"Exploring Superconducting Orbitronics: From Quantum Phenomena to Devices"

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In this seminar, I present the emerging concepts of orbital moments and orbital currents, and contextualize them within the framework of Cooper pairs. The common view of superconductivity centers on Cooper pairs, which can exist in either a spin singlet state or a spin triplet state. Typically, magnetic fields and magnetic materials are extensively utilized to convert spin singlet states into spin triplet states, serving both fundamental research purposes and applications for superconducting spintronics. In this context, I will pursue an entirely different approach by elucidating and demonstrating how to attain superconducting quantum states with high orbital angular momentum. To achieve this goal, I focus on the importance of electrical and mechanical methods over magnetic forces in designing superconducting orbitonic effects. The use of orbital degrees of freedom introduces a completely new range of quantum phases and phenomena. For instance, I explore the electric-versus-magnetic dichotomy in superconductors by demonstrating that novel forms of non-Abrikosov vortices can be generated using electric or strain fields rather than magnetic fields. I demonstrate that colossal magneto-electric effects can be achieved by exploiting the orbital Edelstein effect. Orbital antiphase pairing and π-Josephson coupling can be effectively realized without violating time-reversal symmetry. Finally, I discuss how the discovered quantum phases and effects enable us to create new superconducting devices that could be utilized for quantum sensing, quantum computing and energy efficiency.