Observation of the Mollow Triplet from an Optically Confined Single Atom

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Resonance fluorescence from atomic systems consists of a single spectral peak that evolves into a Mollow triplet for a strong excitation field [1]. Photons from different peaks of the triplet show distinct timing correlations that make the fluorescence a useful light source for quantum information purposes.

Here, we report the observation and analysis of fluorescence collected from a strongly driven single $^{87}$Rb atom in a far off-resonance optical dipole trap (FORT) [2]. By utilizing the available closed transition, we can study the frequency spectra of the resonance fluorescence emitted from a near ideal two level system under different driving strength.

In our experiment, an aspherical lens focuses near-resonant probe laser light onto the atom and collects backscattered photons with minimal laser background. The probe is near-resonant with the closed transition $5^2S_{1/2}|F = 2, m_F = -2⟩ \equiv |g⟩$ to $5^2P_{3/2}|F = 3, m_F = -3⟩ \equiv |e⟩$. We record the spectra of the light scattered by the atom at different excitation intensities with a scanning Fabry-Perot cavity and the results are shown in Fig. 1. As the excitation power increases, the three-peak structure emerges and the splitting between the peaks also increases.

We also investigate the timing cross-correlation between photons originated from two distinct Mollow sidebands. While the atom is excited resonantly, the emission of the sideband photons does not have a preferred order. As such, the cross-correlation between photons from different sidebands is symmetric with respect to zero time delay, $\tau = 0$. However, if the excitation field is detuned from the atomic resonance, this symmetry is broken as the emission process of the sideband photons now have a preferred order [3].

Fig. 2 shows the cross-correlation measurement between the opposite Mollow sidebands where we use photon from the lower energy sideband as ‘start’ trigger and the photon from the other sideband as ‘stop’ signal. The normalized correlation is then fitted by two exponentials, with time constants of $\tau_{\text{rise}} = 7.8(9)$ ns and $\tau_{\text{fall}} = 30(2)$ ns, respectively. The asymmetry of the correlation function indicates that the emission of the sideband photons has a preferred time-order for off-resonant excitation.

Example References
[1] B. R. Mollow, “Power spectrum of light scattered by two level systems,” Phys. Rev. 188, 1969 (1969).
[2] B. L. Ng, C. H. Chow, and C. Kurtsiefer, “Observation of the Mollow triplet from an optically confined single atom,” Phys. Rev. A 106, 063719 (2022).
[3] C. A. Schrama, G. Nienhuis, H. A. Dijkerman, C. Steijger, and H. G. M. Heideman, “Intensity correlations between the components of the resonance fluorescence triplet,” Phys. Rev. A 45, 8045 (1992)