Motional State Resolved Readout in Optical Tweezers

Tim Schiffer,[1,*] Tobias Hammel,[1] Maximilian Kaiser,[1] Daniel Dux,[1] Finn Lubenau,[1] Matthias Weidemüller,[1] and Selim Jochim[1]

[1] *Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany*

The Heidelberg Quantum Architecture [1] is a modular quantum gas platform consisting of disentangled optical modules forming a versatile cold atom experiment. Here, optical units allow flexible trap geometries, fast reconfiguration and precise mechanical alignment, enabling straightforward adaptation to evolving experimental requirements in our Lithium-6 experiment.

In this talk, we present our current project on the implementation of a single optical pickup tweezer controlled by two acousto-optic deflectors (AODs) in a 4f configuration. The goal is to achieve precise control over tunnelling processes as well as maintaining full control over the tweezer position.

We report on the progress in implementing self-aligning modules. We discuss the already implemented experimental toolbox, including optical tweezers, repulsive potentials and single atom and spin resolved imaging. Using this, we present data of the pickup of motional states using a movable optical tweezer and outline prospects for how this can be used for the characterisation of complex many-body quantum states in the future.

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[1] T. Hammel *et al.*, *Phys. Rev. A* **111**, 033314 (2025).

* tschiffer@physi.uni-heidelberg.de; https://ultracold.physi.uni-heidelberg.de/