Theory of quantum computation using quantum optics tools: performance of quantum annealers

contact: **Giulia Ferrini;** email address: **ferrini@chalmers.se**

Quantum Annealing is a quantum algorithm based on Adiabatic Quantum Computation, that aims at solving hard combinatorial optimization problems. Such problems seek the best answer from a vast collection of configurations. A typical example is the travelling salesperson problem, where a salesperson seeks the shortest travel distance between different locations, such that all locations are visited once. The naive solution method would be to make a list of all the different routes and find the best answer in the list. However, the number of possible configurations increases exponentially with the number of locations. Thus, this naive method is not efficient.

Quantum annealing exploits the idea that combinatorial optimization problems like the travelling salesman problem can be mapped onto finding the ground state of Ising Hamiltonians [1,2]. The Ising spin lattice is first prepared in the non-degenerate ground state of an initial Hamiltonian that is easy to engineer. Then, the system is adiabatically evolved to the ground state of an Ising Hamiltonian encoding the solution of the desired problem. The hope is that quantum annealing might provide an advantage over classical algorithms, due to the ability of quantum systems to tunnel through energy barriers present in the energy landscape of the problem Hamiltonian (Fig.1). However, characterizing the performance of quantum annealers is difficult. Attempts have been made in terms of the Hamiltonian properties [1]. These characterizations involve unproven conjectures, and much is yet to be understood about the computational powers of quantum annealers.

In this Master thesis project we aim at providing a convincing characterization of the performances of a quantum annealer. In particular, we aim at establishing a link between its Hamiltonian properties and relevant quantities that are related to quantum advantage in quantum optics.

For this project, we look for a motivated master student to join the group of Giulia Ferrini at Applied Quantum Physics. Regular exchanges with Göran Johansson and Per Delsing, working on superconducting quantum circuits (theory and experiments respectively), are in order.

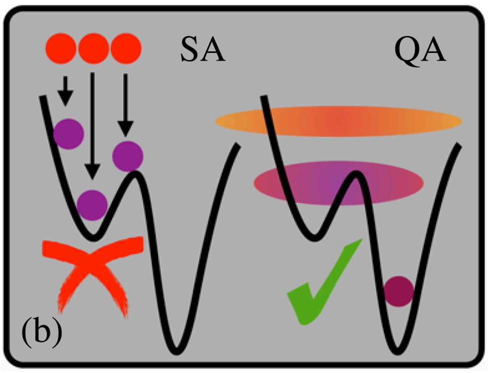

Fig1: A quantum annealer can find the minimum energy configuration of an energy landscape associated to the Hamiltonian encoding combinatorial optimization problems by exploiting quantum tunneling. From Phys. Rev X 5, 031026 (2015)

[1] T. Albash and D. Lidar, Rev. Mod. Phys. **90**, 015002 (2018)
[2] J. Rodríguez-Laguna and S. N. Santalla, Am. J. Phys. **86**, 360 (2018)