

Measuring the Electron’s Electric Dipole Moment Using Ultracold YbF Molecules

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The Standard Model predicts a value for the electron’s electric dipole moment (eEDM, d_e), $d_e \sim 10^{-35} e \text{ cm}$ [1], far smaller than what is predicted by theories beyond the Standard Model, typically $d_e \sim 10^{-31} - 10^{-24} e \text{ cm}$. To date, the current experimental upper limit is set at $|d_e| < 4.1 \times 10^{-30} e \text{ cm}$ [2]. Further improvements in experimental precision are likely to discover new physics or rule out much of the parameter space of popular theories. The eEDM can be measured through the precession of the electron spin in an applied electric field. The precision is enhanced enormously when the electron is bound into a heavy polar molecule. The statistical precision depends on the spin precession time so a slow, ultracold beam of molecules has the potential to measure the eEDM to greater precision than the current limit.

We use a beam of collimated ultracold YbF molecules produced by a cryogenic buffer gas source and then laser cooled to $100 \mu\text{K}$ in the two transverse axes [3]. Such cooling increases beam brightness and allows for a longer spin-precession time, leading to a projected statistical uncertainty below $10^{-30} e \text{ cm}$ [4]. However, magnetic field noise can severely limit the precision of our phase-sensitive measurement of d_e . To overcome this source of noise, we have developed and characterised a novel spin precession region, including ceramic electric field plates, a glass vacuum chamber, a four-layer magnetic shield with a shielding factor $> 10^6$, and an array of magnetometers which measure the magnetic field noise in our experiment below $40 \text{ fT}/\sqrt{\text{Hz}}$ at 1 Hz [5]. We prepare the eEDM-sensitive state using stimulated Raman adiabatic passage and can detect the molecules with near unit efficiency. Having made spin interferometer fringes in our experiment, we are currently working towards reaching the shot-noise-limited statistical sensitivity of the experiment.

References

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