Coherent Dynamics of the Swing-up Excitation Technique

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Finding a suitable excitation method for quantum two-level systems in the solid state is a widely investigated research area in quantum technologies. The challenge of combining efficient filtering of quantum emission from residual excitation laser leakage, spin- and polarization preservation and coherence of the technique, as well as good quality of the emitted photons has led to a variety of excitation methods. However, each of these schemes has specific disadvantages, such as being suitable only for specific level schemes or setup configurations. Recently, Bracht et al. proposed a promising technique based on two red-detuned excitation pulses which enable a high-fidelity population inversion in a coherent manner [1], with successful experimental demonstration of its functionality by Karli et al. [2].

In this contribution, we extend the analysis of this method and explore the coherent dynamics of the swing-up technique with an InGaAs quantum dot [3]. We investigate the multidimensional parameter-space of the excitation to study their impact on the scheme and to find optimal conditions for high-fidelity population inversion, where we find several resonances and investigate the effects of the interdependence of the excitation parameters - both in experiments and numerical simulations as exemplarily presented in Fig.1.

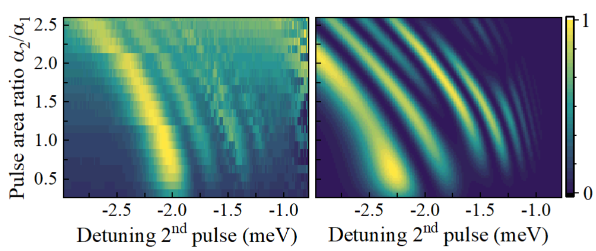

Fig.1. Experimental (left) and simulated (right) swing-up excitation fidelity of two 5ps pulses, dependent on detuning and intensity of the second pulse with the first pulse (-1.65 meV detuning, pulse area of 9π).

Furthermore, we analyze the single-photon performance of our two-level system under swing-up excitation. We find near perfect single-photon purity with a raw value of $g^2_{\text{swing, raw}}(0) = 0.033$. In contrast, the measured indistinguishability is limited to $v_{\text{HOM, swing}} = 0.439$, which can be attributed mostly to the impact of the high laser intensities on the semiconductor environment of the quantum dot. Therefore, we conclude that the method is very promising, although further engineering is required to make it suitable for applications.

References

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[3] K. Boos *et al.*, Adv Quantum Technol. 2300359 (2024).