Wigner 121 Scientific Symposium

Wigner Research Centre for Physics
Institute for Solid State Physics and Optics,
Dept. of Quantum Optics and Quantum Information
Quantum Information and Complex Systems Research Group

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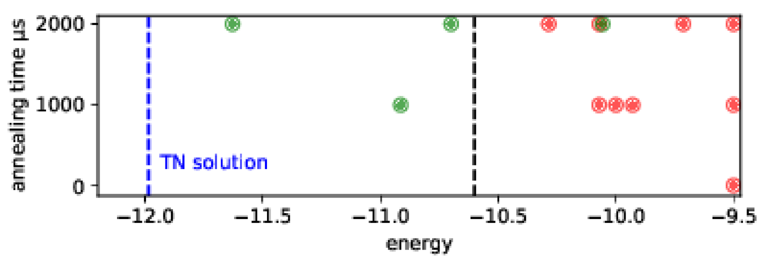
Research highlights

Quantum Optimization

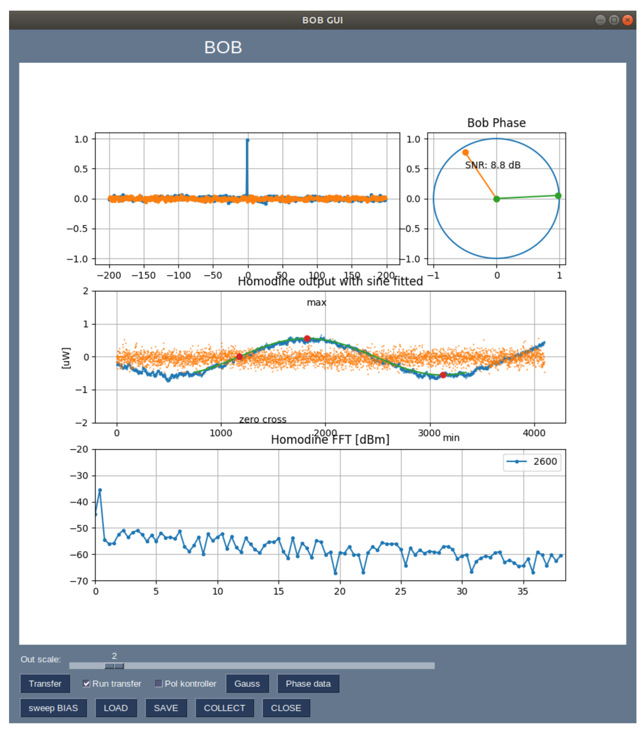
Quantum annealers are amongst the readily available devices in our Noisy Intermediate-Scale Quantum (NISQ) computing era. We propose Hamming-packings of coding theory as suitable benchmarks for this solution strategy. We have demonstrated the applicability of these solution strategies in practical real-life applications such as railway conflict management or the scheduling of automated guided vehicles in industry. In addition to quantum hardware we have successfully applied other physics-motivated heuristics such as tensor networks. We have proposed a statistical-physics based quality assessment method for hardware quantum annealers. We conduct research towards a better understanding and more efficient treatment of the respective hard computational problems, orchestrating methods of operations research and quantum information.



Quantum information transfer

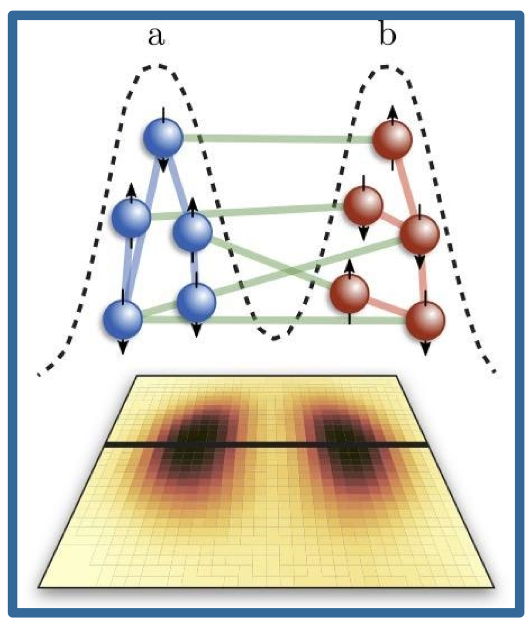
Transfer of quantum information between distant locations is essential for quantum computation and quantum communication as well. In this field we have several experimental and theoretical research projects:

- We have a long term collaboration with the Budapest University of Technology and Economics to realize quantum key distribution networks. First successful field experiment were done in 2022.
- We develop single photon sources to produce stream of photons both for quantum information transfer and quantum computation. This research involves both theoretical and experimental research. On the experimental side, we want to realize the single photon sources using rare earth ion doped nanocrystals. This work is accompanied by developing dielectric nanostructures to enhance the coupling between the atoms and photons.

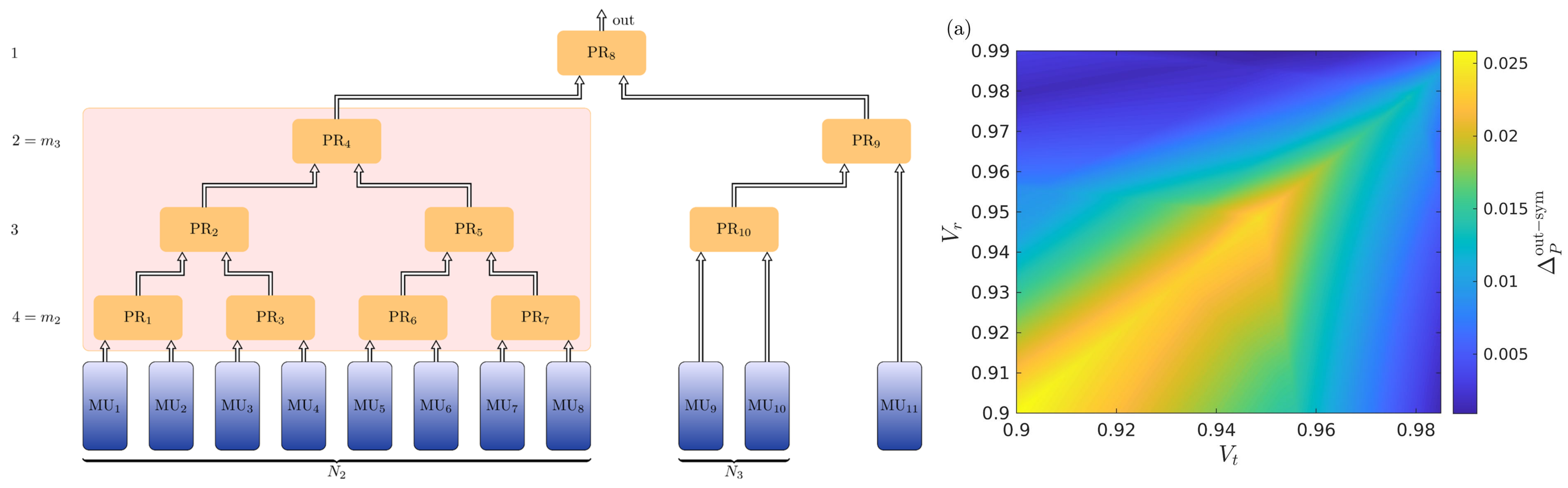


Quantum entanglement detection

Quantum entanglement plays a crucial role in quantum theory and also in quantum information processing applications. Due to the recent rapid technological development, large scale entanglement has been created in many experiments with photons, cold neutral atoms, cold trapped ions and superconducting circuits. Hence, it is very important to verify the presence of entanglement after a successful experiment. We work on entanglement conditions that can prove the presence of multipartite entanglement in an ensemble of many particles or in a spin chain, and can show that the quantum state is useful for quantum metrology. We also work on detecting bipartite entanglement of spatially separated parties in a large ensemble, since such entanglement is needed in many applications.

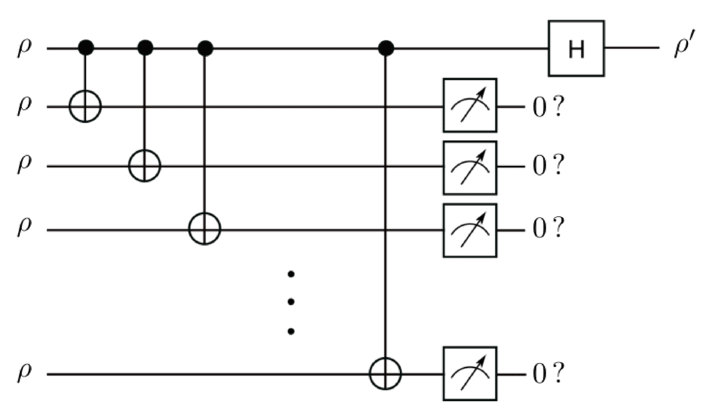


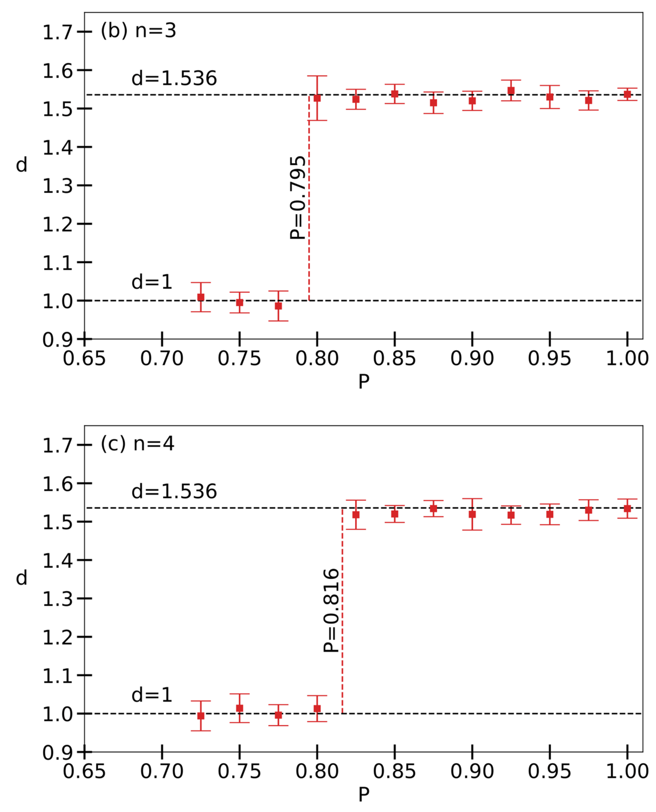
Multiplexed single-photon sources



Novel types of spatially multiplexed single-photon sources based on incomplete binary-tree multiplexer is developed. Single-photon probabilities higher than 0.93 can be achieved. These systems show improved performance even for suboptimal system sizes relevant in experiments.

Nonlinear quantum dynamics





We investigate iterated measurement-induced dynamics of qubits and study phenomena such as phase transition, quantum state purification, and quantum state discrimination in these schemes. These protocols offer ways to investigate different types of noise present in current quantum computers (e.g. state preparation, measurement, or quantum gate error), as well as possible ways to benchmark the performance of these devices.

Exact bounds on the energy gap of transverse-field Ising chains by mapping to random walks

The efficiency of adiabatic quantum computing is determined by the minimal energy gap along the annealing path. The one-dimensional Ising machine is a frequently used model for testing the efficiency of quantum annealing schemes. Based on a relationship with random walks, we derived exact lower and upper bounds on the energy gap, which are explicit in the couplings and transverse fields.

$$\epsilon_1 > \left[\sum_{l=1}^{L}\sum_{m=1}^{l}\frac{1}{h_l^2}\prod_{i=m}^{l-1}\frac{J_i^2}{h_i^2}\right]^{-\frac{1}{2}}$$

$$\epsilon_1 < \left[\sum_{n=1}^{L}\prod_{i=1}^{n-1}\frac{h_i^2}{J_i^2}\right]^{\frac{1}{2}}\left[\sum_{n=1}^{L}\left(\prod_{i=1}^{n-1}\frac{h_i^2}{J_i^2}\right)\sum_{l=n}^{L}\sum_{m=1}^{l}\frac{1}{h_l^2}\prod_{j=m}^{l-1}\frac{J_j^2}{h_j^2}\right]^{-\frac{1}{2}}$$

Using these bounds, we have demonstrated that, by applying appropriately chosen heterogeneous driving fields, the gap closing can be mitigated and thus the quantum annealing can be made more accurate.

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