From engineering a half-open Floquet qu-bit to thermodynamics of topological effects in multi-terminal Josephson junctions

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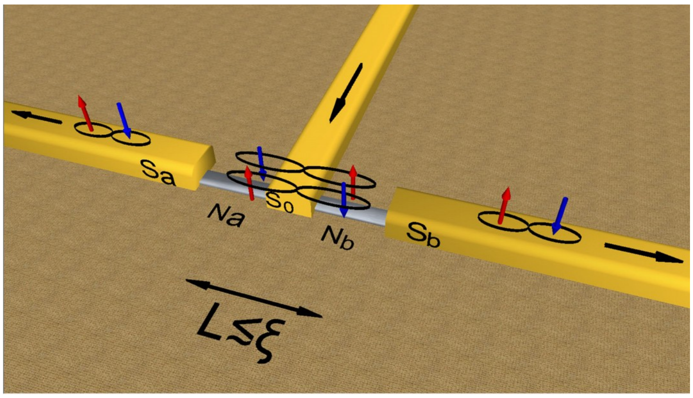
Many experimental and theoretical works in the field of quantum nanoelectronics aim at manipulating **simple systems** with small numbers of degrees of freedom. Several implementations have been realized, on the basis of Josephson junctions.



Two theoretical proposals have been made recently, which aim at using a Josephson junction as a simulator of some effects appearing in band theory. Superconducting phase variable between 0 and 2pi plays the role of wave-vector in the Brillouin zone:

1. The first proposal [1] consists in using a three-terminal Josephson junction in order to simulate the wave-function of an electron in the presence of electric field, and in a periodic potential. The time periodicity of the Josephson Hamiltonian plays the role of the potential of the crystal lattice, which is periodic in space. The physics is then related to **Bloch oscillations** and to **Wannier-Stark resonances**. It is possible to fabricate on this basis a two-level system in Floquet space, namely, a qu-bit sharing some features of open systems, and others of closed systems.

2. The second proposal consists in using a four-terminal Josephson junction to produce **nontrivial topology** [2] analogous to conductance quantization in the integer quantum Hall effect.

A phase-biased Josephson junction gives rise to a **classical** current. At the level of BCS theory, increasing voltage from V=0 in a Josephson junction is thus a way to **increase the strength of quantum fluctuations**, starting from the classical limit for V=0. Those multi-terminal Josephson junctions are thus well suited for application of the **mathematical tools of semi-classical theory**. Moreover, topology fits well in the framework of semi-classical theory. Numerical Keldysh Green's function calculations will also be a useful point of comparison for those analytical approaches beyond the adiabatic limit.

Another direction of research consists in developing a description based on **quantum thermodynamics**, more especially regarding the distinction between dissipative and non-dissipative currents, and the open problem of the classification of all processes contributing to transport and noise in those set-ups, beyond the adiabatic or perturbative regimes.

Another proposed line of research is to **optimize the coherence time** of this Floquet two-level system, with time-dependent voltages which can allow preventing quasiparticle trapping on the junction. Implementing **back-action** seems to be promising.

Methodology: It is expected that the candidate will acquire experience on numerical calculations, with emphasis on more theoretical and mathematical issues, in connection with development of semi-classics in collaboration with Alain Joye and Frederic Faure in the mathematical physics group of Institut Fourier in Grenoble. The candidate will also be encouraged to interact with experimental groups.

References: [1] R. Mélin *et al.*, Phys. Rev. B **95**, 085415 (2017).
[2] R. P. Riwar *et al.*, Nature Comm. **7**, 11167 (2016).