Stacking and twisting 2D materials for quantum nano-optoelectronics

Frank Koppens
ICFO – The Institute of Photonics Sciences
Frank.koppens@icfo.eu

Two-dimensional (2D) materials offer extraordinary potential for control of light and light-matter interactions at the atomic scale. In this talk, we will show a new toolbox to exploit the collective motion of light and charges as a probe for topological, hyperbolic and quantum phenomona.
We twist or nanostructure heterostructures of 2D materials that carry optical excitations such as excitons, plasmons or hyperbolic phonon polaritons. Nanoscale optical techniques such as near-field optical microscopy reveal with nanometer spatial resolution unique observations of topological domain wall boundaries, hyperbolic phononic cavities [1], and interband collective modes in charge neutral twisted-bilayer graphene near the magic angle [2]. The freedom to engineer these so-called optical and electronic quantum metamaterials [3] is expected to expose a myriad of unexpected phenomena. Intriguingly, we define nanoscale phonon polaritonic cavities, where the resonances are not associated to the eigenmodes of the cavity. Rather, they are multi-modal excitations whose reflection is greatly enhanced due to the interference of constituent modes. We will also show a new type of graphene-based magnetic-resonance that we use to realize single, nanometric-scale cavities of ultra-confined acoustic graphene plasmons [4]. We reach record-breaking mode volume confinement factors of $\sim 5 \cdot 10^{-10}$. This AGP cavity acts as a Mid-infrared nanoantenna, which is efficiently excited from the far-field, and electrically tuneable over an ultra-broadband spectrum. Finally, we present near-unity light absorption in a monolayer WS_2 van der Waals heterostructure cavity [5].

References

[1] Herzig Sheinfux et al., in preparation
[2] Hesp et al., Arxiv 1910.07893
[3] Song, Gabor et. al., Nature Nanotechnology (2019)
[4] Epstein et al., Science (2020)
[5] Epstein et al., Nano Letters (2020)

Figures

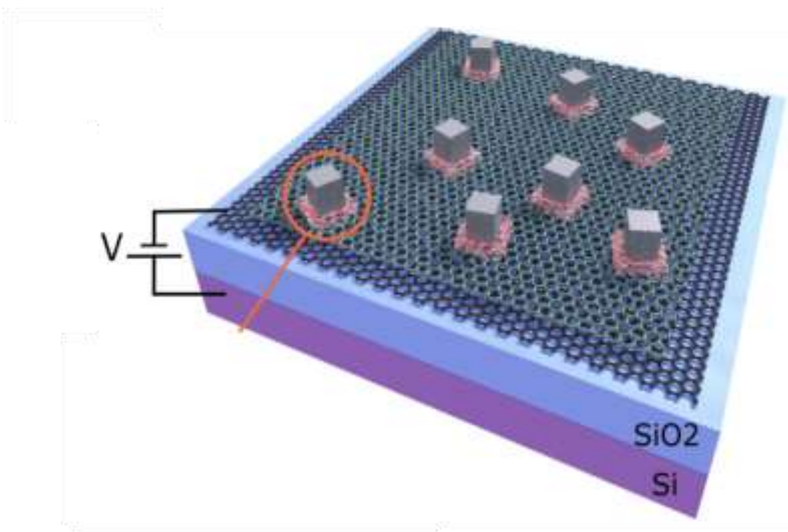

Figure 1: Acoustic graphene plasmon cavities