

2024 年度年次報告書

量子・古典の異分野融合による共創型フロンティアの開拓

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初期の誤り耐性量子計算に向けた量子シミュレーションと機械学習

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研究成果の概要

We published more than 15 papers in the following related areas: quantum information, quantum open systems, quantum optics, quantum measurements, machine learning applied to quantum information, quantum error correction, and quantum thermodynamics.

One example of our results is highlighted here: Y. Zeng, W. Qin, Y.H. Chen, C. Gneiting, F. Nori, *Neural-Network-Based Design of Approximate Gottesman-Kitaev-Preskill Code*, Phys. Rev. Lett. **134**, 060601 (2025). The Gottesman-Kitaev-Preskill (GKP) encoding holds promise for continuous-variable fault-tolerant quantum computing. While an ideal GKP encoding is abstract and impractical due to its nonphysical nature, approximate versions provide viable alternatives. Conventional approximate GKP codewords are superpositions of multiple large-amplitude squeezed coherent states. This feature ensures correctability against single-photon loss and dephasing at short times, but also increases the difficulty of preparing the codewords. To minimize this tradeoff, we utilize a neural network to generate optimal approximate GKP states, allowing effective error correction with just a few squeezed coherent states. We find that such optimized GKP codes outperform the best conventional ones, requiring fewer squeezed coherent states, while maintaining simple and generalized stabilizer operators. This optimization drastically decreases the complexity of codewords while improving error correctability.

A few selected publications are listed below. Their titles summarize the topics we have studied.

[代表的な原著論文情報]

- 1) W. Qin, A. Miranowicz, F. Nori, *Exponentially Improved Dispersive Qubit Readout with Squeezed Light*, Phys. Rev. Lett. **133**, 233605 (2024).
- 2) Y. Zeng, W. Qin, Y.H. Chen, C. Gneiting, F. Nori, *Neural-Network-Based Design of Approximate Gottesman-Kitaev-Preskill Code*, Phys. Rev. Lett. **134**, 060601 (2025).
- 3) Z.Y. Zhou, C. Gneiting, J.Q. You, F. Nori, *Frustration Elimination and Excited State Search in Coherent Ising Machines*, Phys. Rev. Lett. **134**, 090401 (2025).
- 4) N. Lambert, M. Cirio, J. Lin, P. Menczel, P. Liang, F. Nori, *Fixing detailed balance in ancilla-based dissipative state engineering*, Phys. Rev. Research **6**, 043229 (2024).
- 5) P. Nandy, T. Pathak, and M. Tezuka, *Probing quantum chaos through singular-value correlations in the sparse non-Hermitian Sachdev-Ye-Kitaev model*, Phys Rev B, **111**, L060201 (2025).