Search for an Atomic EDM with Optical-Coupling Nuclear Spin Oscillator

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A permanent electric dipole moment (EDM) of a particle violates the time-reversal invariance and, if it shows a detectable size, would represent a clear evidence for the presence of physics beyond the standard model of elementary particles. Until now, the experimental upper limits for EDMs of neutron [1], ^{129}Xe atom [2], and ^{199}Hg atom [3] are $|d_n| < 6.3 \times 10^{-26}$ e·cm, $|d_{Xe}| < 4.0 \times 10^{-27}$ e·cm, and $|d_{Hg}| < 2.1 \times 10^{-28}$ e·cm. Extensions to models beyond the standard model, such as those with supersymmetry, typically predict values on the orders 10^{-25}-10^{-27} e·cm for neutron, and are thus already subjected to a meaningful constraint by the experimental d_n. The EDMs of diamagnetic atoms Xe and Hg receive contributions not only from the nucleon EDMs but also (and even largely) from the P, T-violating nucleon-nucleon interaction, and pose constraints different from that by d_n. Presently, the experimental d_{Hg} poses the most stringent constraint on theories, but d_{Xe} has potential for a drastic improvement, as discussed below.

Recently, we have developed a new type of nuclear spin oscillator, that is a ^{129}Xe nuclear spin maser with an artificial feedback mechanism [4]. Spin maser is a system of spins that executes self-sustained spin precession under an external magnetic field, thereby providing an unlimitedly long observation time for the spin precession and hence a high-precision frequency determination. The present spin maser is expected to operate at much (by 2-3 orders of magnitude) lower field. The low field maser operation enables an EDM measurement with very low drift in field and also the use of ultrahigh-precision magnetometry based on nonlinear magneto-optical rotation [5]. Until now a clear maser oscillation has already been obtained at fields as low as 29 mG, and Xe celles with mesh electrodes are being tested. A setup aiming at the measurement of a ^{129}Xe EDM with 10^{-29}-10^{-30} e·cm precision is under development.

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