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Experimental search for electric dipole moment in ^{129}Xe atom using active nuclear spin maser

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A permanent electric dipole moment (EDM) of a particle, atom, or molecule is an observable directly violating the time reversal symmetry, and hence probes CP-violating phases beyond a frame of the Standard Model of elementary particles. The present study aims at measuring the EDM in a diamagnetic atom of ^{129}Xe to a size of $|d| = 10^{-28}$ ecm, stepping into a domain below the present upper limit $|d| < 4.1 \times 10^{-27}$ ecm [1] by one order of magnitude. The value of EDM is determined from difference between the frequencies of ^{129}Xe spin precession measured with the electric field applied parallel and antiparallel to the magnetic field. The EDM search to a size of $|d| = 10^{-28}$ ecm requires an improvement in the frequency precision down to a level of 1 nHz under an electric field of 10 kV/cm.

In the present EDM measurement we employ an active nuclear spin maser [2] which enables us to sustain the spin precession of ^{129}Xe in a long measurement duration. The active spin maser operates as follows: the longitudinal polarization of ^{129}Xe spin is produced through spin exchange with Rb atoms which are optically pumped. Then the ^{129}Xe spin starts precession, which is detected optically through Rb atoms which are repolarized by contact with ^{129}Xe . By referring to the precession signal thus obtained, a magnetic field rotating in the transverse plane is generated such that its direction is kept orthogonal to transverse component of spin, which thus prevents the transverse spin relaxation. The previous developments of the active spin maser have improved the precision of frequency determination to $\delta\nu = 9.3$ nHz for a one-shot measurement within a limited duration [2,3]. A comagnetometer using ^3He has been incorporated to the nuclear spin maser system in order to cancel out a long-term drift in the external magnetic field, by taking advantage that it directly measures the magnetic field that acts on the volume where the ^{129}Xe spin precesses. Both the ^{129}Xe gas and the ^3He gas are contained in a cell of which the gas volume is divided into an optical pumping part and an optical detection part, in order to reduce the longitudinal spin polarization of Rb atoms in the optical pumping part and thus to suppress the frequency shift due to polarized Rb atoms. Electrodes are attached to the both sides of the optical detection part in order to apply an electric field of 10 kV/cm.

With the success in the above developments, the EDM search for ^{129}Xe to a size of $|d| = 10^{-28}$ ecm has been ready and the measurement is now being started. The developments and the status of the measurement will be presented.

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[3] T. Inoue et al., Physica E 43, 847 (2011).