Institut für Angewandte Physik

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COLLOQUIUM „OPTICS AND CONDENSED MATTER“

Nadine Leisgang [1,2,3]

[1] *Department of Physics, Philipps-University Marburg, Marburg, Germany*
[2] *mar.quest | Marburg Center for Quantum Materials and Sustainable Technologies, Marburg, Germany*
[3] *Department of Physics, Harvard University, Cambridge, MA, USA*

Bilayer MoS_2: a tunable platform for many-body physics

Two-dimensional materials and their heterostructures provide a highly tunable platform for many-body interactions and strongly correlated phenomena, including Mott insulators, generalized Wigner crystals and excitonic insulators. Of particular interest are atomically thin transition metal dichalcogenides (TMDs), which strongly interact with light to form excitons – bound electron-hole pairs. Owing to reduced dielectric screening and quantum confinement, Coulomb interactions are strongly enhanced in these materials, resulting in robust excitons and enabling strong interactions between charge carriers and excitonic quasiparticles. In bilayer structures, electrons and holes can reside in different layers, forming interlayer excitons with large electric dipole moments and highly tunable properties.

In this presentation, I will focus on naturally-grown MoS_2 homobilayers integrated in dual-gate device structures. By independently controlling carrier density and out-of-plane electric field, we investigate the evolution of interlayer excitons and their interactions. We find that interlayer excitons combine large electric dipole moments with strong optical oscillator strength, enabling giant Stark shifts and tunable exciton-exciton interactions [1,2]. In the electron-doped regime, we observe unconventional interaction effects between interlayer excitons that evolve strongly with carrier density and temperature, consistent with the emergence of interlayer electron coherence [3]. Together, these results establish bilayer MoS_2 as a versatile platform for electrically tunable excitonic and many-body physics.

References

[1] N. Leisgang, S. Shree, I. Paradisanos, L. Sponfeldner, C. Robert, D. Lagarde, A. Balocchi, K. Watanabe, T. Taniguchi, X. Marie, R. J. Warburton, I. C. Gerber and B. Urbaszek, Nat. Nanotechnol. **15**, 901–907 (2020).
[2] L. Sponfeldner, N. Leisgang, S. Shree, I. Paradisanos, K. Watanabe, T. Taniguchi, C. Robert, D. Lagarde, A. Balocchi, X. Marie, I. C. Gerber, B. Urbaszek and R. J. Warburton, Phys. Rev. Lett. **129**, 107401 (2022).
[3] X. Liu, N. Leisgang, P. E. Dolgirev, A. A. Zibrov, J. Sung, J. Wang, T. Taniguchi, K. Watanabe, V. Walther, E. Demler, H. Park, P. Kim and M. D. Lukin, Nat. Phys. **21**, 1563–1569 (2025).

July 7th, starting with discussion at 17:00 h, talk at 17:15 h, live IAP lecture hall or via Zoom
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