Electronic properties of vortex matter in nanostructured and hybrid superconducting systems

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We report on the results of our recent theoretical studies of the electronic structure of vortex states in various nanostructured and hybrid superconducting (S) systems in the context of their applications in quantum computing and single electronic devices.

In particular, we show that the semiconducting (Sm) nanowires fully covered by a thin S shell trapping vortices in an external magnetic field host an unusual modification of the subgap Caroli - de Gennes - Matricon (CdGM) quasiparticle (QP) states. The spectrum of these modes propagating along the vortex axis is strongly affected by the interplay of spin-orbit coupling inside the nanowire and the normal and Andreev reflections at the SmS interface. This interplay increases the group velocity of the CdGM states along the vortex line and transforms them into the waveguide type modes with quite exotic behavior. We study such CdGM waveguides within the framework of the Bogoliubov - de Gennes theory and predict a number of fascinating phenomena such as the giant oscillations of the CdGM levels, the closure and reopening of the hard gap in the QP spectrum controlled by the vortex entry/exit and the formation of the Majorana-type evanescent modes bound to the nanowire ends.

Focusing then on the dirty limit we consider the electronic structure of the giant vortex states in a mesoscopic superconducting disk using the Usadel approach. The local density of states profiles are shown to be strongly affected by the effect of QP tunneling between the states localized in the vortex core and the ones bound to the sample edge. Decreasing temperature leads to a crossover between the edge-dominated and core-dominated regimes in the magnetic field dependence of the tunneling conductance. This crossover is discussed in the context of the efficiency of quasiparticle cooling by the magnetic-field-induced QP traps in various mesoscopic superconducting devices.

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