Universität Basel

Research Project

Quantum-Transport Phenomena in Hybrid Devices based on Nanowires

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A large excitement arose recently in solid-state physics when it was realized that quasi-particles with unconventional properties can appear in edge-states of topological insulators (TI) coupled to a superconductor (SC). The typical TI material is a bulk three-dimensional (3D) crystal or a twodimensional (2D) film, where, for example, a quantum spin-Hall state can emerge. However, TI have also been considered in one dimension (1D). A particular clean example is a tight-binding chain, the so-called Kitaev chain,1 of spin-less electrons that are pairwise coupled by a SC. Under appropriate conditions two excitations located at the end of chain appear with properties of a Majorana particle, a particle that is its own antiparticle and referred in this context as Majorana bound-state (MBS). 2 The Kitaev chain has been realized in semiconducting nanowires (SNWs) with large spin-orbit interaction, such as InAs and InSb, and experimental evidence for MBSs is slowly accumulating. Since we have many years of experience in realizing and studying multi-terminal hybrid devices with superconducting contacts, and since there are currently much more theoretical proposals for testing properties of MBSs than actual experiments, we plan with this proposal to embark on this. Both SNWs and carbon nanotubes (CNTs) will form the basis to engineer and explore topological properties. We will in particular study the MBS with high-spectral resolution using quantum-dot based tunneling spectroscopy. We will explore non-local properties in multiterminal devices, compare Andreev-bound states with MBSs and search for, as well as engineer, helical gaps using both intrinsic and synthetic spin-orbit interaction realized by either ferromagnetic side-gates or through hyperfine interaction that can drive a spin-helical state. In addition to conventional DC transport measurements, we will study high-frequency properties, such as the RF admittance, noise properties in novel geometries, such as the phase-controlled Majorana charge-box. A large excitement arose recently in solid-state physics when it was realized that quasi-particles withunconventional properties can appear in edge-states of topological insulators (TI) coupled to asuperconductor (SC). The typical TI material is a bulk three-dimensional (3D) crystal or a twodimensional(2D) film, where, for example, a quantum spin-Hall state can emerge. However, TI have alsobeen considered in one dimension (1D). A particular clean example is a tight-binding chain, the so-calledKitaev chain,1 of spin-less electrons that are pairwise coupled by a SC. Under appropriate conditions twoexcitations located at the end of chain appear with properties of a Majorana particle, a particle that is itsown antiparticle and referred in this context as Majorana bound-state (MBS). 2 The Kitaev chain hasbeen realized in semiconducting nanowires (SNWs) with large spin-orbit interaction, such as InAs andInSb, and experimental evidence for MBSs is slowly accumulating. Since we have many years ofexperience in realizing and studying multi-terminal hybrid devices with superconducting contacts,and since there are currently much more theoretical proposals for testing properties of MBSs than actualexperiments, we plan with this proposal to embark on this. Both SNWs and carbon nanotubes (CNTs)will form the basis to engineer and explore topological properties. We will in particular study the MBS withhigh-spectral resolution using quantum-dot based tunneling spectroscopy. We will explore non-localproperties in multiterminal devices, compare Andreev-bound states with MBSs and search for, as wellas engineer, helical gaps using both intrinsic and synthetic spin-orbit interaction realized by eitherferromagnetic side-gates or through hyperfine interaction that can drive a spin-helical state. In addition toconventional DC transport measurements, we will study high-frequency properties, such as the RFadmittance, noise properties in novel geometries, such as the phase-controlled Majorana charge-box.

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