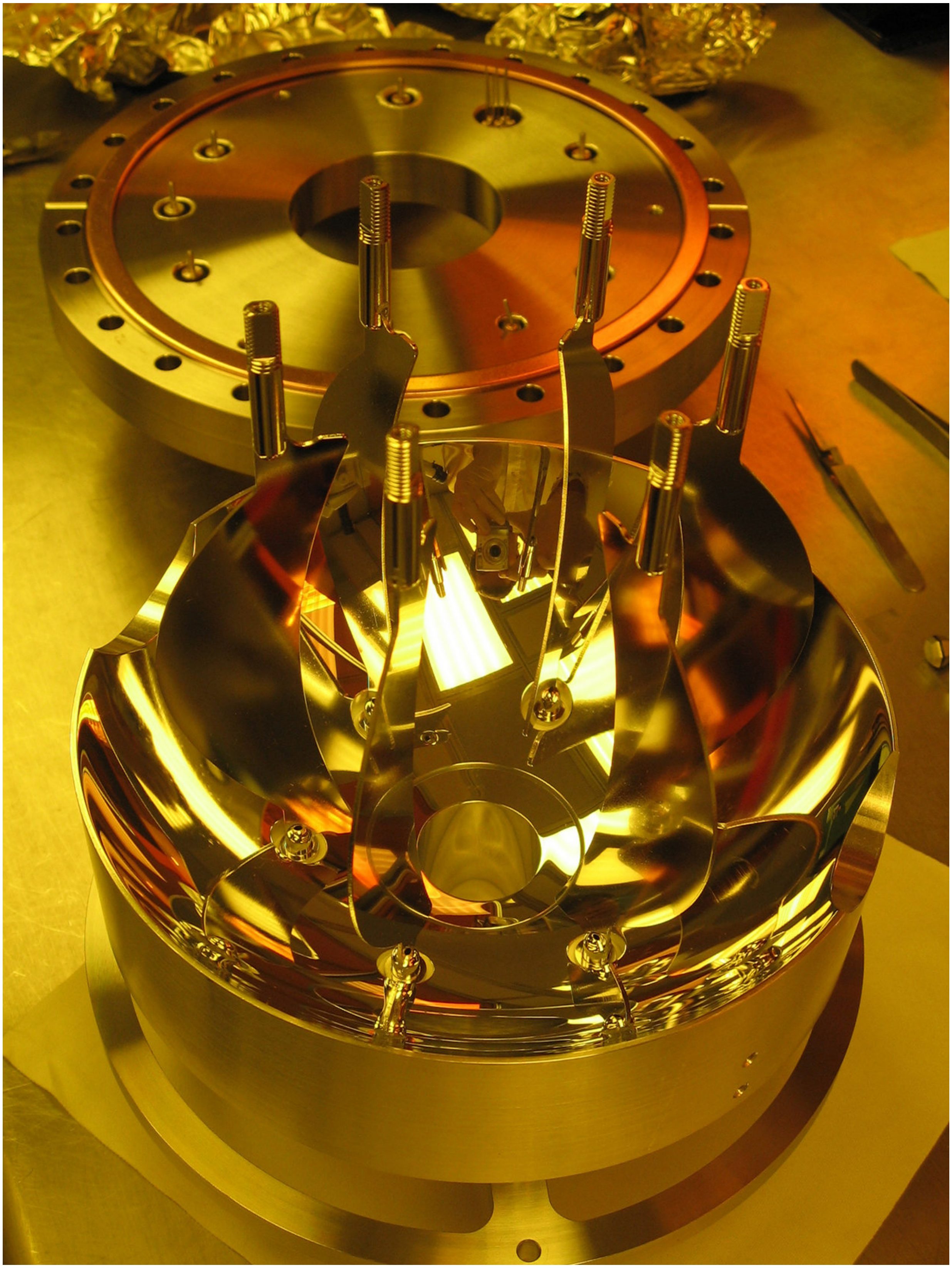
JILA spinning method confirms the electron still seems round

October 10 2017



JILA's gold-plated ion trap for measuring the electron's roundness, or electric dipole moment (EDM). The six "fins" in the foreground are electrodes attached to the trap's lower endcap. When assembled, the trap is placed in a vacuum chamber and the electrodes are charged with up to 100 volts to confine hafnium fluoride ions (charged molecules). Researchers rotate electric and magnetic fields fast enough to trap the molecular ions but slowly enough for the ions to line up with the electric field. The ions then rotate individually while scientists measure their properties. The EDM is the difference between two magnetic energy levels. Credit: JILA

JILA physicists have for the first time used their spinning molecules technique to measure the "roundness" of the electron, confirming the leading results from another group and suggesting that more precise assessments are possible.

The researchers trapped and spun electrically charged molecules (ions) to measure their electrons' symmetry, technically known as the electron's electric dipole moment (eEDM), which is the uniformity of the charge between the electron's two poles. Tiny deviations from perfect electron roundness (an eEDM other than zero) would provide new insights into fundamental physics, including the values of natural constants during the earliest history of the universe and whether current physics theories are correct. The eEDM experiment also pioneers new precision measurement technologies.

As reported in *Physical Review Letters* , the JILA team reported an upper bound on the eEDM of 1.3 x 10^{-28} e-cm—a miniscule number indicating the electron is essentially round—thereby confirming a 2014 result by The ACME Collaboration .

JILA is operated jointly by the National Institute of Standards and Technology (NIST) and University of Colorado Boulder.

"Our answer is that an electron's electric dipole moment is very small, consistent with zero," NIST/JILA Fellow Eric Cornell said. "We are really just a confirming measurement, not setting a new limit, but it's important because we use an approach that is radically different from all previous measurements. The fact that we nonetheless get the same answer pretty much eliminates the possibility that we simply got it wrong, or that the other group did."

The JILA work provided independent confirmation of ACME's result using a different physical system and experimental technique, including a special trap developed in 2013. The method offers unique advantages, notably long measurement time periods, offering future potential for more sensitive eEDM searches and other tests of fundamental physics.

Cornell has devoted much of the past decade to the eEDM quest.

"New particle physics has been discovered from measurements of other precision dipole moments," Cornell explained. "The EDM is like a big telescope looking at remnants of asymmetry left over from the Big Bang 14 billion years ago. The universe as we see it today exists only because way back when there were a few more particles than antiparticles. We are looking for modern-day fossils of that ancient asymmetry, and a likely candidate would be an electron that is misshapen, so that its mirror image looks different. The fact that we haven't see that fossil yet is surprising, but it's also a clue."

The JILA technique spins hafnium fluoride ions, "polar" molecules with a positive charge at one end ("pole") and a negative charge at the other pole. Polar molecules can be trapped and manipulated with electric fields to remain in desired states for relatively long periods of time—700 milliseconds in the new experiment, nearly 700 times longer than the best competing methods (thermal beams of neutral atoms or molecules).

JILA researchers rotate electric and magnetic fields fast enough to trap the molecular ions but slowly enough for the ions to line up with the electric field. The ions then rotate in individual micro-circles while scientists measure their properties. The electric field inside the molecules amplifies the potential signal of eEDM, which is the difference between two magnetic energy levels.

JILA researchers collected 360.3 hours of data, including 1,024 eEDM measurements. The team used a variety of techniques to find and correct for systematic errors.

In the near future, researchers expect to double their measurement sensitivity using a new ion trap, which will contain twice as many ions, cool them to a volume up to 100 times larger, and use a more uniform rotating electric field.

The rotating field technique may be useful in other experiments. For instance, quantum bits used in quantum computing could hold information longer in electric and magnetic energy levels than in more commonly used quantum states. In addition, the new technique might be used to investigate any variations over time in the fundamental "constants" of nature used in scientific calculations.

More information: William B. Cairncross et al. Precision Measurement of the Electron's Electric Dipole Moment Using Trapped Molecular Ions, *Physical Review Letters* (2017). DOI: 10.1103/PhysRevLett.119.153001

Provided by National Institute of Standards and Technology