Topological pump in N-leg spin ladder and its plateau transition by the Chern number

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A topological pump is a quantized charge transport as a time-periodic process in the adiabatic approximation proposed by Thouless and its pumped charge is given by the Chern number [1]. It is experimentally realized by using ultracold atoms and the quantization of the discontinuous shift of the center of mass (CoM) of an atomic cloud is observed [2,3]. The experimental realization triggers further studies. The bulk-edge correspondence guarantees that the shift of the CoM is equal to the Chern number and is quantized due to the edge states [4]. Ref. [5] proposes a general idea to construct a topological pump from the viewpoint of the SPT phases and phase transitions among them. Application to spin systems is also considered[6,7].

In this study [8], we consider a topological pump in an N-leg spin ladder by applying the framework of Ref. [5]. Spin ladders are known to have a rich symmetry protected topological (SPT) phase structure and several gapless transition points [9,10] and thus various pumps whose pumped spin is quantized as different integer values can emerge.

We introduce spatial clusterization to the N-leg spin ladder whose strong coupling limit is a set of $2N$-site staircase-shaped clusters. By changing the modulation amplitude, STP phases emerge. We find that the N-leg ladder experiences N-time SPT phase transitions. We use these gapless transition points as topological obstructions to construct a topological pump. A pump parameter path is set to connect two different SPT phases enclosing the gapless points . Specifically, we add the time-dependent staggered magnetic field, which breaks all the symmetries protecting the SPT phases. By the Chern numbers we characterize the pump and numerically find plateau transitions. We also discuss the pump in an open boundary and the bulk-edge correspondence.

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