Optimal Quantum States for Frequency Estimation Limited by Spontaneous Emission

Marius Burgath[*1], **Klemens Hammerer**[1,2]

1. Institut für Theoretische Physik, Leibniz Universität Hannover, Germany
2. Institut für Theoretische Physik, Universität Innsbruck, Austria

We investigate ultimate bounds for frequency estimation with an ensemble of qubits subject to local spontaneous decay. For that purpose, a numerical maximization of the quantum Fisher information (QFI) over the initial state of the ensemble is carried out. For different numbers N of qubits, the QFI is maximized by very different state classes. In the regime of small N, unbalanced GHZ states with a correlated measurement and a nonlinear estimator perform close to optimal. Above a critical number of qubits, the QFI can be maximized by spin Gottesman-Kitaev-Preskill (Spin-GKP) states [1], which are the compact phase space analogues of the GKP states known from quantum error correction with a harmonic oscillator. The Spin-GKP states show a comb structure in phase space, and the performance of different phase space lattices is investigated. Spin-GKP-like states can also be created with a simple gate sequence. Two one-axis twisting gates and a rotation can be used to create Spin-GKP-like structures around the equator of the Bloch sphere to reach QFI values close to the ultimate bounds.
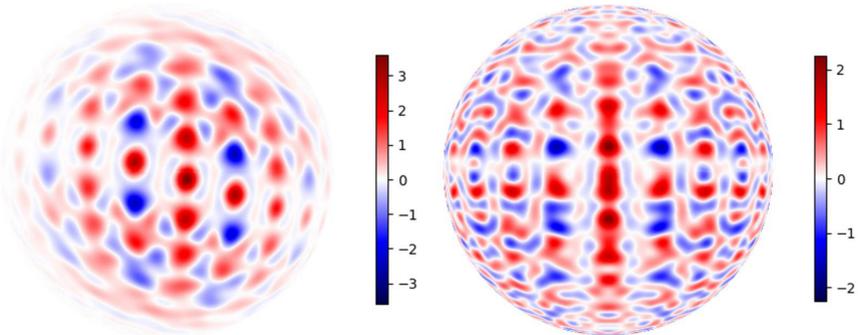
Fig. 1: Exemplary Wigner functions of Spin-GKP states shown on the collective Bloch sphere. Those states can be used to get close to the maximum of the quantum Fisher information. In both cases $N = 53$ qubits were used, and the viewing plane is the y-z-plane.

References

[1] T. J. Volkoff, S. Omanakuttan, Phys. Rev. A **108** 022428 (2023)

[*]marius.burgath@itp.uni-hannover.de