Atomic Spin Squeezing Towards Sub-Shotnoise Measurement Of Permanent Electric Dipole Moment

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We have been studying laser cooled and trapped atoms towards the detection of the permanent electric dipole moment (p-EDM). The existence of the p-EDM shows the CP-violation and its detection has significant implications for the verification and the determination of the models of the elementary particle. However, the current experimental accuracy has not yet reached the range of the predicted value of the standard model. Especially, a measurement error due to a shot noise is one of the important factors, which limits the accuracy of the measurement. So, we are now trying to generate the atomic squeezed spin state, which is not limited by shot noise.

At first, let us think atomic spin ensemble polarized in the z-direction. Then, the uncertainty relation of angular momentum, $\triangle S_x{}^2 \triangle S_y{}^2 \geqq |\langle S_z \rangle|^2/4$, causes the uncertainty in the x- and y- directions. For coherent state of spin, which corresponds to the classical spin-polarized state, the uncertainties are isotropic, i.e., $\triangle S_x{}^2 = \triangle S_y{}^2 = |\langle S_z \rangle|/2$ holds. This is the limit of classical spin measurement, called shot noise limit. However, for the spin ensemble, quantum correlation allows a state like $\triangle S_x{}^2 < |\langle S_z \rangle|/2$、$\triangle S_y{}^2 > |\langle S_z \rangle|/2$, which is called a squeezed spin state.

We proposed the quantum non-demolition measurement of spin ensemble for generating the squeezed spin state. Our experimental setup is shown in Fig.1. This method uses the Faraday rotation, which is the phenomenon that the polarized spin ensemble rotates the plane of polarization of incident linear-polarized light. The rotation angle is proportional to spin polarization in the incident direction. If the results of two successive measurements of the rotation angles Φ1 and Φ2 have correlation, spin squeezing is achieved.

In poster, I will report current status of our experiment using laser cooled ytterbium atoms.

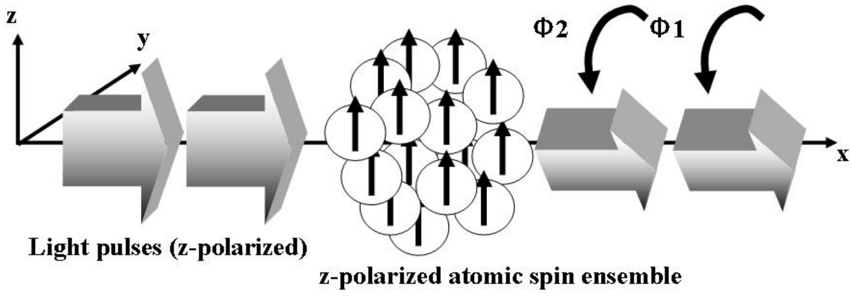

FIGURE 1. Experimental Setup