Fast High Fidelity Operation of Fluxonium Qubits

Florian Wallner
J. Schirk, N. Bruckmoser, I. Tsitsilin, L. Koch,
N. Glaser, M. Singh, G. Krylov, F. Haslbeck,
M. Werninghaus, C. Schneider & S. Filipp

Technical University of Munich, TUM School of Natural Sciences, Physics Department, James-Franck-Str. 1, 85738 Garching, Germany
Walther-Meißner-Institute, Walther-Meißner-Str. 8, 85738 Garching, Germany

Florian.Wallner@wmi.badw.de

Estimates for error corrected quantum computation with today's state of the art qubits indicate a two to three orders of magnitude overhead in the physical to logical qubit ratio [1]. This demand can be significantly reduced by building better underlying physical qubits. In particular, entanglement and measurement operations are currently prone to errors.

Due to its simplicity, the Transmon qubit is the widespread choice for state of the art superconducting quantum processors [2]. Nevertheless, in the last years it became clear that this simplicity comes at the expense of serious trade-offs. Thus, the community now dedicates significant efforts towards building novel circuits that promise higher fidelities on all operations.

Here we present our recent results on building Fluxonium qubits that excel in three key aspects when compared to Transmons [3]. We demonstrate the primary advantage of an increase in T_1- and T_2^*-times through a reduced transition frequency and smaller dipole matrix element. Secondly, leakage is highly supressed since the computational states are more isolated arising from to the large qubit anharmonicity above 1 GHz. This allows us to perform single qubit gates with a fidelity of 99.97%. We evaluate our gates using randomized benchmarking with a so-called restless protocol that eliminates the need for a reset and enables cycling times above 100 kHz. To significantly reduce the control line overhead in future devices we combine the flux and microwave-drive line without showing degradation in qubit gate fidelities [4].

The readout of Fluxonium qubits is performed through a mediated coupling between higher qubit states and the resonator levels. This results in a rich dispersive shift landscape that can be exploited for fast qubit readout. We discuss methods on how a flux pulse to an operating point with high dispersive shift can shorten and improve the readout fidelity. In combination with a mid-circuit active feedback, a measurement induced reset is realized. In addition, we report on our efforts to scale up the number of qubits and readout multiple qubits simultaneously.

References

[1] A. G. Fowler et al., Phys. Rev. A 86, 032324 (2012)
[2] F. Arute et al., Nature 574, 505-510 (2019)
[3] L. B. Nguyen et al., PRX Quantum 3, 037001 (2022)
[4] I. N. Moskalenko et al., npj Quantum Inf 8, 130 (2022)

Figures

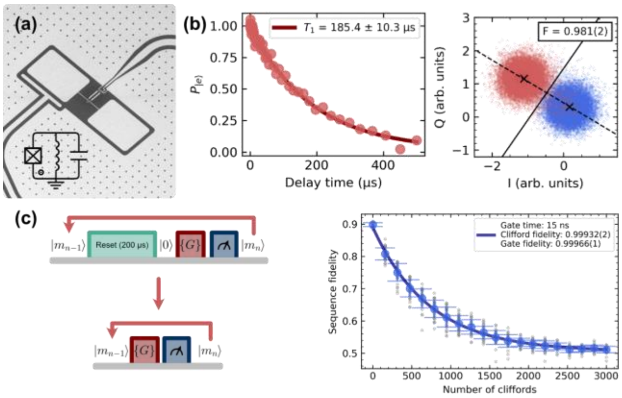

Figure 1: (a) Microscope image of Fluxonium made of Niobium sputtered on a Silicon substrate. Insert shows the Fluxonium circuit. **(b)** Measured T_1-time and readout assignment fidelity. **(c)** Comparison of standard sequence with the reset-free restless protocol. Measured randomized benchmarking for a 15 ns long single qubit gate.