A new magnetic trap for ultra-cold atoms and molecules - status report
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Trapping of neutral species in magnetic traps has proven to be a very successful method to spatially confine cold samples for precision spectroscopy or the production of degenerate Bose and Fermi gases. For atoms, it usually relies on an effective two-level electronic structure that allows for optical precooling. However, the lack of a general cooling method has so far prevented trapping of most molecules.

In this project, we exploit a novel technique developed by the group of J. Doyle at Harvard University [1] to trap paramagnetic atoms as well as molecules. We combine buffer-gas loading with a strong magnetic quadrupole trap (fig. 1) in a $^3$He/$^4$He dilution refrigerator to collisionally cool and capture paramagnetic particles. Increasing the phase space density of the trapped species should be possible by evaporative cooling using both reduction of the magnetic field and RF evaporation.

The general applicability of this cooling method opens up the opportunity to work with a great variety of paramagnetic species, including rather big molecules. In particular, precision spectroscopy on certain trapped molecules with special properties could be used to perform a series of fundamental tests (e.g. symmetrization postulate, time reversal symmetry, and parity violation in chiral molecules).

In our setup, optical access from 6 sides will allow the exploration of different detection schemes, including absorption and fluorescence spectroscopy. Additionally, this unique feature offers enhanced flexibility for future experiments, e.g. the transfer of the trapped species to an optical dipole trap.

After having tested our apparatus with atomic chromium, oxygen $\text{O}_2$ will be the first molecular candidate for trapping. One reason is the relatively high magnetic moment of 2 $\mu_B$. Due to the relatively low absorption cross section of $\text{O}_2$ at 761 nm, we have to use cavity enhanced spectroscopy for detection [2]. In a preliminary room temperature setup (fig. 2), we were able to see a line in the Atmospheric $\lambda$-Band in transmission (fig. 3). Building on our extensive experience with cryogenic resonators [3], we hope to be able to implement this detection scheme to the cryogenic environment.


Figure 1: Superconducting magnet.

Figure 2: Experimental setup of cavity enhanced oxygen spectroscopy.

Figure 3: Measured $\text{O}_2$ lines at different pressures.