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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 cm [1], far smaller than what is predicted by theories beyond the standard model, typically $d_e \approx 10^{-31} - 10^{-24}$ e cm. To date, the current experimental upper limit is set at $d_e < 4.1 \times 10^{-30}$ e 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 μK in the two transverse axes [3]. Such cooling increases beam brightness and spin-precession time, leading to a projected statistical uncertainty below 10^{-30} e cm [4]. However, magnetic field noise can severely limit the precision of our phase sensitive measurement of de. 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, magnetometry, and a four-layer magnetic shield with a shielding factor > 10^5 [5]. We prepare the eEDM-sensitive state using stimulated Raman adiabatic passage and detect the molecules with near unit efficiency. We are currently working to reach the shot noise limit of statistical sensitivity.

References

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