Graphene quantum devices

Klaus Ensslin

ETH Zurich, Otto Stern Weg 1, Zurich, Switzerland

Bilayer graphene is a promising platform for electrically controllable qubits in a two-dimensional material. In general charge, spin and valley states can be used as a starting point for qubits. Of particular interest is the ability to encode quantum information in the valley degree of freedom, a two-fold orbital degeneracy that arises from the symmetry of the hexagonal crystal structure. The use of valleys could be advantageous, as known spin- and orbital-mixing mechanisms are unlikely to be at work for valleys, promising more robust qubits. The Berry curvature associated with valley states allows for electrical control of their energies, suggesting routes for coherent qubit manipulation. In this talk we report about the characteristic relaxation times of these spin and valley states in gate-defined bilayer graphene quantum dot devices. Different valley states can be distinguished from each other with a fidelity of over 99 percent.. The relaxation time between valley triplets and singlets exceeds 500 ms and is more than one order of magnitude longer than for spin states. We also report about quantum devices such as Josephson junctions and SQUIDs in superconducting twisted graphene layers.

This work was done in collaboration with Chuyao Tong, Rebekka Garreis, Wister Huang, Artem Denisov, Hadrien Duprez, Jonas Gerber, Max Ruckriegel, Lisa Gächter, Christoph Adam, Marta Perego, Alexandra Mestre Tora, Elias Portoles, Giulia Zheng, Shuichi Iwakiri, and Thomas Ihn.

[1] Giulia Zheng, Elías Portolés, Alexandra Mestre-Torá, Marta Perego, Takashi Taniguchi, Kenji Watanabe, Peter Rickhaus, Folkert K. de Vries, Thomas Ihn, Klaus Ensslin, Shuichi Iwakiri, Gate-defined superconducting channel in magic-angle twisted bilayer graphene, Phys. Rev. R 6, L012051 (2024)

[2] Chuyao Tong, Annika Kurzmann, Rebekka Garreis, Kenji Watanabe, Takashi Taniguchi, Thomas Ihn, Klaus Ensslin, Pauli blockade catalogue in bilayer graphene double quantum dots, Phys. Rev. Research 6, L012006 (2024)

[3] Shuichi Iwakiri, Alexandra Mestre-Torà, Elías Portolés, Marieke Visscher, Marta Perego, Giulia Zheng, Takashi Taniguchi, Kenji Watanabe, Manfred Sigrist, Thomas Ihn, Klaus Ensslin , Tunable quantum interferometer for correlated moiré electrons , Nature Com. 15, 390 (2024)

[4] Rebekka Garreis, Chuyao Tong, Jocelyn Terle, Max Josef Ruckriegel, Jonas Daniel Gerber, Lisa Maria Gächter, Kenji Watanabe, Takashi Taniguchi, Thomas Ihn, Klaus Ensslin, Wei Wister Huang, Long-lived valley states in bilayer graphene quantum dots, Nature Physics 428, 20 (2024)