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Magnon Blockade for Photonic Magnonic system

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Abstract

We theoretically investigate the magnon blockade in a cavity magnonic system. The cavity system is coupled with a strong coupling regime. The blockade system is achieved by tuning different system parameters with the help of some recent experimental results. Perfect magnon blockade is achieved under a weak coupling regime. By solving the Master's equation numerically we determined the second-order correlation function of magnon coupling with different system parameters. We controlled the magnon blockade perfectly by tune different system parameters. Single magnons have different potential applications in quantum simulation and quantum information processing.

Keywords: Magnon Blockade, Second order correlation function, Quantum Simulation.

1 Introduction

Single magnon source has many more applications in quantum optics, especially in quantum communication. In different experiments, it is clear the single magnon has basic tools for communication due to its extremely high spin density [1, 2, 3, 4]. Optical cooling magnon [5] has important applications. In a cavity, a magnonic system to generate Bell states magnon photon phonon coupling [6] and magnon phonon squeezed states [7] is required. In recent, some nonlinear system photon phonon and magnon blockade effects is discussed [8, 9, 10]. To generate a Magnon-polariton system magnon blockade effect is a common phenomenon [11, 12]. To design, a magnon emitter magnon blockade phenomena are used [13]. In recent magnon, the blockade effect mechanism is discussed theoretically and experimentally by using a YIG sphere in a cavity magnonic system [14, 15, 16]. To our knowledge, our work has many aspects to achieve blockade effects in Nonlinear Optics. Also, this study covers many parts to enhance nonlinear phenomena, Blockade phenomena is the fundamental study to generate a single magnon or photon.
This paper's design is as follows: In section 1 we discussed the model and different parts of our model. In section 2 we numerically solve our system Hamiltonian. In this section, we also discussed the numerical results of the Magnon Blockade. In section 3 we discussed our results with the help of different experimental studies. At last, we discussed the Conclusion of this study.

2 The Model

The cavity Magnonic system represented by the Hamiltonian (taking $\hbar = 1$)[17, 18]
H=$\omega_a\ a^*\ a + \omega_m\ m^*\ m + \zeta\ m^*\ mm^*\ m + g_m\ (a^*\ m + am^*\ ) + \Omega(m^*\ e^{-i\omega_d\ t} + me^{i\omega_d\ t})$——1
The first part of this Hamiltonian represents cavity Photons and $a^*(a)$ represents the creation (annihilation) operator of photons with a frequency ω_a. The second part of this Hamiltonian represents the Magnonic system and $m^*(m)$ represents the creation (annihilation) operator of Magnons with frequency ω_m. The third term represents a magnon nonlinear term. Where $\zeta = \frac{\mu_o\gamma}{M^2 V_m}$ μ_o is magnetic permeability, γ gyromagnetic ratio, M saturation magnetization, V_m The volume of the magnetic cavity. The fourth term represents the coupling between photon with magnon, where g_m is the coupling strength.The last term represents as driving term, where Ω is the strength of the laser source, which is equal to $\sqrt{\kappa P/\hbar\omega_c}$ with P and κ being the drive laser power and the cavity damping rate, ω_c probe field frequency and ω_d drive field frequency. In the rotating frame with the drive frequency ω_c the interaction Hamiltonian has the form
$H = \Delta_a a^* a + \Delta_m m^* m + \zeta m^* m m^* m + g(m a^* m + am^*) + \Omega(m^* e^{-idt} + me^{idt})$——-2

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Where $\Delta_a = \omega_a - \omega_c$, $\Delta_m = \omega_m - \omega_c$, $\Delta_d = \omega_d - \omega_c$ we derive the coupled equations for the macroscopic fields $\bar{a}$, $\bar{m}$.

3 Master Equation

To study the perfect magnon blockade effect we use a Classical field with a frequency ω_d and coupling between cavity field and driving field amplitudeΩ with zero pumping phase. Using the noise term from the environment, the master equation for the density operator in a double cavity optomechanical system
$\dot{\rho} = \frac{\partial \rho}{\partial t} = -i[H,\rho] + \kappa_1 \mathcal{L}_{a1}(\rho) + \kappa_2 \mathcal{L}_{a2}(\rho) + \gamma_o(n_{th}+1)\mathcal{L}_b(\rho) + \gamma_o n_{th} \mathcal{L}_{b^*}(\rho)$——3
The Lindblad dissipation for the phonons $\mathcal{L}_o(\rho) = o\rho\ o^* - o^*\ o\rho - \rho\ o^*\ o$ ————4
Where $o =\ a_j (j = 1,\ 2)$ or corresponds to the photon or magnon here κ_1, κ_2 , γ_o are the decay rates of photon and magnon respectively, $n_{th} = 1/e^{\omega\kappa T}$ where k is the Boltzman constant and T is the temperature. Now the second-order correlation function
$g_2(0) = Tr(m^* m^* mm)/Tr[m^* m)]^2$——-5

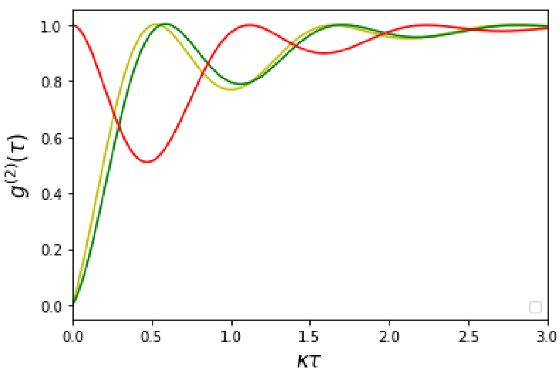

Figure 1: Second Order correlation under time

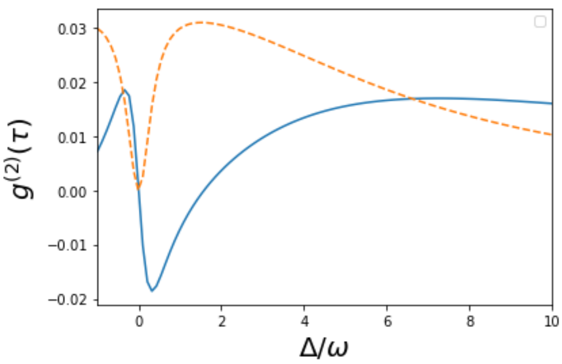

Figure 2: Second order Correlation under Detuning parameter

Fig (1-2) Plots of Second order corelation function as a function of normalized Detuning frequency. $\omega_m = 2\pi \times 10.5\ GHz$, $\kappa_1 = 6.5 \times 10^6 \omega, \kappa_2 = 2.5\omega, g_m = 5\omega$, $\Omega = 10.65MHz, n_{th} = 200(a)\kappa = 0.5, = \quad 0.5, 0.8, 1.0(red, yellow, green)(b)\kappa = 0.5, 1.0. = 0.5$.

4 Conclusion

We have observed numerically and analytically the Magnon Blockade effect in this system Hamiltonian by calculating the second-order correlation function. To generate the perfect Magnon blockade in a weak coupling region we have predicted the distinguishable relationship with different system parameters. We have discussed the necessary condition for generating antibunched and sub-Poissonian Magnon sources. We have derived the steady state condition and have given the emission efficiency of generated single Magnon source. In presence of weak Kerr, nonlinearity is taken for the generation of the Magnon Blockade effect. This Study opens a new window for an experimentalist to produce a single Magnon source by controlling different system parameters and is useful in Quantum communication technology.

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