati, 'Single-layer silicon metalens for broadband achromatic focusing and wide field of view', *Sci Rep*, vol. 15, no. 1, p. 43343, Dec. 2025, doi: 10.1038/s41598-025-27208-1.

[2] J. Sun, E. Timurdogan, A. Yaacobi, E. S. Hosseini, and M. R. Watts, 'Large-scale nanophotonic phased array', *Nature*, vol. 493, no. 7431, pp. 195–199, Jan. 2013, doi: 10.1038/nature11727.

[3] X. Zhang, K. Kwon, J. Henriksson, J. Luo, and M. C. Wu, 'A large-scale microelectromechanical-systems-based silicon photonics LiDAR', *Nature*, vol. 603, no. 7900, Art. no. 7900, Mar. 2022, doi: 10.1038/s41586-022-04415-8.

[4] S. Salhi, X. Xin, D. Benedikovič, C. Alonso-Ramos, L. Vivien, D. Marris-Morini, E. Cassan, W. N. Ye, and D. Melati, 'Polarization independent silicon micro antenna based on a subwavelength metamaterial', *Sci Rep*, vol. 15, no. 1, p. 13276, Apr. 2025, doi: 10.1038/s41598-025-97833-3.

[5] D. Melati, D.-X. Xu, Y. Grinberg, and M. Al-Digeil, 'Inverse design of photonic integrated devices: Optimization and machine learning', *APL Photonics*, vol. 10, no. 10, p. 101101, Oct. 2025, doi: 10.1063/5.0283179.