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Active nuclear spin maser oscillation with double cell

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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 will be an evidence for unknown CP-violating phases beyond the Standard Model. The present study aims at measuring the EDM in ^{129}Xe atoms to a size of $|d| = 10^{-28}$ $e$cm. In the EDM measurement, we employ the active nuclear spin maser [1] which enables us to sustain the spin precession of ^{129}Xe in a long measurement duration. The spin precession of ^{129}Xe is detected optically through Rb atoms which are polarized by contact with ^{129}Xe. A magnetic field is generated according to the phase in the direction orthogonal to the spin precession, in order to prevent the transverse spin relaxation.

The previous developments of the active spin maser have improved the precision of determination of the frequency to $\delta\nu = 9.3$ nHz for one-shot measurement within a limited duration [1,2]. However, systematic uncertainty arises from long-term drifts in frequency, amounting even to 400 μHz, which mainly arises from drifts in the external magnetic field and frequency shifts due to contact interaction with the polarized Rb atoms. A co-magnetometer using ^{3}He was incorporated to the nuclear spin maser system in order to cancel out the former drifts which were commonly sensed by ^{129}Xe and ^{3}He. On the other hand, the latter one could not be removed even by the ^{3}He co-magnetometer because the strengths of the Rb-^{129}Xe and Rb-^{3}He contact interaction are different [3,4]. Therefore we decided to employ a double cell [5] in which the gas volume is divided into an optical pumping part and an optical detection part in order to reduce the spin polarization of Rb in the optical detection part and thus to suppress the frequency shift due to the contact interaction.

In this work, we studied operation of the active nuclear spin maser in a double cell configuration. Optimum settings for the parameters of the double-cell maser operation either for ^{129}Xe and ^{3}He, such as the magnitude of the feedback field, phase and the gas temperature, were estimated through tests using a single cell where the pumping part and the detection part were unified. Using the optimized parameters thus obtained, the active spin maser in the double cell configuration was actually operated. The performance of the maser in this new operation mode may undergo difference arising from the diffusion of the gas between the two regions of cell. The difference will be discussed with the comparison to that using the single cell. The improvement in the frequency precision will also be discussed in the presentation.

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