The IQARO (SpIn-orbitronic QuAntum bits in Reconfigurable 2D-Oxides) project hosts a series of monthly seminars to communicate the work being done as part of the project.
The seminars will feature presentations from IQARO partners from across all areas of the project, followed by a brief Q&A.

The next seminar will take place on **Tuesday, 4th of November at 3 p.m.**

Carmine Antonio Perroni

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Charge and spin transport properties of STO-based nanostructures in normal and superconductive phases

We have computed the spin-Hall conductance in a multiband model describing the two-dimensional electron gas at the $LaAlO_3/SrTiO_3$ interface in the presence of impurities. By combining linear response theory with a systematic calculation of impurity effects on both the self-energy and vertex corrections, we reproduced the full spin-Hall versus sheet-conductance dependence observed experimentally by Trier et al. [Nano Lett. 20, 395 (2020)], achieving excellent agreement below and above the Lifshitz transition. Our analysis shows that the multiband electronic structure leads to a partial—rather than complete—screening of the spin-Hall conductance, which decreases with increasing carrier density. This approach can be generalized to other two-dimensional systems with broken inversion symmetry and multiband characteristics.
We have also analyzed transport through single and double quantum dots coupled to fermionic leads, a representative setup for nanoscale systems with strong local electron-electron interactions. Using the Lindblad equation, we investigated steady-state and dynamical behaviors. To go beyond the limitations of Markovian and weak-coupling approximations, we applied matrix product state methods to simulate the full system, including the fermionic reservoirs. This nonperturbative approach accurately captures regimes of small bias and strong correlations, where simpler models fail and incorrectly predict zero current. We further included magnetic fields to explore their interplay with spin-orbit coupling.
In addition, we studied superconducting properties of multiband two-dimensional transition-metal oxide superconductors, focusing on the $LaAlO_3/SrTiO_3$ (001) interface. We analyzed the roles of both singlet and triplet pairing channels, the latter being favored by strong spin-orbit coupling and low carrier densities. Finally, we extended our transport analysis to quantum dots connected to superconducting leads, enabling a comprehensive understanding of charge and spin transport in hybrid quantum systems.

Zoom link: https://us02web.zoom.us/j/88555934876?pwd=6QnqUy7UvlR4wzDf4hnb1QpKZKBrTv.1
meeting ID: 885 5593 4876
passcode: QG7y2X

for more information about the project: www.iqaro.eu

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