INSTITUT DE PHYSIQUE ET CHIMIE DES MATERIAUX DE STRASBOURG
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Séminaire AXE 1 - Sciences et Matériaux Quantiques

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Nonlocality at the Microscopic Scale: The Andreev Molecule in Ultraclean Carbon Nanotubes

Nonlocality is a defining feature of quantum mechanics: wavefunctions may extend over distances far exceeding the size of the object they describe. In Josephson junctions, this manifests through Andreev bound states (ABS), coherent electronic states whose spatial extent is set by the superconducting coherence length. When two Josephson junctions are placed closer than this length scale, the ABS wavefunctions hybridize, forming an Andreev molecule. In this regime, the Josephson effect becomes intrinsically nonlocal: the supercurrent flowing through one junction acquires a dependence on the superconducting phase applied to the other.

In this seminar, I will present our recent experimental realization of an Andreev molecule using ultraclean carbon nanotube weak links, which constitute ideal one-dimensional quantum conductors with only one or two electronic channels. This platform allows us to probe the microscopic structure of nonlocal superconducting states with unprecedented clarity. I will show how ABS hybridization emerges in a double quantum dot configuration, how it reshapes the current-phase relations of both junctions, and how it reveals the behavior of electrons with possible nonlocal Cooper pair splitting.

By engineering nonlocality at the level of a few microscopic fermionic states, our work opens a controlled route toward multi-terminal superconducting devices, correlated Andreev physics, and engineered quantum matter.

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