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Measurement-induced macroscopic entanglement generation in a hot, strongly interacting atomic system

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Abstract

We study non-local entanglement and macroscopic singlet state generation in a hot, strongly-interacting atomic system by using quantum non-demolition (QND) measurement, and particularly, the Bayesian estimation technique of Kalman filtering (KF) [1] to recover the spin information. By comparing the total spin variance against spin squeezing inequalities [2], we observe 1.9 dB spin squeezing, and at least 1.5×10^{13} atoms have entered singlet state with entanglement bonds extending thousands of times the nearest-neighbor distance. The results show that the hot, strongly-interacting media, now in use for extreme atomic sensing, together with QND and KF techniques can operate beyond the standard quantum limit (SQL).

We work with a vapor of ^{87}Rb contained in a glass cell with buffer gas to slow diffusion, and housed in magnetic shielding and field coils to control the magnetic environment, see Fig. 1 **a)**. The density is maintained at $n_{\mathrm{Rb}} = 3.6 \times 10^{14}$ atoms/cm^3, and the magnetic field, applied along the $[1, 1, 1]$ direction, is used to control the Larmor precession frequency $\omega_L/2\pi$. At low ω_L, the vapor enters the SERF regime, characterized by a large increase in spin coherence time as shown in Fig. 1 **b)** with spin noise spectroscopy [3]. The KF provides both a best estimate and a covariance matrix for the state variable, which gives an upper bound on the variances of the post-measurement state. In particular, the total variation can be compared against spin squeezing inequalities to detect and quantify entanglement. Fig. 1 **c)** shows the total variance including a transition to squeezed/entangled states as the system enters the SERF regime.

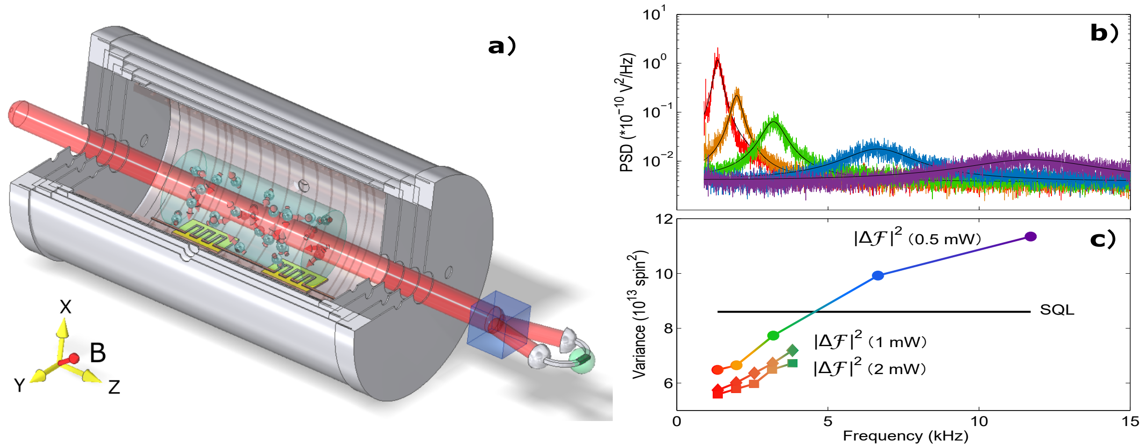

Figure 1: Experimental Principle. **a)** Experimental setup. **b)** Spin noise spectra with different bias field strengths. **c)** Spin variance $|\Delta\mathcal{F}|^2$ versus Larmor frequency corresponding to the spectra in b). Black solid-line shows the standard quantum limit (SQL). Round, diamonds and squares symbols show $|\Delta\mathcal{F}|^2$ measured with 0.5 mW, 1 mW and 2 mW probe light, respectively.

References

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