IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Enhancement of Entanglement to realize the effect on Wireless Communication in Optomechanical System.

Anjan Samanta[1,2*], Tuhina Sinha[2] , Paresh Chandra Jana[2]

[1]Sabang Sajanikanta Mahavidyalaya Lutunia, Paschim Medinipur, 721166. India

[2]Vidyasagar University Medinipur, Paschim Medinipur, 71102. India

Abstract

In this paper, we consider an optomechanical system containing, a cavity field and Coulomb interaction effects. In this work, we theoretically present an indicative enhancement of the steady-state Entanglement in an optomechanical system. We observe the various effects of Entanglements between optical cavity systems by taking the pump field power for different coulomb coupling parameters. Quantum Entanglement is observed by calculating fluctuations of position and momentum parameters. We also verified the maximum entanglement for this System for experimental data. The Entanglement is enhanced by increasing the strength of Coulomb interaction effects. In our study, we successfully enhance the footstep of steady-state optomechanical entanglement to improve quantum communication like optical Switching. Our study is necessary to achieve quantum computing and also for long-range quantum communication.

Keywords- Optomechanical System, Entanglement, Fluctuation Parameters.

Introduction

The central concept of quantum theory that violates Bell's inequalities is the result of entangled states. The amount of entanglement of a bipartite system can be quantified in terms of a quantity called the entropy of entanglement. It is more important that entanglement between mechanical mode and a mechanical oscillator has a large application in quantum information processing. It has been observed that the maximum entanglement between two modes via dissipation-induced coupling can be achieved using various experimental parameters [1]. Effects of Laser on optomechanical entanglement in non-linear Kerr system [2], entangled states in macroscopic oscillator [3]and the various proposal have been studied for generating this state [4-7]. Entanglement is one of the tools for a wide range of applications in quantum telecommunication [8], Enhancement of mechanical entanglement in a hybrid optomechanical system [9]. are necessary for quantum computing[10], quantum teleportation [11], quantum cryptography [12], quantum dense coding[13]. Nowadays field-field Entanglement is achieved for various studies [14]. An experimental application is there in mechanical-mechanical Entanglement [15-17], Squeezed optical field and mechanical resonator Entanglement [18-21]and two film Entanglement [22]. The Entanglement process is very important for Quantum Signal Processing and Quantum Communication technology. In our study, we have shown how Entanglement study is useful for wireless communication for our defence system.

Dynamical Equation

The optomechanical system for our investigation is composed of a system Hamiltonian [23].The Hamiltonian of the system can be written as($\hbar = 1$)

$$H = \Delta_a a^\dagger a + \Delta_c c^\dagger c + \frac{\omega_m}{2}(P_j^2 + Q_k^2) + \lambda\left(a^\dagger c + a c^\dagger\right) + g c^\dagger c Q + c^\dagger \varepsilon_i e^{-i\delta t} + c\varepsilon_i^* e^{i\delta t} \quad [1]$$

Here $\Delta_i = \omega_i - \omega_m$, $(i = a, c)$ is the detuning of the pump field for the cavity, δ is the detuning for the probe field,w_m is the mechanical frequency, Here $a(a^\dagger)$, $c(c^\dagger)$are annihilation (creation) operators for the cavity field modes, P, Q denote the position and momentum operators respectively $P_j = \frac{p}{\sqrt{m\omega_m\hbar}}$, $Q_k = \frac{qm\omega_m}{\hbar}$, (j,k =a,c) these parameters obey commutation relation $[P_j, Q_k] = i\delta_{jk}$, λ represent the optomechanical interaction term between the cavity field and mechanical vibrator, g indicates the Coulomb interaction between cavity field and pump field, $g = \frac{CV}{4\pi\varepsilon_{o} r^3}$. The field strength is related to control field power by the relation $\varepsilon_i = \sqrt{\frac{4\pi P k_c}{\omega h}}$, P denotes Laser power, k_j cavity decay rate. In this model, the last two-terms denote the interaction between cavity, pump & probe field. Now considering noise term the Heisenberg-Langevinn equations are

$\dot{Q} = \omega_m P + g c^+ c$

$\dot{P} = \omega_m Q$

$\dot{a} = \Delta_a a + \lambda c + \xi_1$

$\dot{c} = \Delta_c c + \lambda a + g c Q + \varepsilon_i + \xi_2$

The perturbation operators satisfy the following correlations

$< a(t)a^\dagger(t') > = < c(t)c^\dagger(t') > = \delta(t-t')$

$< a^\dagger(t)a(t') > = < c^\dagger(t)c(t') > = 0$

We analytically solve the above relations and determine relative momentum and position fluctuation in terms of $<\delta P>$ & $<\delta Q>$. In this calculation ξ_1, ξ_2 are the thermal noise components.

Result and Discussion

In this work, we analyze the entanglement with sufficient conditions to calculate the product of position and momentum fluctuation term. In this regards, we analytically solve the product of $< \delta P^2 > < \delta Q^2 >$ to analyze the entanglement for this system by taking suitable system parameters. We take the parameters of the recent experimental studies[24]:

$\lambda = 105nm, r_o = 24nm,\ m = 150\ kg, \kappa = 2\pi * 213 * 10^{13}\ HZ,\ \omega_m == 2\pi * 900 * 10^{13}\text{HZ},\quad g = -6 * 10^{35} * \tau$

where τ is a dimensionless constant which is related with coulomb coupling strength. we normalized our results by using frequency $\omega = \sigma * \omega_m + \omega_m$. For the resonance condition $\Delta_a = \Delta_c = \omega_m = \omega$. Now we have plotted $< \delta P^2 > < \delta Q^2 >$ as a function of σ for different values of recent experimental studies as in ref[24].

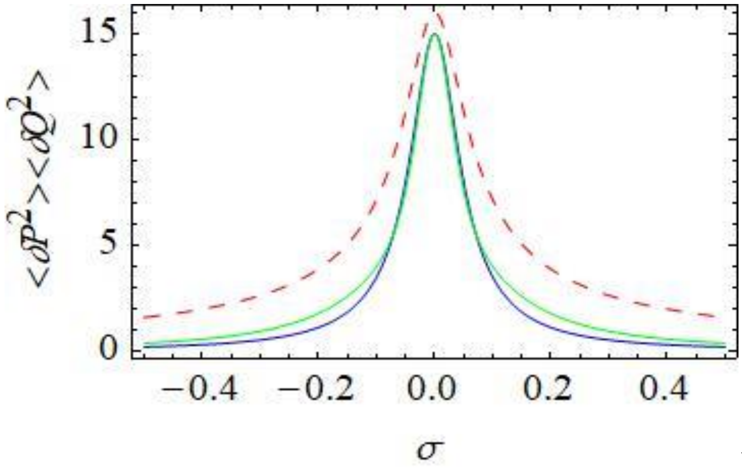

Fig-1

Fig 1. The fluctuation product as a function of σ with a pump power of 13 mW and for different values of τ. $\tau = 20, (red)\tau = 30, (green)\tau = 35, (blue)$ other parameters are set as above.

From this figure-1, we see that Coulomb interaction effect on the entanglement between the cavities. When switched on it means $\tau = 20$ is high. This implies the presence of coulomb interaction affects entanglement . In this Criterion, we use optical switching for wireless communication.

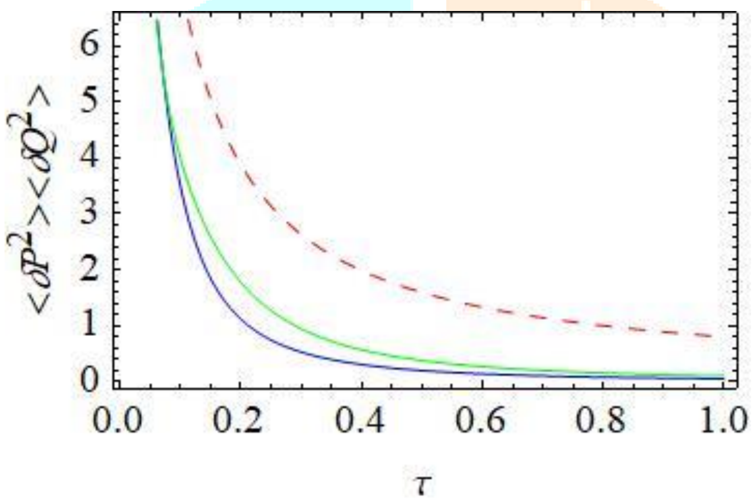

Fig 2. The product of fluctuation term vs the Coulomb interaction amplitude τ for different pump power red(20mW) green (25mw) blue(29mW), Other parameters are same as in fig.1

This implies that Entanglement with Coulomb interaction amplitude is remarkable with pump power. This property can be used for quantum communication like wireless systems.

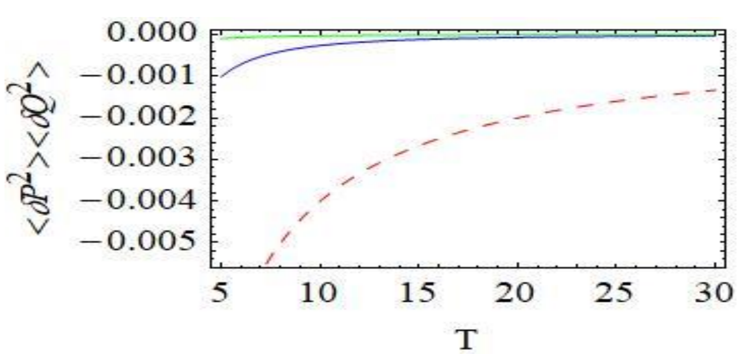

Fig 3. The product of fluctuation vs temperature in Kelvin, for $\tau = 0$ with different pump power red(20mW) green (25mw) blue(29mW),Oother parameters are same as in fig.1.

We observe that as temperature is low the Entanglements are destroyed or week.. So under the environment temperature entanglement between the cavity optomechanics is relaxed by Coulomb interaction effects.

Conclusion

In this investigation, we theoretically calculated and graphically represent how entanglement is established between the cavity field with Coulomb interaction in Quantum Optomechanical System. In our study, we have also discussed about the pump field power, coulomb coupling interaction term, and also environment temperature on entanglement..Our graphical representations show the enhanced effect on the field power, interaction amplitude. we also present the effect of environmental temperature for destroying the Entanglement Process. We have also correlated our results with recent experimental studis[24] in this field. We have used the experimental system parameters and studed our results theoretically in order to use our system in the field of Quantum Communication, Optical Switching, and to Improve wireless communication for defense.

Author Contribution Statement

This work has been was discussed by three authors and carefully verified the output profile.

References

1. E. A. Sete, H.Eleuch,and C.H.Raymond,Phys. Rev. A 92,033843(2015).
2. G Wendin, rep. Prog. Phys. 80. 106001 (2017).
3. L. Tian, Phys. Rev. Lett. 108,153604(2012)
4. S. Mancini, V. Giovannetti, D. Vitali, and P. Tombesi, Phys. Rev. Lett. 88, 120401(2002)
5. M. Schmidt, M. Ludwig, and F. Marquardt, New J. Phys. 14, 125005(2012).
6. M. J. Wooley and A.A. Clerk, Phys. Rev. A 87, 063846 (2013).
7. H. Tan, L.F. Buchmann, H. Seok, and G. li, Phys. Rev. A 87, 022318 (2013).
8. Jones, J., & Jaksch, D. (2012). Quantum communication. In *Quantum Information, Computation and Communication* (pp.152-162). Cambridge University Press.
9. A. Sohail, M. Rana, S Ikram, T. Munir, T. Hussain, R. Ahmed, C. S. Yu. Quantum Information Processing 19372(2020).
10. A. Barenco, D. Deutsch, A. Ekert, R. Jozsa, Phys. Rev. Lett. 74, 4083 (1995).
11. C.H. Bennett, G.Brassard, C.Crepeau, R. Jozsa, A. Peres, W. K. Wootters. Phys. Rev. Lett. 70, 1895 (1993)
12. A. K. Ekert. Phys. Rev. Lett. 67, 661 (1991)
13. X. Wang, L. Qiu, S. Li, C. Zhang, B. Ye. JETP 9, 120 (2015)
14. Y. D. Wang, A. A. Clerk. Phys. Rev. Lett. 110, 253601 (2013)
15. H. Tan, G. Li, P. Myestre, Phys. Rev. A 87, 033829 (2013)
16. Woolley, M.J., Clerk, A.A. Phys. Rev. A 89, 063805 (2014)
17. Amjad, Sohail, Rizwan, Ahmed, Yu. Chang-Shui, Tariq, Munir. Phys. Scr. 95, 035108 (2020)
18. Pinard, M. Inard, A. Dantan, D. Vitali, O. Arcizet, T. Briant, A. Heidann, Europhys. Lett. 72, 747 (2005)
19. S. Huang, G. S. Agarwal. New J. Phys. 11, 103044 (2009)
20. R. Ahmed, S. Qamar, Phys. Scr. 92, 105101 (2017)
21. R. Ahmed, S. Qamar. Phys. Scr. 94, 085102 (2019)
22. M. J. Hartmann, M. B. Plenio. Phys. Rev. Lett. 101, 200503 (2008)
23. Samanta. A., Mukherjee. K., Jana. P.C., Int. J. Phys. Res. Appl. 4: 019-025. (2021)
24. S. Grobalcher, K. Hammerer, M. R. Vanner, M. Aspelmeyer,.Nature 460. 724. (2009)