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Analysis of Correlation Effects in the Kitaev Chain Using the Density Matrix Renormalization Group (DMRG)

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Topological phases of matter, such as those realized in the Kitaev chain, are of great interest due to their robustness and potential applications in quantum computing. The Kitaev chain, a one-dimensional superconducting model, hosts Majorana edge modes in its topological phase.
This project investigates how electron-electron interactions impact the chain's topological properties using the Density Matrix Renormalization Group (DMRG) method, which is particularly well-suited for studying strongly correlated one-dimensional systems.

We simulated a 10-site Kitaev chain, first in the non-interacting case, and then with an on-site Coulomb interaction:

$U = \sum_i^{N=10} n_i n_{i+1}$

For U=0, correlations decay exponentially, signaling the presence of topological edge states. Introducing U≠0 suppressed this behavior, indicating a transition to a trivial phase. The superconducting parameter Δ was key in inducing correlations, while the interaction U suppressed them.

Entanglement entropy, computed from the single-particle correlation matrix, exhibited a peak within the range 2 < μ/t < 2, consistent with the topological regime. Outside this range, entropy dropped sharply.

These results demonstrate how interactions can destabilize topological order, offering insights into designing more realistic quantum systems.

Primary author: ZAWISZ, Jagoda Honorata (Politechnika Wrocławska)

Presenter: ZAWISZ, Jagoda Honorata (Politechnika Wrocławska)

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