

Quantum-optimal-control methods for amplitude and detuning robust operations on cQED systems

Marko Kuzmanović

Ilya Moskalenko, Yu-Han Chang, Isak Bjorkman, Ognjen Stanisavljević, John J. McCord, Gheorghe Sorin Paraoanu et al.

QTF Centre of Excellence and InstituteQ, Department of Applied Physics, Aalto University, 00076 Aalto, Finland

marko.kuzmanovic@aalto.fi

The toolbox of quantum optimal control enables noise- and parameter-insensitive operations, and gives rise to control schemes not possible using conventional techniques. This presentation covers three of our recent results in the field:

1) Landau-Zener driven population transfers between two states of a quantum system [1,2], targeting either single- or two-photon transitions, resulting in an operation robust under substantial drive frequency and amplitude variations (cf. Figure 1). This is achieved by sweeping the drive frequency through resonance, allowing the quantum state to adiabatically follow the shifting energy levels and naturally suppress errors from parameter fluctuations.

2) A complete single-qubit gate set [1], where the desired angle of rotation is encoded in the phase modulation of the drive. This effectively decouples the drive amplitude from the dynamics of the system, allowing for amplitude deviations greater than 20% while still realizing the desired operation.

3) A neural-network-based approach for realizing arbitrary operations. It produces smooth, non-discretized pulses, without the need to choose a specific basis for the drive field expansion. The method is showcased by generating a detuning-robust $\pi/2$ pulse [3], highly relevant for applications such as photon detection experiments (cf. Figure 2) and Wigner tomography.

All techniques are studied theoretically, verified experimentally, and demonstrated to achieve high-fidelity operations.

References

- [1] M. Kuzmanović, I. Björkman, J.J. McCord, et al, *Physical Review Research*, 6(1) (2024) 013188
- [2] I. Björkman, M. Kuzmanović, and G. S. Paraoanu, *Physical Review Letters*, 134(6) (2025) 060602
- [3] M. Kuzmanović, I. Moskalenko, Y.H. Chang, et al *arXiv*, 2505.02054 (2025)

Figures

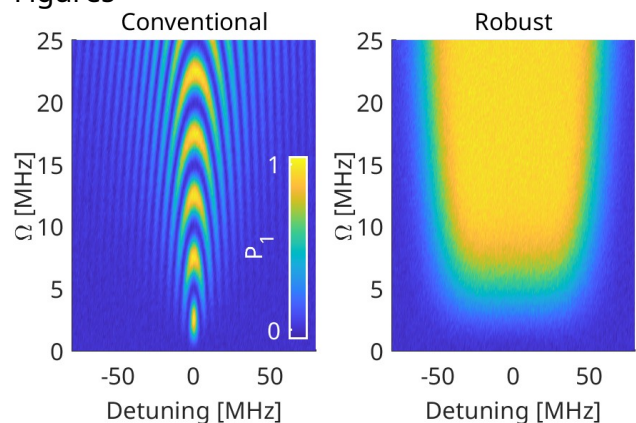


Figure 1: Amplitude and detuning robustness of the Landau-Zener pulse from [1] (right) compared to a conventional Rabi drive (left).

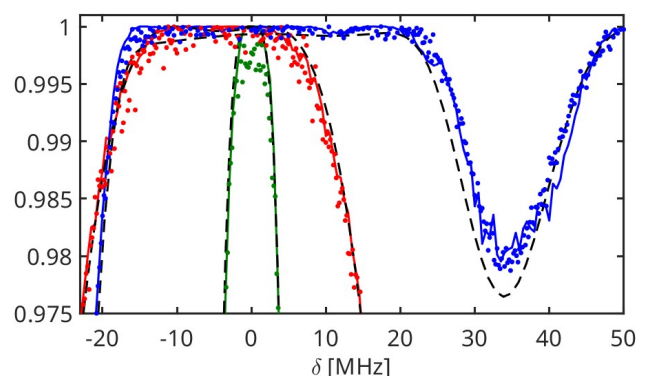


Figure 2: Photon-number parity-measurement efficiency versus the AC-Stark-induced frequency shift (δ) for the neural-network pulse [3] (blue), a DRAG pulse (red), and a conventional Rabi drive (green).