Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES ***Type of funding:*** ERC Advanced grant (ANAPOLIS)

Stacking photonic graphene sheets: towards 3D polaritonics

The aim of this project is to study the physics of "synthetic photonic materials", which consist of synthetic platforms designed in the lab in order to make photons bahave like matter particles. In our lab, we use photons trapped in micron-size semiconductor cavity as a building block to realize such materials [1]. For example, by arranging an ensemble of microcavities in the form of a honeycomb lattice, it is possible to create "photonic graphene" structures (see Fig. 1). As shown in Fig. 1, the band structure of such photonic graphene lattices is similar in every respect to the electronic band structure of real graphene.

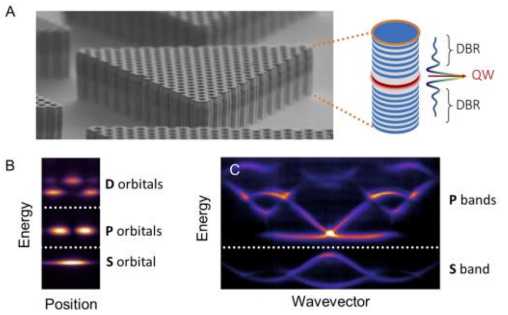

Fig. 1: Micropillar lattices *can be realised by etching planar semiconductor microcavities. The lattice building blocks are micropillars (**A**), which emission spectrum (**B**) reveals discrete energy levels reminiscent of atomic orbitals. Angle-resolved emission from a lattice of coupled micropillars (**C**) directly reveals the band structure emerging from hybridization of the pillar orbitals.*

Recent developments in condensed matter physics have shown that stacking together graphene sheets provides the ability to engineer novel materials (multilayer graphene) featuring rich electronic properties. Multilayer graphene is indeed a highly tunable material, where the number of layers and their stacking arrangements can be chosen at will. This provides the ability to control and manipulate the electronic band structure, leading to the emergence of insulating, superconducting, and also topological phases of matter. One particularly striking example is *twisted bilayer graphene*, where small-angle rotations between layers lead to the formation of a Moiré pattern, giving rise to phenomena such as superconductivity and strongly correlated phases at certain "magic angles" [2].

In this project, we will build upon recent developments in the field of multilayer graphene, to investigate how these concepts transfer to photonic graphene. In particular, how is the band structure of photonic graphene modified when several vertically coupled cavities are stacked? In the presence of a torsion angle between the two layers, what is the impact of the Moiré effect caused by this superposition? Finally, what advantages can be derived from the additional degrees of freedom offered by the photonic platform, for example when the degeneracy between the different polarization states of light is lifted (effective spin-orbit coupling) or when light is coupled to electronic excitations (polaritons)?

References:
[1] A. Amo and J. Bloch, C. R. Phys. **17** (2016).
[2] Y. Cao, *et al.*, Nature **556**, 43 (2018).

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES