Engineering non-local correlations in fermionic systems

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Large correlations and entanglement constitute two fundamental elements in quantum many-body physics, which are basic resources in quantum communications and computation. As example, the ground states of quantum systems are known to present very interesting entanglement properties indicating by the *area-law* which describes the entanglement entropy of a certain block for gapped systems. Nevertheless, this *area-law* can be maximally violated when systems are gapless. In these cases the entanglement presents a volumetric entanglement, doing it difficult to implement in actual quantum devices. Therefore, for attractive applications a large entanglement preserved by a gapped systems is traced to do real devices in quantum computation [1].

In this work, we have studied large correlations between distant locations and entanglement properties in 1D deformed systems that maximally the gap. The systems studies are mainly finite fermionic chains (top view of Fig. 1). Then, we have established the properties of different systems derived from the previous one (inset in the bottom graph of Fig. 1).

From the Su-Schrieffer-Heeger (SSH) model, we have used machine-learning techniques to obtain the trade-off line between the end-to-end correlations and the energy gap for open chains at half-filling [2]. We find that edge-dimerized chains, where the second and penultimate hoppings are reinforced, are very often close to the optimal configuration.

This pattern is then generalized to provide strongly correlated superlattices on a fermionic chain, characterizing the strongly correlated subsystem via its entanglement properties. From these studies we have introduced the concept of entanglement detachment, i.e., enlarging a few couplings of a Hamiltonian can effectively detach a block within the ground state [3]. Lastly, we show that edge-dimerized legs can induce strong correlations among the extremal sites of a star-graph with a central ring. In this last case, a magnetic flux through the ring can alter significatively the correlations [3], via an analogue of the Aharonov-Bohm effect (see bottom panel of Fig. 1).

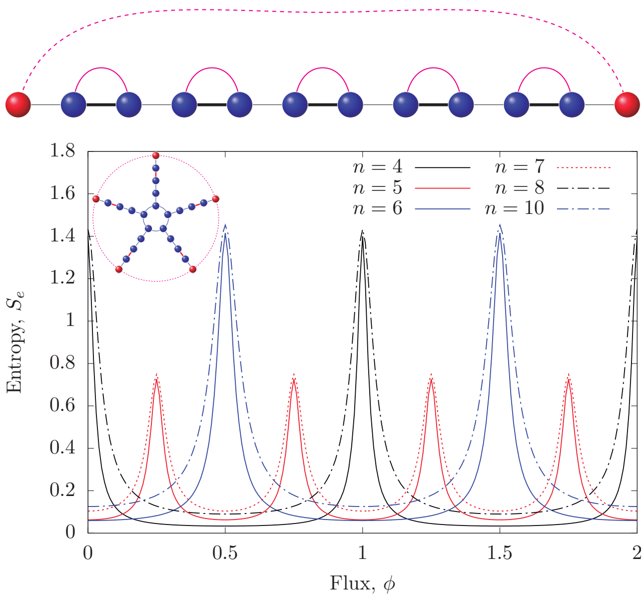

Fig. 1. (Top) Illustration for dimerized fermionic chain with alternate lighter and stronger links. Dashed line represents a large distance correlation between end-to-end sites. (Bottom) Entropy of star-graph system (shown at the upper left corner) as a function of the flux traversing the central ring.

[1] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information* (Cambridge University Press, 2018).

[2] H. Santos, J. E. Alvarellos, and J. Rodríguez-Laguna, arXiv:1809.06246.

[3] H. Santos, J. E. Alvarellos, and J. Rodríguez-Laguna, Eur. Phys. J. D (in press) [arXiv:1809.06793].