$\mathbf{Z}_Q$ topological invariants of gapped quantum systems for integer Q

I. Maruyama[a] and Y. Hatsugai[b]

[a]Graduate School of Engineering Science, Osaka University, Osaka, Japan
[b]Institute of Physics, University of Tsukuba, Ibaraki, Japan

The quantized Berry phase as a local order parameter of gapped quantum liquids at zero temperature is proposed for characterization of a topological or quantum order in various models including strongly correlated electron systems, where the Berry phase is quantized as Z_2 value, i.e., 0 or π, due to the time-reversal, or lattice-inversion symmetry in any dimension. [1] The system can be characterized by a set of Z_2 values.

Recently, we have proved that the lattice-rotational symmetry enables Z_Q quantization of Berry phases for interacting electrons,[2] where Z_{d+1} ($Q = d + 1$) Berry phases are defined for d-dimensional lattices: Polyacetylene, Kagome and Pyrochlore lattice respectively for $d = 1, 2$ and 3. The invariants are order parameters for quantum Q-multimer, and characterize the topological phase transitions by the multi-merization. Not only bulk systems but also molecules like C_{60} have Z_Q topological invariants, which are topologically protected by the multimerization gap.

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