**Photodetection and nano-photonics of graphene and heterostructures of 2d materials**

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The interaction of light with graphene and heterostructures of related 2d materials embodies a wide variety of physical processes such as ultra-fast photoconversion, strong light-matter interactions and highly confined plasmons, with strong potential for disruptive opto-electronic technologies. In this talk, several examples of the ultra-fast opto-electronic and nano-photonic capabilities of novel 2d material heterostructures are being addressed.

We argue that graphene encapsulated in hexagonal boron nitride (h-BN) is a material system with remarkable nano-photonic properties. First, we find that it is an excellent host for extremely strongly confined light with reduced plasmon losses. We identify experimentally and theoretically the main damping channels. Second, h-BN itself is an interesting optical material as it shows natural hyperbolic behaviour, meaning that the in- and out-of-plane component of the permittivity have opposite signs in the reststrahlen frequency bands. This implies that h-BN supports deep subwavelength slow-light phonon polariton modes within those bands. Combining h-BN with graphene gives rise to unconventional plasmon–phonon hybridization and this hybrid system can be used for tailoring novel subwavelength metama-terials.

Next, we address recent photovoltage generation experiments with unprecented time resolution, applied to graphene and heterostructures of 2d materials. We control and study the underlying carrier-carrier interactions and charge carrier transfer dynamics.

**References**

**1. Electrical Control of Optical Emitter Relaxation Pathways enabled by Graphene**
K.J. Tielrooij, L. Orona, A. Ferrier, M. Badioli, G. Navickaite, S. Coop, S. Nanot, B. Kalinic, T. Cesca, L. Gaudreau, Q. Ma, A. Centeno, A. Pesquera, A. Zurutuza, H. de Riedmatten, P. Goldner, F.J. García de Abajo, P. Jarillo-Herrero, F.H.L. Koppens
Nature Physics [online DOI: 10.1038/nphys3204] (2015)

2. **Highly confined low-loss plasmons in graphene–boron nitride heterostructures**
A. Woessner, M. B. Lundeberg, Y. Gao, A. Principi, P. Alonso-González, M. Carrega, K. Watanabe, T. Taniguchi, G. Vignale, M. Polini, J. Hone, R. Hillenbrand, F. H. L. Koppens
Nature Materials [online DOI: 10.1038/NMAT4169] (2014)

**3. Ultrafast electronic read-out of diamond NV centers coupled to graphene**
Andreas Brenneis, Louis Gaudreau, Max Seifert, Helmut Karl, Martin S. Brandt, Hans Huebl, Jose A. Garrido , Frank H.L. Koppens, Alexander W. Holleitner
Nature Nanotechnoly [online DOI: 10.1038/nnano.2014.276] (2014)

**4. Hybrid 2D–0D MoS2–PbS Quantum Dot Photodetectors**
Kufer, Dominik, Ivan Nikitskiy, Tania Lasanta, Gabriele Navickaite, Frank HL Koppens, and Gerasimos Konstantatos
Advanced Materials 27, no. 1, 176-180 (2015)

**5. Photodetectors based on graphene, other two-dimensional materials and hybrid systems**
F. H. L. Koppens, T. Mueller, Ph. Avouris, A. C. Ferrari, M. S. Vitiello, M. Polini
Nature Nanotechnol. 9, 780-793 (2014)

**6. Phonon-mediated mid-infrared photoresponse of graphene**
M. Badioli , A. Woessner, K. J. Tielrooij, S. Nanot, G. Navickaite, T. Stauber, F. J. Garcia de Abajo, F. H. L. Koppens
Nano Lett. 14, 6374–6381 (2014)