Quantum Limits in the Miniaturization of Tunnel Junctions

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Abstract:
Sixty years ago in December 1959, when Richard Feynman said that there is "Plenty of Room at the Bottom", he envisioned the seemingly endless possibilities of the microscopic world, which we now refer to as Nanoscience. However, his statement also implies that there is a bottom meaning that there is a limit to the miniaturization of every process. The tunneling effect is a quantum mechanical phenomenon that allows particles to pass through a potential barrier for which classically they would not have enough energy. It is not just of fundamental scientific interest in experimental techniques, such as scanning tunneling microscopy (STM), but also technologically relevant as it has found its way into several applications in memory storage, such as hard disks and solid state drives. I will discuss the fundamental limits of transport through a tunnel junction by means of STM. This concerns, for example, the changes in the tunneling process imposed by revealing the quantum nature of the electron charge at extremely low temperatures. Further, we exploit magnetic impurities coupled to a superconductor to create single quasiparticle levels inside the superconducting gap (Yu-Shiba-Rusinov states). I will show how we use these states to demonstrate the bare minimum of what is necessary to create a current through a tunnel junction.