Seminar of Farkhad Aliev

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IJL- Room 4.014

Superconducting spintronics with spin-orbit coupling and symmetry filtering

Symmetry filtering plays a crucial role in enhancing giant tunnelling magnetoresistance (TMR) by selectively allowing specific electronic states to tunnel through the barrier. Such a mechanism is key for high-performance spintronic devices like magnetic random-access memories, magnetic sensors or spin-light emitting diodes. On the other hand, spin-orbit coupling (SOC) is a central mechanism for perpendicular magnetic anisotropy in spintronics.

Recently, it has become clear that SOC is crucial in mediating the interactions in heterostructures combining superconductors and ferromagnets, otherwise antagonistic materials where exotic interfacial quantum phenomena have been discovered over the last decade. Building on recent advances in studies of various V/MgO/Fe(100)-based, this talk provides a comprehensive review of superconducting spintronics driven by electron symmetry filtering and interfacial SOC [1-6]. It emphasizes the critical role of a crystalline MgO barrier in selectively transmitting specific electronic states between V(100) and Fe(100). It also highlights how interfacial SOC enables symmetry mixing, allowing for the interaction between ferromagnetic and superconducting orderings though MgO(100). This mutual interaction, mediated by interfacial SOC, facilitates the conversion of spin-singlet to spin-triplet Cooper pairs. The goal is to provide key insights into designing SOC based superconductor-ferromagnet hybrid structures for advanced superconducting spintronic functionalities [1-6].

[1] I. Martínez et al., Phys. Rev. Appl. **13**, 014030 (2020).
[2] C. González-Ruano et al., Phys. Rev. B **102**, 020405(R) (2020).
[3] C. González-Ruano et al., Adv. Elect. Materials, **8**, 2100805 (2021).
[4] C. Gonzalez-Ruano, et al., Phys. Rev. Lett. **130**, 237001 (2023).
[5] P. Tuero et al., Phys. Rev. B **110**, 094504 (2024)
[6] C. Gonzalez-Ruano, et al., Nat. Commun. **16**, 9524 (2025).

Farkhad Aliev graduated with top honors from the Faculty of Physics at Lomonosov Moscow State University, where he also completed and defended his doctoral thesis. He has served as an invited professor and visiting scientist at both the Universidad Autónoma de Madrid and Katholieke University Leuven. He is currently a full professor at the Universidad Autónoma de Madrid. His research focuses on strongly correlated systems, thermoelectric effects, magnetization dynamics, electron transport and noise in magnetic and superconducting nanostructures. Since 2026, he has been actively collaborating with the University of Lorraine / CNRS, resulting in nearly 20 joint publications. His talk will present an overview of the latest developments from this collaboration, highlighting work published over the past five years.

Séminaire organisé dans le cadre du programme interdisciplinaire MAT-PULSE

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