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Topological Quantization by Controlled Paths : Application to Cooper Pair Pumps

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Exact *topological quantization* of a physical observable is a phenomenon which occurs in some idealized well-known systems. In the field of condensed matter physics, there are principally two effects given rise to such a quantization outlined by an integer topological number called *first Chern number* (or *Chern index*) : the *AC Josephson Effect* (*ACJE*) and miscellaneous *quantum Hall conductances* (e.g. *Integer Quantum Hall Effect* — *IQHE* — in 2D and 3D, *Spin Hall Effect*). Due to the topological nature of the Chern index, these quantum process present an intrinsic robustness towards unavoidable experimental imperfections. This is why they are *de facto* strongly interesting for metrological purposes.

In order to redefine physical standards, one of the actual challenges is to close the so-called *metrological triangle* which vertices are the ultra-precisely known unit of time (*second*), and the electrical units of voltage (*Volt*) and current (*Ampère*). *Volt* and *second* are linked by the *ACJE*, whereas the *IQHE* converts *Volt* into *Ampère*. It remains to relate *Ampère* to *second*. While some researches focus on normal single electron pumps or hybrid single electron transistors, one studies an entire superconducting quantum circuit named *Cooper Pair Pump* (*CPP*), polarized in phase [1]. This is simply composed of two islands each submitted to a gate voltage (resp. V_{g1} and V_{g2}) included in a phase polarized (through a transverse magnetic field of strength B) array of three Josephson junctions. That is, the evolution of the *CPP* is controlled by three parameters defining a parameter space $\mathscr{P}$ of triplets (V_{g1}, V_{g2}, B). Some points in this space exhibit a ground state degeneracy which is a topological defect with respect to the "globally non-degenerate ground-state band structure", assigning a non-zero Chern index to some surfaces in $\mathscr{P}$. One has theoretically demonstrated the possibility of an ultra-precise charge transfer of Cooper pairs while operating adiabatic cycles through resonant toroidal helices lying on a bidimenisional torus $\mathbb{T}$ which encloses a single degeneracy in $\mathscr{P}$ [2]. More precisely, the pump is susceptible to generate a current $\mathscr{I} = 2e\, c_1(\mathbb{T})\, \nu$, where ν is the operating frequency and $c_1(\mathbb{T})$ is the Chern index of the torus.

[1] R. Leone, L.-P. Lévy & P. Lafarge, *Cooper-Pair Pump as a Quantized Current Source*, Phys. Rev. Lett. **100**, 117001 (2008).

[2] R. Leone & L.-P. Lévy, *Topological quantization by controlled paths: Application to Cooper pairs pumps*, Phys. Rev. B **77**, 064524 (2008).