

Confinement and charge ordering in the 1D \mathbb{Z}_2 lattice gauge theory with long-range density interactions

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We study a one-dimensional \mathbb{Z}_2 lattice gauge theory with hard-core bosons at half-filling, focusing on the effects of extended interactions beyond nearest neighbors [1]. Using matrix product state methods within the density matrix renormalization group framework, we compute the charge gap, static structure factor, and pair–pair correlation functions. Starting from two representative nearest-neighbor interaction regimes that realize Luttinger liquid and Mott insulating phases, we show that the inclusion of second nearest-neighbor repulsion qualitatively alters the low-energy physics. For weak nearest-neighbor interactions, increasing the second nearest-neighbor coupling drives a direct transition from a Luttinger liquid to a charge-ordered insulating phase. In contrast, for stronger nearest-neighbor interactions, the Mott insulator is destabilized in favor of an intermediate Luttinger liquid regime before the system enters the charge-ordered phase. Extended interactions enhance charge ordering and suppress pair coherence, as signaled by pronounced peaks in the structure factor and rapidly decaying pair–pair correlations. Our results highlight how longer-range interactions enrich the physics of one-dimensional \mathbb{Z}_2 lattice gauge theories [2] and modify the interplay between gauge fields and confinement.

References:

[1] Y. Zambrano, A. Alekseev, K.J. Kapcia, K. Cichy and A. Cichy, *Phase structure of the one-dimensional \mathbb{Z}_2 lattice gauge theory with second nearest-neighbor interactions*, <https://arxiv.org/abs/2512.10755>, (2025).

[2] M. Kebrić, U. Borla, U. Schollwöck, S. Moroz, L. Barbiero, and F. Grusdt, *Confinement induced frustration in a one-dimensional \mathbb{Z}_2 lattice gauge theory*, *New J. Phys.* 25, 013035 (2023).