

Physikalisches Kolloquium

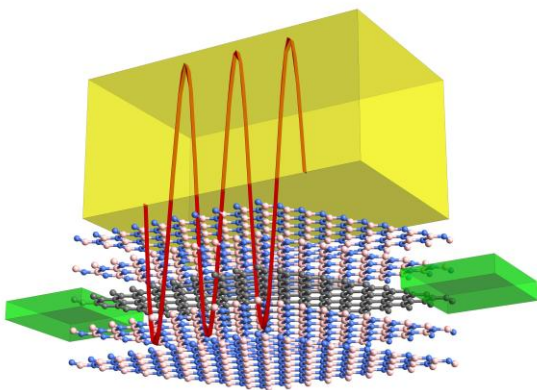
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Layer by Layer: Emergent Phenomena in 2D Material Heterostructures

Stacking various 2D materials together creates multiple research opportunities across diverse fields such as electronics, photonics, optoelectronics, plasmonics, spintronics, and even nanofluidics. In the first part of my talk, I will demonstrate the research potential of merging 2D materials with metals, focusing on resonant field-emission devices¹ and the interfacial generation of plasmon polaritons². In the second part, I will turn to 2D semiconductors, with a focus on excitonic effects, which turn out to be extremely strong in the 2D limit. I will show how the electron-hole interaction responsible for exciton formation can be tuned in a 2D semiconductor by an adjacent gated graphene layer³ or by ferroelectric substrates^{4 5}. Finally, I will demonstrate how charged dopants locally dissociate excitons, establishing point-like junctions that serve as elementary photovoltaic units⁶.



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¹ **M. Trushin**. Resonant field emission from noble-metal/graphene heterostructures. *Nano Letters* **26**, 3760 (2026).

² **M. Trushin**. Electrical generation of surface plasmon polaritons in plasmonic heterostructures. *Physical Review Letters* **136**, 016901 (2026).

³ Z. Qiu, **M. Trushin**, H. Fang *et al.* Giant gate-tunable bandgap renormalization and excitonic effects in a 2D semiconductor. *Science Advances* **5**, eaaw2347 (2019).

⁴ **M. Trushin**, S. Sarkar, S. Mathew *et al.* Evidence of rotational Fröhlich coupling in polaronic trions. *Physical Review Letters* **125**, 086803 (2020).

⁵ X. Wang, M. Grzeszczyk, **M. Trushin** *et al.* Ferroelectric brightening of spin-forbidden dark excitons in a WSe₂/hybrid-perovskite heterostructure. *Nature Communications* **17**, 6285 (2026).

⁶ N. T. T. Vu, M. Chen, Y. W. Ho *et al.* Point-like photovoltaic junction in a 2D semiconductor homobilayer. *Nature Nanotechnology*, accepted for publication (2026).