Electrical detection of high quality 2D polaritonic nanoresonators

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Polaritons are coupled excitations of incident light with charged particles (plasmons polaritons) or lattice vibrations (phonon polaritons). In particular, for two dimensional (2D) materials their properties become even more intriguing in several aspects such as extreme light confinement and long lifetimes. Hence, they lead to a myriad of applications such as gas and molecular sensors, enhancing photodetection and quantum computing.

In this talk, we initially show efficient coupling between plasmonic nanoantennas with hyperbolic phonon-polaritons (HPPs) in hBN for highly concentrate mid-infrared light into a graphene pn-junction in order to overcome its small absorption and photoactive area [1]. We guide these HPPs with constructive interferences towards the photodetector active area. This room temperature ultrafast infrared photodetector exceeds any commercial technology. It has a response time of <15 ns (setup limited), while at the same time showing excellent sensitivity: we extracted a noise-equivalent-power (NEP) down to 82 pW/√Hz at 6 μm (50 THz). [1]

Then, we show a novel concept of 2D polaritonic nanoresonators that consist on merging into one single platform the polaritonic material and the detector as shown in Figure 1 [2]. We obtain a highly compact device since we get rid of the need of an external detector for performing infrared spectroscopy. We show high Q factors (>200) and confinement record of these nanoresonators. [2] We geometrically and electrically tune these nanoresonators to change their spectral photoresponse. Due to this, we are able to identify different interactions such as the hybridization between graphene plasmons with the HPPs, modification of the HPPs waveguide modes and the interplay between the different graphene plasmons (acoustic and optical).

Finally, we investigate the photoresponse of these 2D polaritonic nanoresonators as a function of the temperature, reaching values down to 30 K. [3] The devices show higher values of photocurrent due to the interplay of the contributions of the photothermoelectric effect and longer lifetimes of the polartionic resonators. We determine that the Q factor values increase significantly at these lower temperatures and the results are supported by theoretical simulations.

References

[1] S. Castilla, I. Vangelidis, VV. Pusapati, et al. Plasmonic antenna coupling to hyperbolic phonon-polaritons for sensitive and fast mid-infrared photodetection with graphene. Nature Communications, 11, 4872 (2020)
[2] S. Castilla, et al. To be submitted (2022)
[3] S. Castilla, et al. In preparation (2022)

Figures

Figure 1: Schematic of the 2D polaritonic nanoresonator that show the field intensity of the propagating mode.