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UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

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FIM-S3 SEMINAR

Ultrafast nanophotonics and opto-electronics: from metamaterial-based all-optical switching to plasmon-driven polaritonic chemistry

Wednesday June 12th, 2024 – 11.00 (sharp)

S3 Seminar Room, 3rd Floor, Physics building
Remote link: Teams

Speaker

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Abstract

Ultrafast control of light-matter interactions is fundamental to mark new technological frontiers, for instance in light-driven information processing and nanoscale photochemistry [1]. In this context, we have recently investigated metal-dielectric nanocavities to achieve all-optical modulation of light reflectance – a first step to achieve all-optical transistor functionalities. Without the need of driving higher order effects, this archetypical system is based on linear absorption, provides large relative modulation exceeding 100% and switching bandwidths of few hundred GHz at moderate (1 mJ/cm2) excitation fluence [2]. This concept becomes even more interesting if the dielectric layer is not just a “passive” insulator but an inorganic van der Waals semiconductor, like a transition metal dichalcogenide (TMD), which present interesting electronic and optical properties promising for next-generation opto-electronic devices working at optical frequencies. In this framework, understanding ultrafast carrier dynamics, as well as charge and energy transfer at the interface between metals and semiconductors, is crucial and yet quite unexplored. By employing a pump-push-probe scheme, we experimentally study how optically-induced thermionic charge carrier injection affects the exciton formation dynamics in bulk WS2 [3]. This type of investigations at the interface between metals and quantum materials can disclose excellent opportunities also in polaritonic chemistry. In fact, if an electronic transition (e.g., an exciton or more simply a singlet) strongly interacts with the electromagnetic field inside a resonator (e.g., an optical cavity), we can tailor the energetics and the morphology of a molecular state. By combining quantum mechanical modelling and pump-probe spectroscopy, we recently shed new light on the ultrafast dynamics of an archetypical polaritonic system composed of photo-switchable dye molecules coupled to optically anisotropic plasmonic nanoantennas, which allow to selectively switch between two regimes where the molecule-antenna interaction is either weak or strong [4]. This synergistic approach is instrumental to devise new strategies for tailoring photochemical reactions by using plasmons for applications on femtosecond timescales.

References

[1] A. N. Koya et al., Appl. Phys. Rev. **10**, 021318 (2023)
[2] J. Kuttruff et al., Commun. Phys. **3**, 114 (2020)
[3] K. R. Keller et al., ACS Photonics **9**, 2683 (2022)
[4] J. Kuttruff et al., Nat. Commun. **14**, 3875 (2023)

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