

Quantum-Enhanced Two-Photon Spectroscopy Using Two-mode Squeezed Light

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Studies of atomic and molecular spectra are among the most common spectroscopic tools. Typically, a broadband or broadly-tunable light source is used to determine the characteristics of various optical transitions through their absorption spectrum. However, some applications have limits on the light level allowed for interrogation. In biological systems, for example, too much light can induce temporary or permanent photo-damage. Since for optical measurements the sensitivity is ultimately limited by the shot noise, the low-light applications will benefit the most from the possibility of the sub-shot noise measurements using squeezed light. Here we investigate the prospects of using two-mode intensity squeezed twin-beams, generated in Rb vapor, to improve the sensitivity of spectroscopic measurements by engaging two-photon Raman transitions. In this proof-of-principle demonstration we were able to detect the level structure of the $5D_{3/2}$ state of ^{87}Rb by means of two-photon Raman absorption with detection noises 5 dB below the classical shot noise limit using a source of two-mode intensity-squeezed light based on four-wave mixing in ^{85}Rb vapor cell. With the reduced measurement noise floor we were able to observe Raman absorption resonances at the reduced pump power and Rb atomic density.

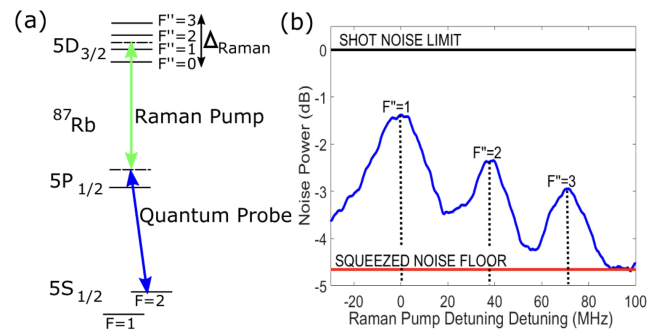


Figure 1: (a) The two-photon transition ($5S_{1/2}, F = 2 \rightarrow 5D_{3/2}, F'' = 1, 2, 3$) of the probe field coupled to the Raman pump field. (b) Differential intensity noise trace from spectrum analyzer mapping the $5D_{3/2}$ structure as the Raman pump field frequency is tuned through the corresponding two-photon resonances. The Raman pump power is 5 mW, and the cell temperature is 65°C (atomic density $3.7 \cdot 10^{11} \text{cm}^{-3}$)