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Enhancing photon generation in cavity through antiresonant terms of the vacuum Rabi coupling

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Abstract

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Abstract

The Rabi model describes the simplest interaction between a two-level system and a bosonic mode beyond the rotating wave approximation. The antiresonant terms that result from this coherent interaction play an important role. In this paper, we go beyond the rotating wave approximation even for the interaction with vacuum. This leads to the 'incoherent' antiresonant terms. Using the master equation which includes both coherent and incoherent antiresonant terms, we numerically compute the mean photon number and show that these incoherent antiresonant terms enhance the generation of mean photon number. Moreover we study numerically the effect of the detuning and show that it also enhances the generation of photons. Finally, we generalize our result to two two-level and two-mode systems. © 2021, The Author(s), under exclusive licence to Società Italiana di Fisica and Springer-Verlag GmbH Germany, part of Springer Nature.

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References (30) View in search results format >

All

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1 Jaynes, E.T., Cummings, F.W.

Comparison of Quantum and Semiclassical Radiation Theories with Application to the Beam Maser

(1963) *Proceedings of the IEEE*, 51 (1), pp. 89-109. Cited 4110 times.
doi: 10.1109/PROC.1963.1664

View at Publisher

2 Rempe, G., Walther, H., Klein, N.

Observation of quantum collapse and revival in a one-atom maser

(1987) *Physical Review Letters*, 58 (4), pp. 353-356. Cited 1277 times.
doi: 10.1103/PhysRevLett.58.353

View at Publisher

3 Weidinger, M., Varcoe, B.T.H., Heerlein, R., Walther, H.

Trapping states in the micromaser (Open Access)

(1999) *Physical Review Letters*, 82 (19), pp. 3795-3798. Cited 252 times.
doi: 10.1103/PhysRevLett.82.3795

View at Publisher

4 Blais, A., Gambetta, J., Wallraff, A., Schuster, D.I., Girvin, S.M., Devoret, M.H., Schoelkopf, R.J.

Quantum-information processing with circuit quantum electrodynamics (Open Access)

(2007) *Physical Review A - Atomic, Molecular, and Optical Physics*, 75 (3), art. no. 032329. Cited 454 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevA.75.032329&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevA.75.032329

View at Publisher

5 Blais, A., Huang, R.-S., Wallraff, A., Girvin, S.M., Schoelkopf, R.J.

Cavity quantum electrodynamics for superconducting electrical circuits: An architecture for quantum computation (Open Access)

(2004) *Physical Review A - Atomic, Molecular, and Optical Physics*, 69 (6), art. no. 062320, pp. 062320-1-062320-14. Cited 1856 times.
http://pra.aps.org.ezproxy.um.edu.my/
doi: 10.1103/PhysRevA.69.062320

View at Publisher

6 Chiorescu, I., Bertet, P., Semba, K., Nakamura, Y., Harmans, C.J.P.M., Mooij, J.E.

Coherent dynamics of a flux qubit coupled to a harmonic oscillator (Open Access)

(2004) *Nature*, 431 (7005), pp. 159-162. Cited 620 times.
doi: 10.1038/nature02831

View at Publisher

View PDF

7 Wallraff, A., Schuster, D.I., Blais, A., Frunzio, L., Huang, R.-S., Majer, J., Kumar, S., (...), Schoelkopf, R.J.

Strong coupling of a single photon to a superconducting qubit using circuit quantum electrodynamics (Open Access)

(2004) *Nature*, 431 (7005), pp. 162-167. Cited 2718 times.
doi: 10.1038/nature02851

View at Publisher

8 Johansson, J., Saito, S., Meno, T., Nakano, H., Ueda, M., Semba, K., Takayanagi, H.

Vacuum Rabi oscillations in a macroscopic superconducting qubit LC oscillator system (Open Access)

(2006) *Physical Review Letters*, 96 (12), art. no. 127006. Cited 210 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevLett.96.127006&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevLett.96.127006

View at Publisher

9 Braak, D.

Integrability of the Rabi model (Open Access)

(2011) *Physical Review Letters*, 107 (10), art. no. 100401. Cited 456 times.
http://oai.aps.org.ezproxy.um.edu.my/filefetch?identifier=10.1103/PhysRevLett.107.100401&component=fulltext&description=markup&format=xml
doi: 10.1103/PhysRevLett.107.100401

View at Publisher

10 Rabi, I.I.

Space quantization in a gyrating magnetic field

(1937) *Physical Review*, 51 (8), pp. 652-654. Cited 1107 times.
doi: 10.1103/PhysRev.51.652

View at Publisher

11 Dicke, R.H.

Coherence in spontaneous radiation processes (Open Access)

(1954) *Physical Review*, 93 (1), pp. 99-110. Cited 5035 times.
doi: 10.1103/PhysRev.93.99

View at Publisher

12 Hopfield, J.J.

Theory of the contribution of excitons to the complex dielectric constant of crystals

(1958) *Physical Review*, 112 (5), pp. 1555-1567. Cited 1467 times.
doi: 10.1103/PhysRev.112.1555

View at Publisher

13 Tavis, M., Cummings, F.W.

Exact solution for an N-molecule-radiation-field Hamiltonian

(1968) *Physical Review*, 170 (2), pp. 379-384. Cited 976 times.
doi: 10.1103/PhysRev.170.379

View at Publisher

14 Frisk Kockum, A., Miranowicz, A., De Liberato, S., Savasta, S., Nori, F.
Ultrastrong coupling between light and matter (Open Access)

(2019) *Nature Reviews Physics*, 1 (1), pp. 19-40. Cited 307 times.
nature.com/natrevphys/
doi: 10.1038/s42254-018-0006-2

View at Publisher

15 Saito, K., Wubs, M., Kohler, S., Kayanuma, Y., Hänggi, P.
Dissipative Landau-Zener transitions of a qubit: Bath-specific and universal behavior (Open Access)

(2007) *Physical Review B - Condensed Matter and Materials Physics*, 75 (21), art. no. 214308. Cited 109 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevB.75.214308&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevB.75.214308

View at Publisher

16 Wubs, M., Kohler, S., Hänggi, P.
Entanglement creation in circuit QED via Landau-Zener sweeps

(2007) *Physica E: Low-Dimensional Systems and Nanostructures*, 40 (1), pp. 187-197. Cited 25 times.
doi: 10.1016/j.physe.2007.05.014

View at Publisher

17 Emary, C., Brandes, T.
Chaos and the quantum phase transition in the Dicke model

(2003) *Physical Review E - Statistical, Nonlinear, and Soft Matter Physics*, 67 (6 2), art. no. 066203, pp. 066203/1-066203/22. Cited 379 times.

18 Zueco, D., Reuther, G.M., Kohler, S., Hänggi, P.
Qubit-oscillator dynamics in the dispersive regime: Analytical theory beyond the rotating-wave approximation (Open Access)

(2009) *Physical Review A - Atomic, Molecular, and Optical Physics*, 80 (3), art. no. 033846. Cited 117 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevA.80.033846&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevA.80.033846

View at Publisher

19 Lupaşcu, A., Driessen, E.F.C., Roschier, L., Harmans, C.J.P.M., Mooij, J.E.
High-contrast dispersive readout of a superconducting flux qubit using a nonlinear resonator

(2006) *Physical Review Letters*, 96 (12), art. no. 127003. Cited 99 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevLett.96.127003&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevLett.96.127003

View at Publisher

20 Garziano, L., Stassi, R., Macrì, V., Kockum, A.F., Savasta, S., Nori, F.
Multiphoton quantum Rabi oscillations in ultrastrong cavity QED (Open Access)

(2015) *Physical Review A - Atomic, Molecular, and Optical Physics*, 92 (6), art. no. 063830. Cited 87 times.
http://harvest.aps.org.ezproxy.um.edu.my/bagit/articles/10.1103/PhysRevA.92.063830/apsxml
doi: 10.1103/PhysRevA.92.063830

View at Publisher

21 Niemczyk, T., Deppe, F., Huebl, H., Menzel, E.P., Hocke, F., Schwarz, M.J., Garcia-Ripoll, J.J., (...), Gross, R.
Circuit quantum electrodynamics in the ultrastrong-coupling regime (Open Access)

(2010) *Nature Physics*, 6 (10), pp. 772-776. Cited 858 times.
http://www.nature.com.ezproxy.um.edu.my/nphys/index.html
doi: 10.1038/nphys1730

View at Publisher

22 Ashhab, S., Nori, F.
Qubit-oscillator systems in the ultrastrong-coupling regime and their potential for preparing nonclassical states (Open Access)

(2010) *Physical Review A - Atomic, Molecular, and Optical Physics*, 81 (4), art. no. 042311. Cited 235 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevA.81.042311&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevA.81.042311

View at Publisher

23 Hines, A.P., Dawson, C.M., McKenzie, R.H., Milburn, G.J.
Entanglement and bifurcations in Jahn-Teller models (Open Access)

(2004) *Physical Review A - Atomic, Molecular, and Optical Physics*, 70 (2), art. no. 022303, pp. 022303-1-0223011-2. Cited 70 times.
http://pra.aps.org.ezproxy.um.edu.my/
doi: 10.1103/PhysRevA.70.022303

View at Publisher

24 Forn-Díaz, P., Lamata, L., Rico, E., Kono, J., Solano, E.
Ultrastrong coupling regimes of light-matter interaction (Open Access)

(2019) *Reviews of Modern Physics*, 91 (2), art. no. 025005. Cited 171 times.
http://harvest.aps.org.ezproxy.um.edu.my/bagit/articles/10.1103/RevModPhys.91.025005/apsxml
doi: 10.1103/RevModPhys.91.025005

View at Publisher

25 Garziano, L., Macrì, V., Stassi, R., Di Stefano, O., Nori, F., Savasta, S.
One Photon Can Simultaneously Excite Two or More Atoms (Open Access)

(2016) *Physical Review Letters*, 117 (4), art. no. 043601. Cited 78 times.
http://harvest.aps.org.ezproxy.um.edu.my/bagit/articles/10.1103/PhysRevLett.117.043601/apsxml
doi: 10.1103/PhysRevLett.117.043601

View at Publisher

26 Wang, X., Miranowicz, A., Li, H.-R., Nori, F.
Observing pure effects of counter-rotating terms without ultrastrong coupling: A single photon can simultaneously excite two qubits (Open Access)

(2017) *Physical Review A*, 96 (6), art. no. 063820. Cited 17 times.
http://harvest.aps.org.ezproxy.um.edu.my/v2/bagit/articles/10.1103/PhysRevA.96.063820/apsxml
doi: 10.1103/PhysRevA.96.063820

View at Publisher

27 Werlang, T., Dodonov, A.V., Duzzioni, E.I., Villas-Bôas, C.J.
Rabi model beyond the rotating-wave approximation: Generation of photons from vacuum through decoherence (Open Access)

(2008) *Physical Review A - Atomic, Molecular, and Optical Physics*, 78 (5), art. no. 053805. Cited 84 times.
http://oai.aps.org.ezproxy.um.edu.my/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevA.78.053805&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevA.78.053805

View at Publisher

28 Munoz, C.S., Kockum, A.F., Miranowicz, A., Nori, F.
(2019) *Ultrastrong-Coupling Effects Induced by a Single Classical Drive in Jaynes-Cummings-Type Systems. Arxiv Preprint Arxiv*, 1910, p. 12875.

29 Chen, Y.-H., Qin, W., Wang, X., Miranowicz, A., Nori, F.
Shortcuts to Adiabaticity for the Quantum Rabi Model: Efficient Generation of Giant Entangled Cat States via Parametric Amplification

(2021) *Physical Review Letters*, 126 (2), art. no. 023602. Cited 6 times.
https://journals-aps-org.ezproxy.um.edu.my/prl/abstract/10.1103/PhysRevLett.126.023602
doi: 10.1103/PhysRevLett.126.023602

View at Publisher

30 Gardiner, C., Zoller, P.
(2004) *Quantum Noise: A Handbook of Markovian and Non-Markovian Quantum Stochastic Methods with Applications to Quantum Optics*. Cited 752 times.
Springer Series Synergetics, Springer, Berlin

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