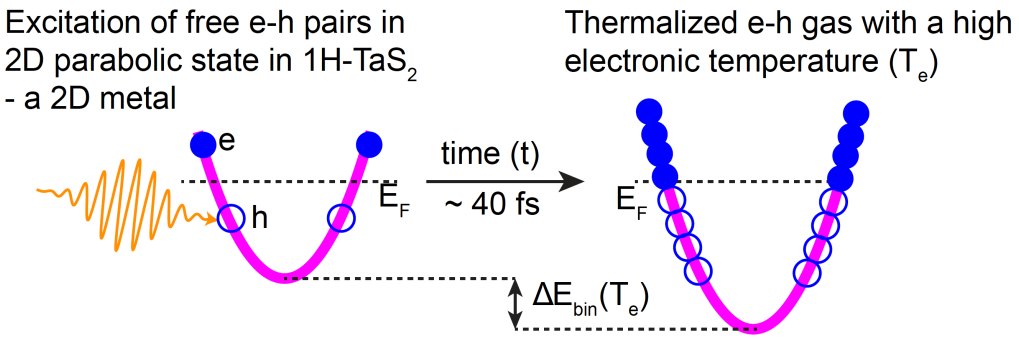
Ultrafast Dynamics of Single Layer TaS_2

Federico Andreatta[1], Habib Rostami[2], Antonija Grubišić-Čabo[1], Deepnarayan Biswas[3], Charlotte E. Sanders[1], Marco Bianchi[1], Cephise Cacho[4], Alfred Jones[4], Richard T. Chapman[4], Emma Springate[4], Phil D. C. King[3], Jill A. Miwa[1], Søren Ulstrup[1], Alexander Balatsky[2], Philip Hofmann[1]

[1]*Aarhus University, DK*
[2]*Nordita, SE*
[3]*University of St. Andrews, UK*
[4]*CLF, STFC Rutherford Appleton Laboratory, UK*
federico@phys.au.dk

Transition metal dichalcogenides (TMDC) at the single layer limit gives rise to new electronic[1] and many-body quantum[2] properties with respect to their bulk counterpart. When a weak van der Waals coupling between the substrate and the TMDC single layer takes place, the electronic properties are retained[3]. Highly correlated metallic TMDCs can host symmetry-breaking electronic instabilities like charge density waves[4]. Among such metallic TMDCs, single layer tantalum disulphide (TaS_2) has been recently synthetized on single crystal metal substrates[5].

Here, we create a model two-dimensional van der Waals heterostructure by synthesizing metallic single layer 1H-TaS_2 on graphene on silicon carbide. We probe the static electronic properties of the single layer TaS_2 and the nonequilibrium carrier dynamics by means of time- and angle-resolved photoemission spectroscopy[6]. The optical excitation induces the excited electrons to adopt a thermalized distribution reaching more than 3000 K within the time-resolution of 40 fs. We show a novel way to fit the spectral function of the band dispersion at the Fermi level tracking the band renormalization on a femtosecond time-scale. An electronic temperature-dependent rigid shift of the excited 1H-TaS_2 metallic band is tracked and related, through a two-dimensional electron gas model, to the electron-electron interactions.



References:
[1] K. F. Mak, C. Lee, J. Hone, J. Shan, and T. F. Heinz. Physical Review Letters 105, 136805, 2010.
[2] X. Xi, L. Zhao, Z. Wang, H. Berger, L. Forró, J. Shan and K. F. Mak. Nature Nanotechnology 10, 765–769, 2015.
[3] J. A. Miwa, M. Dendzik, S. S. Grønborg, M. Bianchi, J. V. Lauritsen, P. Hofmann, and S. Ulstrup. ACS Nano, 9(6), 6502-6510, 2015
[4] K. Rossnagel. J. Phys.: Condens. Matter 23 213001, 2011.
[5] C. E. Sanders, M. Dendzik, A. S. Ngankeu, A. Eich, A. Bruix, M. Bianchi, J. A. Miwa, B. Hammer, A. A. Khajetoorians, and P. Hofmann. Physical Review B, 94(8), 2016.
[6] S. Ulstrup, A. G. Čabo, J. A. Miwa, J. M. Riley, S. S. Grønborg, J. C. Johannsen, C. Cacho, O. Alexander, R. T. Chapman, E. Springate, M. Bianchi, M. Dendzik, J. V. Lauritsen, P. D. C. King, and P. Hofmann. ACS Nano, 10(6), 2016.