Ultracold polar molecules in optical tweezer arrays

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Recent progress in laser cooling has enabled trapping and control of individual polar molecules despite their complex internal level structure. While this complexity makes cooling more difficult, it also provides additional flexibility in state control and manipulation, opening new possibilities for quantum science [1].

In contrast to neutral atoms, their intrinsic electric dipole moments give rise to interactions that can be used, for example, for entanglement generation. In combination with optical tweezer arrays, ultracold molecular systems provide a platform for studying controlled interactions, with potential applications in quantum information, precision measurements, and ultracold chemistry.

Among polar molecules, calcium monofluoride (CaF) is a suitable candidate due to its established laser-cooling scheme [2] and accessible internal degrees of freedom. We are developing an optical tweezer apparatus for trapping and controlling ultracold CaF molecules. The system is designed to enable the preparation, manipulation, and detection of single molecules, with the aim of extending to small interacting arrays. The reconfigurability of them, combined with tunable dipolar interactions, will enable studies of interacting molecular arrays, exploration of molecular qubit encoding, and investigation of Rydberg states in trapped CaF molecules.

In this contribution, I will present the design and current status of the experiment, including the vacuum and laser systems required for trapping molecules in a magneto-optical trap. I will report on progress in construction of the setup and outline the next steps towards control of single CaF molecules.

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[2] S. J. Li *et al.*, *Phys. Rev. Lett.* **132** 233402 (2024).

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