Variational diabatic annealing schedules with Landau-Zener-Stückelberg interference

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In recent years there have been great advances in improving the coherence of quantum annealing hardware. First experiments show the presence of coherence in large devices, sparking hopes for quantum advantage through quantum annealers. However, exponentially closing spectral gaps are a major obstacle to solving computational problems with adiabatic quantum annealers. In a recent paper, variationally optimized diabatic annealing schedules were investigated and an exponential speed-up over the adiabatic model was observed [1].

Here, we propose a theoretical explanation for this observation. We identify the interference between amplitudes of different energy levels after consecutive Landau-Zener crossings, also known as Landau - Zener - Stückelberg (LZS) interference, as the basic mechanism of the observed speed-up. We then proceed by defining a class of variational diabatic annealing schedules that make use of LZS interference and thus drastically reduces the search space for the optimal parameters. We prove that if an efficient, optimal annealing schedule is in this schedule class, the parameters can be optimized efficiently, which also allows us to state conditions when variational schedules provide an exponential speed-up over adiabatic annealing, even if the optimization cost is considered. After trotterization, our results readily extend to gate-based variational algorithms.

References

[1] Jeremy Côté et al. Quantum Sci. Technol. 8 045033 (2023)

Figures

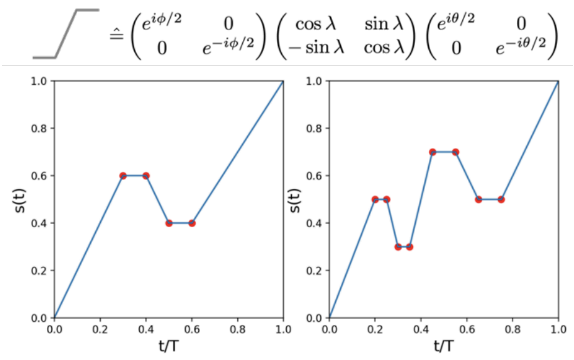

Figure 1: Illustration of a schedule fragment consisting of a ramp flanked with waiting periods (top), which is equivalent to three rotations where j and q are free parameters and l is free within some range. Schedules build from this fragment (bottom) can be optimized to overcome exponentially closing gaps.

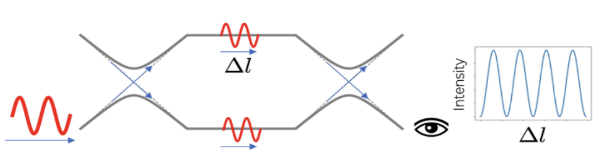

Figure 2: Different energy levels can be thought of as different beam paths: the system starts in the ground state and the population splits when the system is ramped. By adjusting the path length Dl, the measured intensity / ground state population can be adjusted.