Cold Atoms Plus Photonics for Quantum Simulation

A. Simonsen
J. T. Hansen, J. B. Mathiassen, B. Martinez de Aguirre, J. H. Müller, E. S. Polzik & J.-B. Béguin

University of Copenhagen, Blegdamsvej 17, Copenhagen, Denmark

asimonsen@nbi.ku.dk, jbeguin@nbi.ku.dk

We present an experimental apparatus for quantum simulations that combines cold atoms with 2D photonics. The setup follows the proposal in [1] and is illustrated in fig. 1. The photonic structure enhances light-atom coupling by confining optical fields to sub-wavelength dimensions near the atoms. The structure also guides photons that can mediate strong and long-range interactions between atoms according to the Hamiltonian $H = \sum_{ij} J^{ij} \sigma_{eg}^{i} \sigma_{ge}^{j}$, where $\sigma = |e\rangle\langle g|$ refers to atomic states and J^{ij} is a coupling constant that depends on the photonic design. Fig. 2 shows J^{ij} for a structure with a photonic bandgap. More many-body Hamiltonians may be engineered by further customizing the interactions with optical driving and magnetic fields that manipulate internal atomic states.[2]
Our setup uses Cs atoms cooled to μK temperatures, trapped in an array of optical tweezers in the collisional blockade regime, and delivered into the near-field of the photonic structure. The approach is inspired by [3]. The photonic structures are fabricated in silicon nitride membranes as proposed in [4]. We will report progress on construction of the optical tweezer array for delivery of atoms, development of fabrication recipes, and numerical simulation (fig. 2) and optimization of future atom-photonic devices.

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References

[1] A. González-Tudela, C. L. Hung, D. E. Chang, J. I. Cirac, H. J. Kimble, Nat. Photon., 9 (2015) 320-325
[2] C.L. Hung, A. González-Tudela, J. I. Cirac, H. J. Kimble, PNAS 34 (2016) E4946-55
[3] J.-B. Béguin, A. P. Burgers, X. Luan, Z. Qin, S.-P. Yu, H. J. Kimble, Optica 1 (2022) 1-2
[4] S.-P. Yu, J. A. Muniz, C.-L. Hung, H. J. Kimble, PNAS 26 (2019), 12743-51

Figures

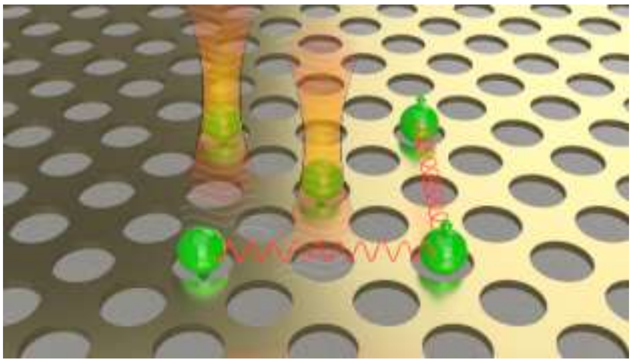

Figure 1: Atoms (green balls) trapped in optical tweezers (orange shaded area) near a membrane perforated with a photonic pattern. Guided photons (wiggly lines) connect atoms by pairwise interaction.

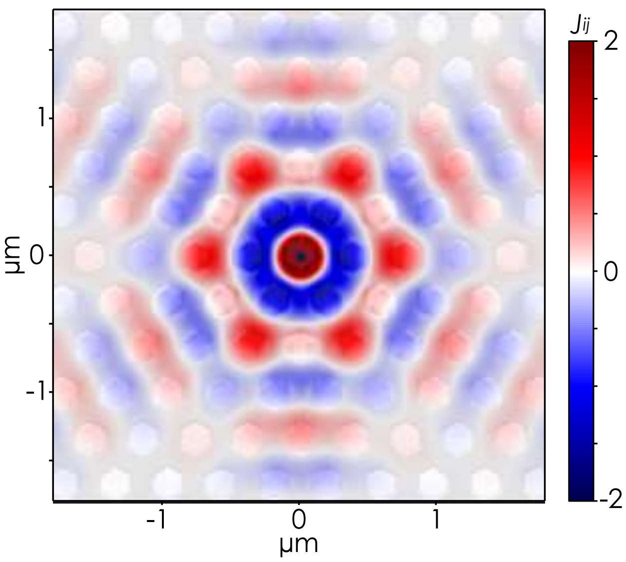

Figure 2: Spin-exchange rate, J^{ij}, normalized to the dissipation rate for an atomic emitter at the center of a hexagonal lattice.