Quantum simulation in arrays of single-addressable traps: multi-layer configurations, qubit synchronization, and tunnel-coupled geometries

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Efficient quantum simulation requires scalable architectures that guarantee the allocation of large-scale qubit resources. In our work, we focus on the implementation of multi-site geometries based on microoptical systems. The use of microlens arrays allows for the creation of massive multi-site trap arrays with structure sizes approaching the wavelength of the light applied, yet the geometry being decoupled from the laser wavelength and therefore customizable. Large scale quantum simulation, quantum computing, and quantum error correction will be accessible.

We give an overview on recent progress and future directions: (a) We report on a novel technique for the optical creation of 3D multi-layer configurations of 2D periodic quantum registers based on the Talbot effect and demonstrate the trapping and imaging of individual atoms in integer and fractional Talbot planes [1]. This will increase the simulation speed by parallelizing different tasks within different planes. (b) The distribution of computational tasks over the full 2D architecture requires a high degree of synchronization of the qubit dynamics. We implemented a scheme for compensation of the differential Stark shift of hyperfine quantum states by adding a weak near-resonant field. This causes a suppression of dephasing and decoherence by more than an order of magnitude [2]. (c) In a novel approach for a bottom-up quantum simulator, we propose to combine site-controllable potential surfaces (Fig. 1) based on microlens arrays with the highly successful technique of tunnel-coupled quantum simulation [3].

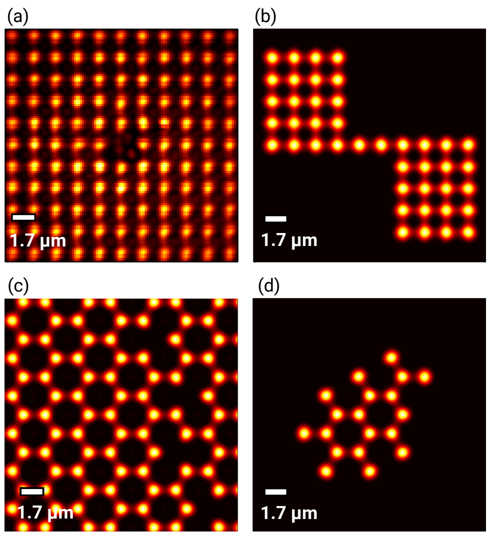

Figure 1. Measured (a) and simulated (b - d) optical potentials for a fully controllable quantum simulator based on tunnel-coupled arrays of independently generated potential wells.

[1] M. Schlosser et al., submitted (2017).
[2] J. Kruse, M. Schlosser, G. Birkl, submitted (2017).
[3] M. R. Sturm, M. Schlosser, R. Walser, G. Birkl, Phys. Rev. A **95**, 063625 (2017).