

Entanglement entropy of free fermions on random fractal lattices

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Random fractal lattices [1] provide a geometrically disordered setting in which quantum correlations can be shaped by noninteger dimensionality rather than onsite randomness. We investigate the entanglement properties of noninteracting fermions on random fractal lattices generated by a stochastic growth algorithm. By varying the growth parameter and adding missing links with probability p , we tune the Hausdorff and spectral dimensions while keeping the system free of onsite disorder. For ground states at different fillings, we compute the bipartite entanglement entropy of subregions defined by graph distance and analyze its scaling with subsystem size. Over a broad parameter range, we find robust power-law behavior governed primarily by the Hausdorff dimension, consistent with a generalized area law and without the logarithmic enhancement familiar from Euclidean free fermions. We also study entanglement growth following a global quench from an uncorrelated checkerboard state and uncover an asymptotic scaling collapse in which the subsystem-size dependence is governed by the Hausdorff dimension, while the temporal evolution is governed by the spectral dimension. The resulting dynamics are logarithmically slow over an extended intermediate-time window. These results show that geometric randomness alone can generate both nontrivial ground-state entanglement structure and slow quantum-information spreading in free-fermion systems.

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References

- [1] A. Kosior, K. Sacha, Phys. Rev. B 95, 104206 (2017).
- [2] A. Kosior, J. Wang, arXiv:2607.05611 (2026)