Superconducting quantum devices for functional brain imaging and innovative qubits

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We will present results regarding superconducting quantum devices for brain function imaging applications and ferromagnetic Josephson junctions for the implementation of innovative superconducting qubits. In particular, we refer to Superconducting QUantum Interference devices (SQUIDs), and ferromagnetic Josephson junctions. SQUIDs are the oldest and most consolidated quantum magnetic sensors but at the same time the most sensitive sensors capable of carrying out measurements with an energy resolution at the quantum limit (few Planck's constants per unit of bandwidth) [1]. We will discuss the most important applications of these magnetic sensors, namely magnetoencephalography (MEG), used with great success in neuroscience and neurodegenerative diseases (Alzheimer's syndrome, Parkinson's disease, amyotrophic lateral sclerosis, frontotemporal dementia) through the study of brain connectivity [2-3].
In ferromagnetic Josephson junctions, a thin layer of ferromagnetic material is inserted inside the superconducting electrodes of the Josephson junctions [4]. In addition to being used as ultrafast digital memories, these junctions can be used for the development of innovative superconducting qubits in which it is possible calibrate the operating frequency digitally using magnetic field pulses. The characterization of the ferromagnetic junctions at temperatures close to absolute zero (10 mK) has also highlighted for the first time a physical phenomenon of great interest which involves an ordered and collective polarization of the spins of the electrons near the interface between the superconducting and ferromagnetic, a phenomenon also known as the inverse proximity effect [5].

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