Towards Fermionic Systems with Dipolar Interactions

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We are constructing a new experimental platform to study spin-polarized fermionic systems with strong dipolar interactions under a quantum gas microscope. The competition of the Fermi energy with the long-range, anisotropic dipolar interactions, alongside the high degree of control on atom number offer a rich platform to study exotic quantum many-body phenomena [1].

We adapt the species-agnostic modular quantum gas platform [2] originally developed for ^{6}Li in the group of Selim Jochim to fermionic ^{161}Dy, which possesses one of the largest atomic magnetic moments. To enable cooling of this lanthanide atom encompassing a complex hyperfine structure, we implement a compact, yet tunable design of a permanent-magnet Zeeman-Slower and 2D MOT with minimized number of degrees of freedom. In the science chamber, consisting of a nano-textured glass cell, atoms will be loaded from a core-shell 3D MOT into a large reservoir optical dipoles trap. A high NA objective will allow us to realize tightly focused optical tweezers and single-atom-resolved imaging.

In this poster, I will showcase the current status of the design and construction of our new ultracold fermionic Dysprosium experiment, as well as the numerical and analytical simulations of the entire precooling stage considering the full hyperfine structure. Furthermore, I will present theoretical investigations of few spin-polarized fermions in a two-dimensional harmonic trap, employing numerical ground-state calculations to observe how dipolar interactions deform the mesoscopic Fermi surface.

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[1] M. A. Baranov et al., 'Condensed Matter Theory of Dipolar Quantum Gases', Chem. Rev. 112(9), 5012-5061 (Aug. 2012).

[2] Tobias Hammel et al., 'Modular quantum gas platform', Phys. Rev. A 111, 033314 (Mar. 2025).

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