Particle-hole symmetry protects spin-valley blockade in graphene quantum dots

Luca Banszerus[1,2] ,Samuel Möller[1,2], Eike Icking[1,2], Kenji Watanabe[3], Takashi Taniguchi[4], Fabian Hassler[5], Christian Volk[1,2], Christoph Stampfer[1,2]

1JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany, EU
2Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich,~Germany,EU
3Research Center for Functional Materials,
National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan
4International Center for Materials Nanoarchitectonics,
National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan
5JARA-Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany, EU
Luca.banszerus@rwth-aachen.de

Particle-hole symmetry plays an important role for the characterization of topological phases in solid-state systems. Graphene is a textbook example of a gapless particle-hole symmetric system, where topological phases can be understood by studying ways to open a gap by breaking symmetries [1]. An important example is the intrinsic Kane-Mele spin-orbit gap of graphene, which renders graphene a topological insulator in a quantum-spin Hall phase [2]. Here, we show that the Kane-Mele spin-orbit gap leads to a lifting of the spin-valley degeneracy in bilayer graphene quantum dots [3], resulting in Kramer's doublets with different ordering for electron and hole states preserving particle-hole symmetry. We observe the creation of single electron-hole pairs with opposite quantum numbers and use the electron-hole symmetry to achieve a protected spin-valley blockade in electron-hole double quantum dots. The latter will allow spin-to-charge conversion and valley-to-charge conversion, which is essential for the operation of spin and valley qubits

References

[1] F. Haldane, Phys. Rev. Lett. **61**, 2015 (1988)

[2] C. L. Kane and E. J. Mele, Phys. Rev. Lett. **95,** 226801 (2005)

[3] L. Banszerus et al., Nat. Commun **12**, 5250 (2021)

Figures

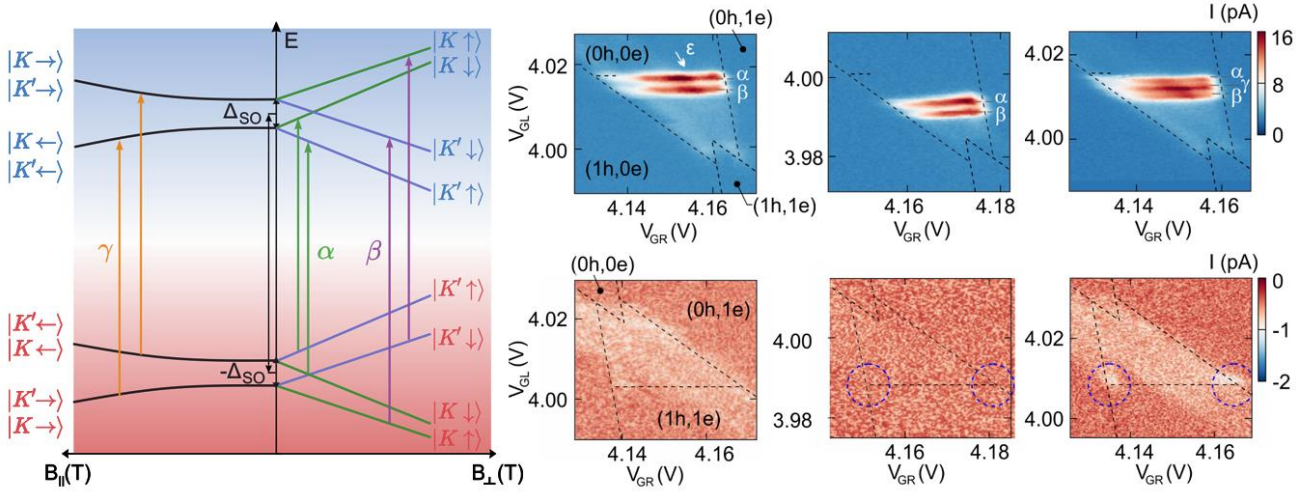

Figure 1: Single particle Pauli-Blockade in an ambipolar electron-hole DQD in bilayer graphene