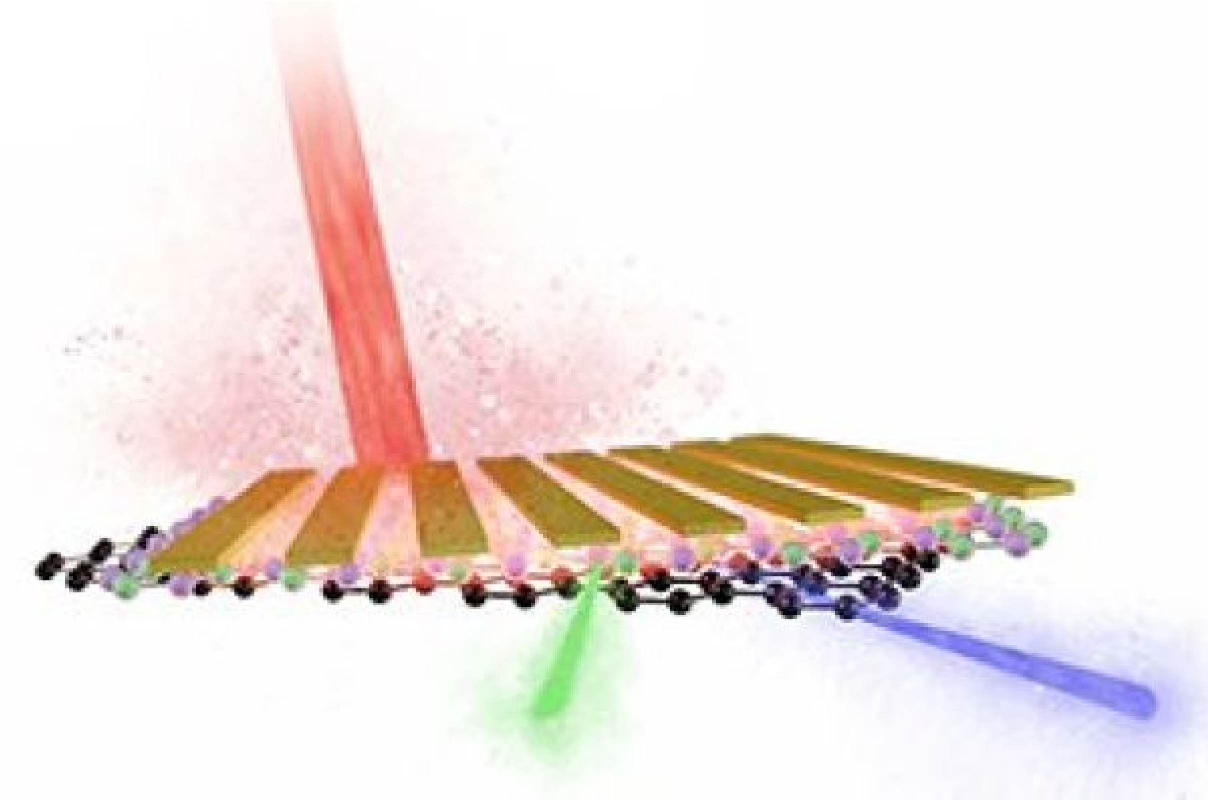

PhD THESIS DEFENSE: Study of Graphene Hybrid Heterostructures for Linear and Nonlinear Optics

DAVID ALCARAZ

June 23, 2020

11:00

ICFO Auditorium and Online (Teams)

Tuesday, June 23, 2020, 11:00. Semi-Presencial & MsTeams

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Quantum Nano-Optoelectronics

ICFO-The Institute of Photonic Sciences

Graphene is the first of the 2D-material family. It is formed by carbon atoms arranged in a honeycomb lattice, which confers it intriguing physical properties that are still being discovered nowadays. A fundamental advantage found in graphene is the ability to gate tune ï¿½in-situï¿½ its optical response from reflective (metallic) to absorptive (lossy dielectric). I
is in the reflective conditions when it becomes more interesting since it supports sur
ace plasmon polaritons in the mid-infrared, similar to metals in the near-infrared and vis

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ble spectral regions. Surface plasmons in metals are known to be more confined than free s ace propagating light. But graphene naturally excels in this aspect by offering a confine ent factor around 100, which causes light to couple in inefficiently.

Several studies on metal plasmonics have shown the possibilities of confining light into tiny spatial dimensions with applications in molecular sensing as an example. Often, metal plasmons are used in the visible and IR regions with moderate confinement. However, Landau damping limits the optical field confinement due to penetration in the material and the consequent losses. In this thesis, it is shown that graphene-insulator-metal hybrid heterostructures can overcome that limitation by efficiently exciting plasmons in unpatterned graphene with vertical confinement down to the ultimate one-atom insulator thickness. It is accomplished by encapsulating graphene with a single layer of h-BN (or thicker oxide layers for the systematic study) and fabricating metallic nano/micro-ribbons on top. The transmission extinction of the samples was measured and compared with theoretical models accounting for material nonlocal permittivity. The ultimate confinement and the validity of the excitation method are confirmed enabling a path towards ultrastrong light-matter interaction.

An example application of the aforementioned method to graphene nonlinear optics is also presented. The large intrinsic graphene third-order nonlinear optical response has been of great interest and it has been studied both theoretically and experimentally. However, there were not experiments covering all the expected features from the theory in the mid-infrared.

This thesis expands the measurement range to cover the mentioned gap in planar graphene. Additionally, field enhancement and confinement provided by the hybrid heterostructure was exploited to increase the nonlinear third-harmonic generation signal in more than three orders of magnitude. Intriguingly, it was found that some structures presented further modulation of the nonlinear signal which is attributed to the oscillatory nature of graphene plasmons. This opened an extra channel for extreme nonlinear gate tunability for the optimized parameters. To summarize, this thesis presented means to achieve the regime of ultrastrong light-matter interaction, it fully characterizes it down to the one-atom spacer limit, and provides an example while demonstrating its applicability in graphene nonlinear optics.

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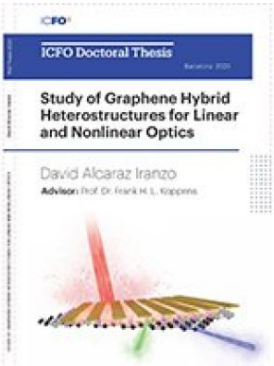
Thesis Advisor: Prof Dr Frank Koppens
Hosted by: Prof Dr Frank Koppens



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