Gate-tunable intervalley coupling in bilayer graphene quantum dots

Simone Sotgiu[1,2]
H. Dulisch[1,2], N. Berg[1], R. Anghel[1], Y. Mirzanejad[1], L. Mester[1,2], K. Watanabe[3], T. Taniguchi[4], K. Hecker[1,2], C. Volk[1,2] and C. Stampfer[1,2]
[1]*JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany, EU*
[2]*Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany, EU*
[3]*Research Center for Functional Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan*
[4]*International Center for Materials Nanoarchitectonics, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan*

s.sotgiu@fz-juelich.de

Bilayer graphene allows the realization of electron-hole double quantum dots (DQDs) that exhibit near-perfect electron-hole symmetry, in which transport can be understood as the creation and annihilation of electron-hole pairs with matching quantum numbers [1,2]. Given the strong transport blockade selection rules, the presence of non-conserving quantum number mechanisms can be studied in details. Here we report on the observation of a valley non-conserving process, which we attribute to the single particle valley mixing $\Delta_{KK'}$. We show that the presence of a non-vanishing $\Delta_{KK'}$ can be observed as the appearance of an additional feature in the finite bias spectra (Fig. 1a). Notably the strength of the spectral feature can be modified via gate voltages defining the DQDs, which we interpret as a gate-tunable $\Delta_{KK'}$ (Fig. 1b). Through a surrogate modelling approach based on rate equation simulations of our system, we are able to determine the intervalley coupling strength $\Delta_{KK'}$. This work paves the way to a deeper understanding of the non-conserving valley processes in bilayer graphene, fundamental for implementing single-particle valley or Kramers qubits [3].

References

[1] L. Banszerus *et al.* Nature 618 (2023) 51-56.
[2] L. Banszerus *et al*. Nano Letters 18 (2018) 4785-4790.
[3] A.O. Denisov *et al*. Nature Nanotechnology 20 (2025) 494-499

Figures

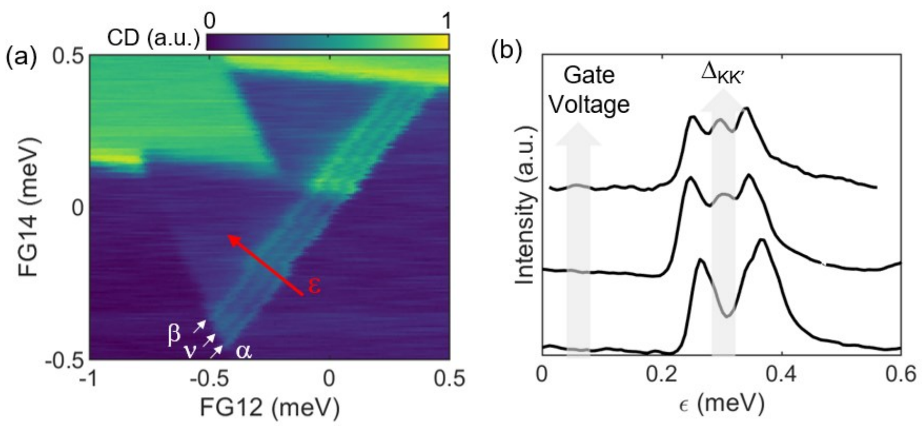

Figure 1: (a) Finite bias spectroscopy of DQDs highlighting the matching-quantum-numbers transitions (α and β) and the transition attributed to a finite $\Delta_{KK'}$ (ν). (b) Linecut along the detuning axis ε, as highlighted in Fig. 1(a), at different gate voltages, showing an intensity increase of feature related to a valley-flip process.