Standard quantum limits for cavity-enhanced optical readout methods of hot atomic vapor quantum sensors

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The phenomenon of Cavity Enhancement (CE) refers to the increase in the effective interaction length between a probing light beam and an atomic platform placed inside a resonant cavity structure. CE methods have been used extensively in the context of single atoms [1], cold atomic ensembles [2] and hot atomic vapors [3]. In this work, we focus on deriving the quantum noise limits of different optical readout techniques for monitoring the intra-cavity collective spin variables of a hot atomic ensemble with high number density. We provide a unified Figure of Merit which combines the sensitivity of each technique with the spin decoherence rate due to light-atom interaction. Our analysis includes the quantum noise limits of Homodyne and Heterodyne interferometric measurements as well as direct detection of phase modulated probe light followed by demodulation (the Pound-Drever-Hall readout method [4]). To highlight the enhancment factor in each of the three distinct CE readout methods presented in this work, the figure of merit of each CE method is compared against the single-pass polarimetric measurement using Faraday rotation.

References

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