CMD2020GEFES mini-colloquium

Hybrid semiconductor-superconducting nanostructures: from Andreev to Majorana bound states

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In superconducting materials, electrons form Cooper pairs, whose condensate can be described by a single order parameter, also called pair potential. The amplitude of this complex order parameter, the superconducting gap Δ, determines the lowest energy level that a single electron can occupy in a bulk, homogeneous superconductor, whereas the phase plays an important role when describing the transport of Cooper pairs through weak links, where the pairing potential changes, or even vanishes. In this case, single electron states can develop below the gap that are localized to the weak link. Collectively, these subgap states are called Andreev bound states (ABSs) and are in the focus of theoretical and experimental efforts owing to their fundamental importance in describing nanoscale superconductivity, and to their technical relevance as the basis of emerging quantum technologies.

Because ABSs host single, unpaired electrons, both the charge and the spin degree of freedom can store quantum information while strongly couple to the embedding superconducting circuit, providing new avenues for quantum information processing. This interplay can also be investigated in quantum dots embedded in superconducting circuits, where Yu-Shiba-Rusinov states emerge and lead to a flexible platform of analog quantum simulations.

Furthermore, a new kind of ABS with exotic properties has been recently discovered in engineered topological superconductors consisting of semiconductor channels proximitized with superconducting contacts. These states are known as Majorana bound states (MBSs) and its first experimental signatures were reported in 2012. The MBSs are localized zero-energy excitations protected by the topology of a superconducting bulk. Owing to this protection, together with their non-Abelian braiding statistics, they form the basis of topologically protected quantum computing. This prospect has spurred a great deal of efforts in recent years towards their creation and manipulation in various solid-state platforms, including semiconductor nanowires, planar heterostructures and quantum dot chains.

In this Mini-colloquium we will bring together key international players in the field and engage in a synergetic discussion on theoretical developments, experimental efforts and materials science. The focus of the colloquium will be on hybrid semiconductor-superconducting nanostructures, which is the most investigated platform for ABSs and MBSs. We will discuss recent advances on different relevant aspects, future challenges, etc.

The minicolloquium will consist of invited talks (see the list of speakers below) and a good amount of contributed talks.

The list of confirmed invited speakers includes:

* Sergey Frolov, Pittsburgh Quantum Institute , (USA)
* Georgios Katsaros, IST, (Austria)
* Angela Kou, Microsoft Quantum Lab Delft, (Netherlands)
* Peter Krogstrup, Microsoft Quantum Materials Copenhagen, (Denmark)
* Yuval Oreg, Weizmann Institute, (Israel)
* Javad Shabani, New York University, (USA)

Funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 828948 (FETOpen AndQC) and from the Condensed Matter Physics Center (IFIMAC) at UAM is available to partially cover the expenses of our invited speakers.

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