Deterministic nuclear spin squeezing and squeezing by continuous measurement using vector and tensor light shifts

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We study the joint effects of vector and tensor light shifts in a set of large spin atoms, prepared in a polarized state and interacting with light. Depending on the ratio ϵ between tensor and vector coupling and a measurement rate Γ, we identify a regime of quantum non-demolition measurement squeezing for times shorter than $(\sqrt{\epsilon}\Gamma)^{-1}$, and a deterministic squeezing regime for times longer than $(\epsilon\Gamma)^{-1}$. We apply our results to fermionic isotopes of strontium, ytterbium, and helium, which are atoms with purely nuclear spin in their ground state, benefiting from very low decoherence. For ytterbium 173, with a cavity such as that of [1], it would be possible to achieve an atomic spin variance reduction of 0.03 in $\simeq 50\text{ms}$.

Used directly, the spin squeezed state for helium 3 could be used in magnetometry and improve the accuracy of fundamental physics experiments [2]. As for alkaline earth atoms or similar atoms, the squeezed state could be transferred to an optical transition [3], to benefit atomic clocks [4, 5].

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