Autotuning quantum dot qubits with FrEQuENTS

Tyler J. Kovach[1], Daniel Schug[2,3], M. A. Wolfe[1], Patrick Walsh[1], Jared Benson[1], E. R. MacQuarrie[1*], Danielle Middlebrooks[3], M. A. Eriksson[1] and Justyna P. Zwolak[2,3]

[1]*Department of Physics, University of Wisconsin-Madison, Madison, WI 53706, USA*
[2]*Department of Chemistry and Biochemistry, University of Maryland, College Park, MD 20742, USA*
[3]*National Institute of Standards and Technology, Gaithersburg, MD 20899, USA*

tkovach@wisc.edu

The future scaling up of quantum dot (QD) qubits into large arrays will depend on efficient methods to select gate voltages that put each dot into the correct operating regime. When scientists choose these gate voltages, they confine electrons within QDs, and they also form reservoirs and setup nearby auxiliary devices, such as single-electron transistor charge sensors (SETs). Hence, every tuning decision is part of a multi-faceted approach in dialing in the proper settings to form qubits. One of the challenges for this platform is alleviating this burden on scientists in order to efficiently initialize devices while also retaining tunability at scale [1].

In this talk, we present *FrEQuENTS*, a Framework Encoding for Quantum-Dots, an Electronically Navigated Tune-up System. We both describe the framework and also report experimental data characterizing quantum dots as part of an automated tune-up process. The *FrEQuENTS*'s architecture enables a *QD Autotuner* to implement the same types of decision making processes that scientists perform when tuning up these devices. With scaling in mind, a single config file sets up the entire autotuning approach for an arbitrarily sized QD device.

Not all steps in the tuning process are equal in complexity, and the framework respects these differences. For instance, checking for gate-to-gate leakage can be done easily by using simple measurements and a thresholding analysis. Other tasks, such as forming simultaneous 1D current channels, require more than two gate voltages to be tuned correctly before declaring success. In these cases, machine learning methods are beneficial [2,3], and *FrEQuENTS* supports them. Generally, *FrEQuENTS* supports easy integration of existing analysis methods into process-parallelized *workflows* inside classes called *Data Workers*.

To demonstrate an implementation on a physical device, we report detailed measurements of gate-defined quantum dots using a specific *Flow Operator*: *Bootstrap* (see Fig. 1). This class enables the assessment of the performance of specific gates in the device, and it bootstraps the device from being grounded to the point where configuring SETs for readout can begin.

FrEQuENTS maps a demanding task to an automated computer algorithm. It intends to streamline choices of individual gate voltages for scientists, enabling them to focus on higher level tasks such as qubit manipulation. It aims ultimately to be compatible with extension beyond traditional software and be reimplemented in hardware to reduce latency or even be placed on-chip to aid with scalable control.

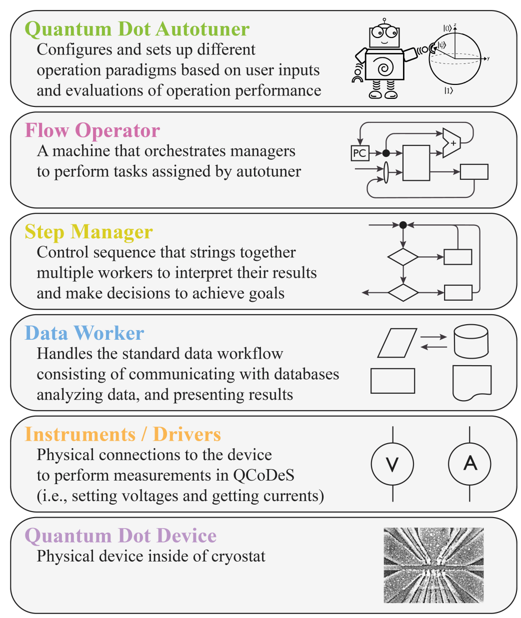

Fig.1. The abstraction levels of the *FrEQuENTS* software visualized as a top-down stack built on top of an experimental device. Cartoons at each abstraction level indicate expected behaviors at each stage. QCoDeS is used for instrument control [4]. The SEM in the QD Device section is of a quad-QD device with two charge sensors placed above the main channel for readout. The SEM is an example of the category of devices the software currently supports.

References

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* Present address: Photonic, Inc.