1.3.31 Quantum computation: protocols and process implementation

Part of the activity was devoted to design and possibly implement, new quantum protocols and platform for general purposes.

In Ref. [1] a nanoscale implementation of a Mach-Zhender interferometer was presented with spin-resolved quantum Hall states – see Fig. 1.

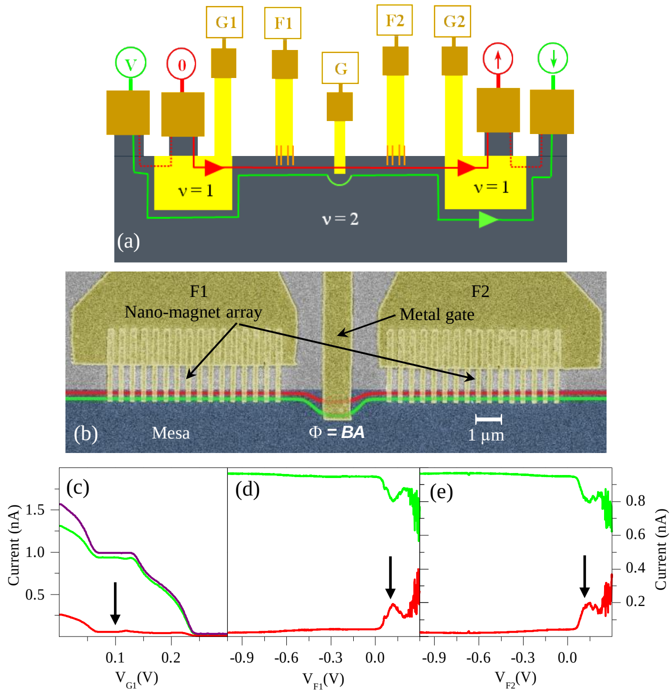

Figure 1. Schematics of the Mach-Zehnder interferometer implemented in Ref. [1] – figure from the paper.

Spontaneous synchronization is a fundamental phenomenon, important in many theoretical studies and applications. Recently this effect has been analyzed and observed in a number of physical systems close to the quantum mechanical regime. In Ref. [2] we proposed the mutual information as a useful order parameter which can capture the emergence of synchronization in very different contexts, ranging from semi-classical to intrinsically quantum mechanical systems.

In Ref. [3] a technique was proposed that enables one the creation of quantum discord between two distant nodes, each containing a cavity consist of the Bose-Einstein condensate, by applying a non-ideal Bell-like detection on the output modes of optical cavities.

In Ref. [4] we addressed the problem of realizing a reliable quantum memory based on zero-energy Majorana modes in the presence of experimental constraints on the operations aimed at recovering the information. In particular, we characterized the best recovery operation acting only on the zero-energy Majorana modes and the memory fidelity that can be therewith achieved.

On the basis of the quantum Zeno effect we showed [5] that a strong amplitude damping process applied locally on a part of a quantum system can have a beneficial effect on the dynamics of the remaining part of the system. Quantum operations that cannot be implemented without the dissipation become achievable by the action of the strong dissipative process. In Refs. [7,8] the mathematical aspects of the problem were formalized and in Ref. [6] we generalize this idea by identifying decoherence-free subspaces (DFS's) as the subspaces in which the dynamics becomes more complex. Applying methods from quantum control theory we characterized the set of reachable operations within the DFS's. We provide three examples which become fully controllable within the DFS's while the control over the original Hilbert space in the absence of dissipation is trivial. In particular, we show that the (classical) Ising Hamiltonian is turned into a Heisenberg Hamiltonian by strong collective decoherence, which provides universal quantum computation within the DFS's.

In Ref. [9] we investigated the supercurrent in a hybrid topological Josephson junction consisting of two planes of topological insulator (TI) in a specific configuration, which allows both local (LAR) and crossed (CAR) Andreev processes at the interfaces with two conventional s-wave superconductors. In particular, we demonstrated that the voltage gating allows the manipulation of the entaglement symmetry of non-local Cooper pairs associated to the CAR process. We established a connection between the Josephson current-phase relationship of the system and the action of the two external fields, finding that they selectively modify the LAR or the CAR contributions. Remarkably, we found that the critical current of the junction takes a very simple form which reflects the change in the symmetry occurred to the entangled state and allows to determine the microscopic parameters of the junction.

As the possibility to decouple temporal and spatial variations of the electromagnetic field, leading to a wavelength stretching, has been recognized to be of paramount importance for practical applications, in Ref. [10] we generalize the idea of stretchability from the framework of electromagnetic waves to massive particles. A necessary and sufficient condition which allows one to identify energetically stable configuration of a 1D quantum particle characterized by arbitrary large spatial regions where the associated wave-function exhibit a flat, non-zero profile is presented, together with examples on well-known and widely used potential profiles and an application to 2D models.

In Ref. [11] we proposed a spatial analog of the Berry's phase mechanism for the coherent manipulation of states of non-relativistic massive particles moving in a two-dimensional landscape. In our construction the temporal modulation of the system Hamiltonian is replaced by a modulation of the confining potential along the transverse direction of the particle propagation. By properly tuning the model parameters the resulting scattering input-output relations exhibit a Wilczek-Zee non-abelian phase shift contribution that is intrinsically geometrical, hence insensitive to the specific details of the potential landscape.

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