Engineering a new type of Kerr-cat qubit

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It has become clear that to preserve quantum information one should store it in a "large quantum system". This *reversed* Schrödinger-cat paradox is a natural extension of classical error protection of information: code words should be sufficiently "far apart" to not be easily scrambled by the environment.
Since large many-body systems are hard to handle, it came as a realization that superpositions of mesoscopic states of light in a *single* degree of freedom is a comparatively simpler way to get a large quantum system [1,2]. Usually, this approach exploits the large Hilbert space of a harmonic oscillator using a nonlinear ancilla for quantum control and are generally known as bosonic codes.
The simplest members of the bosonic code family are known as "cat-codes". They are qubits formed by the quantum superposition of "distant" semiclassical states in an oscillator [2,3]. In their simplest version they do not protect the full quantum information but instead they protect a single axis of the qubit's Bloch sphere. They are then a form of classical error protection applied over a system that can be brought into a quantum superposition to perform a meaningful quantum task.
In this talk I will present the autonomously stabilized Kerr-cat qubit [4] and its new improved variation [5]. The Kerr-cat embodies a new paradigm in quantum error protection since it is encoded in a nonlinear oscillator, its stabilization is provided by Hamiltonian means and requires no ancilla. I will also discuss the experimental implementation of our cat-code, the origin of its protection and how it can be useful as an ancilla for other bosonic codes [6].

References

[1] Gottesman, Kitaev, and Preskill, Phys. Rev. A 64, 012310, Issue (2011)
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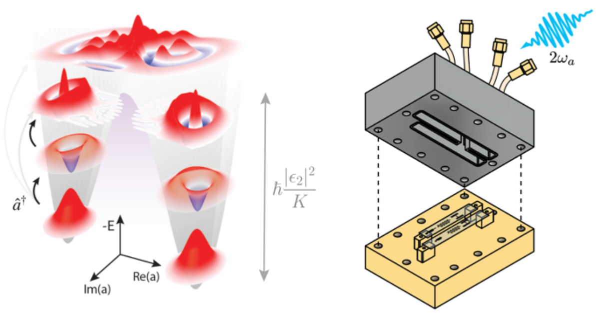
[5] In preparation (2022).
[6] Puri, *et al*, Phys. Rev. X, 9, 041009, (2019)

Figures



$$\hat{H}/\hbar = \underbrace{-\Delta\hat{a}^\dagger\hat{a} - K\hat{a}^{\dagger 2}\hat{a}^2}_{\text{Kerr oscillator}} + \underbrace{\epsilon_2(\hat{a}^{\dagger 2} + \hat{a}^2)}_{\text{Squeezing}}$$

Figure 1: (left) The phase space representation of the Kerr-cat Hamiltonian, the Wigner function of its eigenstates, and (right) its physical implementation in our quantum circuit experiment.