量子光学

强耦合作用下自旋与碳纳米管谐振器之间的动力学研究

李秀红，米贤武

吉首大学物理与机电工程学院，　湖南 吉首 416000

摘要：　理论分析了单电子自旋与碳纳米管机械谐振器之间的耦合对系统动力学行为的影响。用一个主方程，通过半经典的方法具体研究了系统在有量子位-谐振器耦合和没有耦合时平均声子占有数随频率失谐的变化情况、在不同耦合强度时对比了系统在旋波近似和非旋波近似下平均声子占有数随频率失谐的变化情况。在有耦合的情况下，平均声子占有数在共振时，产生了一个分裂，而且在分裂峰值的附近出现了双稳态。通过对碳纳米管谐振器平均声子占有数的分析发现，旋波近似和非旋波近似在耦合强度较弱的情况下能够很好的吻合。当系统进入超强耦合时，旋波近似不再有效，此时非旋波项变得不可忽略。

关键词：　量子光学　平均声子占有数　旋波近似　非旋波近似

Dynamic research between spin and carbon nanotube resonator under strong coupling

LI Xiu-hong, MI Xian-wu

College of Physics, Mechanical and Electrical Engineering, Jishou University, Jishou 416000, China

Abstract: The dynamic behavior of system which influenced by the coupling between the single electron spin and carbon nanotube mechanical resonator is theoretically analyzed.By means of a master equation, average phonon occupation number as functions of the frequency detuning under the case with and without qubit-oscillator coupling is investigated via a semiclassical approach、the variation of average phonon occupation number as functions of the frequency detuning under the case with and without rotating-wave approximation is compared for different coupling strength. For coupling system, average phonon occupation number occurs a splitting phenomenmon when resonance, simultaneously, a bistable state is observed near the splitting peak. By analysing the average phonon occupation number of the carbon nanotubes resonator, it finds that rotating-wave approximation and non-rotating-wave approximation can coincide with each other very well under the weak coupling strength . However, the non-rotating-wave approximation term must be considered in the ultrastrong coupling system due to the rotating-wave approximation is no longer effective.

Keywords: quantum optics　average phonon possession number　rotating-wave approximation　non-rotating-wave approximation

参考文献：

[1] Hanson R, Kouwenhoven L P, Petta J R, et al. Spins in few-electron quantum dots [J]. Rev. Mod. Phy , 2007, 79: 1217－1265. [2] Palyi A, Struck P R, Rudner M, et al. Spin-orbit-induced strong coupling of a single spin to a nanomechanical resonator [J]. Phys.Rev.Lett.., 2012, 108: 206811. [3] Zheng H, Zhu S Y, Zubairy M S, et al. Zeno and Anti-Zeno effects: without rotating wave approximation [J]. Phys. Rev. Lett.., 2008, 101:200404-200408. [4] Ai Q, Li Y, Zheng H, et al. Quantum anti-Zeno effect without rotating wave approximation [J]. Phys. Rev. A, 2010, 81:042116-042127. [5] Zhang Y W, Chen G, Yu L X, et al. Analytical ground state for the Jaynes-Cummings model with ultrastrong coupling [J]. Phys.Rev.A, 2011, 83:065802-065805. [6] Beaudoin F , Gambetta J M , Blais A, et al. Dissipation and ultrastrong coupling in circuit QED [J]. Phys.Rev.A, 2011, 84:043832-043846. [7] Chen Q H, Yang Y, Liu T, et al. Quantum discord dynamics of two qubits in the single-mode cavities [J]. Phys.Rev.A, 2010, 82: 052306-052313. [8] Anappara A A, Liberato S D, Tredicucci A, et al. Signatures of the ultrastrong light-

matter coupling [J]. Phys. Rev. B, 2009, 79: 201303-201313. [9] Todorov Y, Andrews A M, Colombelli R, et al. Ultrastrong Light-Matter Coupling Regime with Polariton Dots [J]. Phys. Rev. Lett., 2010, 105:196402-196405. [10] Fedorov A, Feofanov A K, Macha P, et al. Strong Coupling of a Quantum Oscillator to a Flux Qubit at its Symmetry Point [J]. Phys. Rev. Lett., 2010, 105:060503-060506. [11] Nataf P , Ciuti C. Protected Quantum Computation with Multiple Resonators in Ultrastrong Coupling Circuit QED [J]. Phys. Rev. Lett., 2011, 107: 190402-190405. [12] Lizuain I, Casanova J, García-Ripoll J J, et al. Zeno physics in ultrastrong circuit QED [J]. Phys. Rev. A, 2010, 81:062131 – 062139. [13] Huettel A K ,Steele G A, Witkamp B, et al. Carbon nanotubes as ultrahigh quality factor mechanical resonators [J]. Science, 2009, 325: 1103 . [14] Palyi A, Struck P R, Rudner M, et al. Supplementary electronic material for: Spin-orbit-induced strong coupling of a single spin to a nanomechanical resonator [J]. Phys.Rev.Lett., 2012, 108 :206811. [15] Jaynes E T , Cummings F W. Comparison of quantum and semiclassical radiation theories with application to the beam maser [J]. Proc. IEEE, 1963, 51: 89 . [16] Bulaev D V , Loss D. Spin-orbit-mediated coupling of electron spin dynamics [J]. Phys. Rev. B, 2008, 77: 235-301 . [17] Rugar D, Budakian R, Mamin H, et al. Single spin detection by magnetic resonance force microscopy [J]. Nature (London), 2004, 430: 329 . [18] Rabl P, Cappellaro P, Gurudev Dutt M V, et al. Strong magnetic coupling between an electronic spin qubit and a mechanical resonator [J]. Phys. Rev. B, 2009, 79: 041302(R) . [19] Rabl P, Kolkowitz S J, Koppens F H L, et al. A quantum spin transducer based on nanoelectromecha- nical resonator arrays [J]. Nature Phys., 2010, 6: 602 . [20] Ando T. Spin-Orbit Interaction in Carbon Nanotubes [J]. J. Phys. Soc. Jpn, 2000 , 691: 757 . [21] Schulz A, Martino A D, Egger R. Spin-orbit coupling and spectral function of interacting electrons in carbon nanotubes [J]. Phys. Rev. B, 2009, 80: 075409. [22] Wataru I, Kentaro S, Riichiro S. Spin – Orbit Interaction in Single Wall Carbon Nanotubes: Symmetry Adapted Tight-Binding Calculation and Effective Model Analysis [J]. J. Phys. Soc. Jpn, 2009, 78: 074707 . [23] Klinovaja J, Schmidt M J, Braunecker B, et al. Helical modes in carbon nanotubes generated by strong electric fields [J]. Phys. Rev. Lett., 2011, 106: 156809 . [24] Yang H, E.Itkis M, Moriya R, et al. Nonlocal spin transport in single walled carbon nanotube networks [J].Nature Phys., 2011 , 7: 348 . [25] Alsing P, Carmichael H J. Spontaneous dressed-state polarization of a coupled atom and cavity mode [J].Quantum Opt., 1991, 3: 13. [26] Bishop L S, Ginossar E, Girvin S M. Response of the strongly driven Jaynes-Cummings oscillator [J]. Phys. Rev.Lett., 2010, 105: 100505 . [27] Reed M D, DiCarlo L, Johnson B R, et al. High-Fidelity Readout in Circuit Quantum Electrodynamics Using the Janyes-Cummings Nonlinearity [J]. Phys. Rev.Lett.., 2010, 105: 173601 .

本刊中的类似文章