

Improved sensitivity to the electron's electric dipole moment using YbF molecules

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It is well known that the electron has a magnetic dipole moment. This property has been measured with exquisite precision and provides one of the most successful comparisons between experiment and theory. However, no one has ever been able to detect the analogous *electric* dipole moment (EDM), d_e . In principle, there is no reason why an electron should not have an electric dipole moment, but a non-zero value of d_e will violate time reversal symmetry T. The standard model of particle physics does contain some T-violation, but the value of d_e it predicts is almost vanishingly small ($|d_e| < 10^{-38}$ e.cm) — the displacement of the electron's charge from its centre of mass is predicted to be less than a Planck length. This is many orders of magnitude smaller than current experiments could ever measure. However, theories that extend the Standard Model, such as supersymmetry, will typically include additional sources of T-violation to help explain the matter-antimatter imbalance we see in the universe today. If these theoretical predictions are correct, we expect to measure an EDM between the current experimental upper limit $|d_e| < 8.7 \times 10^{-29}$ e.cm (90% confidence) [1] and the lower theoretical limit $|d_e| > 1 \times 10^{-30}$ e.cm [2].

We measure the electron EDM by performing a spin precession measurement on a beam of supersonic ytterbium fluoride (YbF) molecules [3]. Recently, we have developed a series of improvements to the state preparation and detection of the molecules [4] [5] which has increased the flux of useful molecules by two orders of magnitude. This has significantly improved the statistical sensitivity of our machine and will allow EDMs of a few 10^{-29} e.cm to be measured.

Noise and systematic effects also need to be under good control below the level of the improved sensitivity. With the leading concern being fluctuating magnetic fields, we have also improved our measurement and control of these unwanted fields [6]. With this upgraded apparatus, we are now able to search for evidence of new T-violating physics with even higher precision.

References

- [1] The ACME Collaboration, *Science* **343**, 269 (2014).
- [2] I. B. Khriplovich and S. K. Lamoreaux, *CP Violation Without Strangeness* (Springer, New York, 1997).
- [3] J. J. Hudson, D. M. Kara, I. J. Smallman, B. E. Sauer, M. R. Tarbutt, and E. A. Hinds, *Nature* **473**, 493 (2011).
- [4] J. A. Devlin, PhD Thesis, Imperial College London, 2015.
- [5] I. M. Rabey, PhD Thesis, Imperial College London, 2017.
- [6] I. M. Rabey, J. A. Devlin, E. A. Hinds, and B. E. Sauer, *Rev. Sci. Instrum.* **87**, 115110 (2016).

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