Contribution ID: **78** Type: **Poster**

Towards a high fidelity two-qubit state manipulation and readout using the ARTIQ Phaser and Grabber Modules.

Tuesday 9 July 2024 17:30 (2 minutes)

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The ability to generate and distribute entanglement in open quantum systems is a prerequisite for a fully-fledged quantum computer. The former of which, within this group, has been achieved typically using geometric phase gates, with dressed states (continuous dynamical decoupling) being utilised to protect the states from dephasing noise. The use of dressing fields increases calibration and tone overhead with the number of qubits in any multiqubit gate.

Gates which utilise the J-coupling interaction, often overlooked due to inferior gate times, commute with dephasing noise operators, allowing for straightforward noise cancellation via pulsed dynamical decoupling, in addition to relaxed requirements in terms of motional decoherence [1, 2].

Recent theoretical work [1] has demonstrated an ability for faster than dispersive J coupling gates, using dynamical decoupling on each qubit; an inter-pulse delay is set such that the spectral form of this sequence drives the spin boson interaction, alleviating the main drawback suffered by this type of gate. Pulsed dynamical decoupling sequences can be engineered to ensure robustness to amplitude fluctuations, in addition to environmental noise induced decoherence.

In the regime where available Rabi frequencies are much smaller than trap frequencies, low intensity pulses must be used. In this instance, pulse shaping can be used so that, again, the spin boson interaction is driven. In light of open source STFT pulse generator gateware developed by Norman Krackow [3], pulse shaping as described in this scheme can be achieved using an integrated AWG in Artiq also known as the Phaser. We demonstrate work on the experimental implementation of this new module and its relevance towards developing fast and accurate pulse sequences to perform high fidelity trapped ion experiments.

Developing fast high speed EMCCD readout techniques will provide access to better bell state discernibility, which can be achieved in relevant timescales using Artiq's Grabber module, which offers FPGA handled EMCCD frame data via a low latency link to our Andor Solis camera. We also show the implementation of this module to enable fast readout of two-qubit states. In doing so, improved Bell state analysis can be performed within computational timescales, which will be useful for error correction and teleportation protocols.

References:

[1] : Arrazola, Iñigo, and Jorge Casanova. "Robust oscillator-mediated phase gates driven by low-intensity pulses." Communications Physics 6.1 (2023): 123.

[2]: Valahu, C. H., et al. "Robust entanglement by continuous dynamical decoupling of the J-coupling interaction." New Journal of Physics 23.11 (2021): 113012.

[3]: Kulik, Paweł, et al. "Latest developments in the Sinara open hardware ecosystem." 2022 IEEE International Conference on Quantum Computing and Engineering (QCE). IEEE, 2022.

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Session Classification: Poster session

Track Classification: Quantum Technologies