Rotating Zeeman field as a tool for Majorana zero mode detection in topological superconducting wire

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We consider theoretically a $1D$ Rashba nanowire in proximity to s-wave superconductor, and subjected to Zeeman field. A quantum dot, coupled to one end of the wire, serves as Majorana Zero Mode (MZM) detector. The MZM detection is realized by rotation of the Zeeman field in the wire, in plane perpendicular to the Rashba field, while keeping the Zeeman field in the dot intact. Maintaining the local field in the dot seems to be challenging, however the recent experiments on the local spin control in quantum dots [1] prove it to be achievable. We assume two $CoFe$ magnetic stripes near the dot generate stable Zeeman field in the dot (in z-direction), geometry similar as in [2]. Measurement of the spin polarization at Fermi energy, ϵ_F, is performed by magnetic STM tip (also magnetized in z-direction) hoovering above the dot. Similar geometry has recently been realized experimentally [3]. The measurement is a two step procedure: i) the emergence of MZMs can be spotted as a Zero Bias Peak (ZBP) in the differential conductance through the normal electrode-QD-wire junction, ii) at the same time spin polarization of the QD ($magQD$) is recorded while rotating the Zeeman field in the wire. The field is rotated from x-direction (along the wire axis), $\Theta = 0$, to z-direction, $\Theta = \pi/2$. The QD spin sub-level arrangement is tuned by gate voltage such that $\epsilon_\downarrow < \epsilon_F < \epsilon_\uparrow$. We demonstrate that apart of the ZBP signaling the emergence of Majorana modes, the absolute value of $magQD$ substantially decreases when Θ angle changes from $\pi/2$ to zero. It is caused by the developing of the second MZM at the wire end, visible in the remaining spin sector of the dot as $\Theta \to 0$. This effect is not observed for $\Theta = \pi/2$ and becomes more pronounced for strong QD-wire coupling. It is qualitatively different from the case of spotting the second chiral MZM for strong QD-wire coupling [4]. This behavior is in stark contrast to the case of the wire in its trivial state, when ZBP disappears and $magQD$ is practically independent on Θ angle. In the case of an accidental QD spin sub-level aligned with Fermi energy, the ZBP is observed due to a given level $\epsilon_\sigma = \epsilon_F$, but the $magQD \simeq \mp 1$ depending on the spin level, and is independent on Θ value. The presented measurement procedure enables to distinguish trivial Andreev levels, accidentally placed near Fermi energy, from true MZMs.

References:

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