Stimulated raman adiabatic passage in optomechanics

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Bibliography

[1] Vladimir B. Braginski and Yurii I. Vorontsov, Sov. Phys. Usp. **17**, 644 (1975).

[2] V. B. Braginsky, Y. I. Vorontsov, and S. T. Kip, Science **209**, 547 (1980).

[3] J. D. Cohen, S. M. Meenehan, G. S. MacCabe, S. Gröblacher, A. H. Safavi-Naeini, F. Marsili, M. D. Shaw, and O. Painter, Nature **520**, 522 (2015).

[4] R. Riedinger, A. Wallucks, I. Marinković, C. Löschnauer, M. Aspelmeyer, S. Hong, and S. Gröblacher, Nature **556**, 473 (2018).

[5] G. S. MacCabe, H. Ren, J. Luo, J. D. Cohen, H. Zhou, A. Sipahigil, M. Mirhosseini, and O. Painter, Science **370**, 840 (2020).

[6] J. Chan, T. P. Alegre, A. H. Safavi-Naeini, J. T. Hill, A. Krause, S. Gröblacher, M. Aspelmeyer, and O. Painter, Nature **478**, 89 (2011).

[7] Y. Tsaturyan, A. Barg, E. S. Polzik, and A. Schliesser, Nature Nanotechnology **12**, 776 (2017).

[8] L. Midolo, A. Schliesser, and A. Fiore, Nature Nanotechnology **13**, 11 (2018).

[9] M. Aspelmeyer, T. J. Kippenberg, and F. Marquardt, Reviews of Modern Physics **86**, 1391 (2014).

[10] W. Marshall, C. Simon, R. Penrose, and D. Bouwmeester, Physical Review Letters **91**, 130401 (2003).

[11] R. Penrose, General Relativity and Gravitation **28**, 581 (1996).

[12] M. J. Weaver, F. Buters, F. Luna, H. Eerkens, K. Heeck, S. De Man, and D. Bouwmeester, Nature Communications **8**, 824 (2017).

[13] N. V. Vitanov, A. A. Rangelov, B. W. Shore, and K. Bergmann, Reviews of Modern Physics **89**, 015006 (2017).

[14] H. Xu, D. Mason, L. Jiang, and J. G. Harris, Nature **537**, 80 (2016).

[15] H. Xu, L. Jiang, A. A. Clerk, and J. G. Harris, Nature **568**, 65 (2019).

[16] U. Gaubatz, P. Rudecki, M. Becker, S. Schiemann, M. Külz, and K. Bergmann, Chemical Physics Letters **149**, 463 (1988).

[17] W. P. Bowen and G. J. Milburn, *Quantum Optomechanics* (2015), ISBN 9781107002173, URL `http://www.tandfonline.com/doi/abs/10.1080/00107514.2011.587535`.

[18] A. M. Jayich, J. C. Sankey, B. M. Zwickl, C. Yang, J. D. Thompson, S. M. Girvin, A. A. Clerk, F. Marquardt, and J. G. Harris, New Journal of Physics **10**, 095008 (2008).

[19] C. U. Lei, A. J. Weinstein, J. Suh, E. E. Wollman, A. Kronwald, F. Marquardt, A. A. Clerk, and K. C. Schwab, Physical Review Letters **117**, 100801 (2016).

[20] D. Rugar and P. Grütter, Physical Review Letters **67**, 699 (1991).

[21] F. Difilippo, V. Natarajan, K. R. Boyce, and D. E. Pritchard, Physical Review Letters **68**, 2859 (1992).

[22] A. A. Clerk, F. Marquardt, and K. Jacobs, New Journal of Physics **10**, 095010 (2008).

[23] M. R. Vanner, I. Pikovski, G. D. Cole, M. S. Kim, Č. Brukner, K. Hammerer, G. J. Milburn, and M. Aspelmeyer, Proceedings of the National Academy of Sciences of the United States of America **108**, 16182 (2011).

[24] A. Szorkovszky, A. C. Doherty, G. I. Harris, and W. P. Bowen, Physical Review Letters **107**, 213603 (2011).

[25] X. You, Z. Li, and Y. Li, Physical Review A **96**, 063811 (2017).

[26] J. B. Hertzberg, T. Rocheleau, T. Ndukum, M. Savva, A. A. Clerk, and K. C. Schwab, Nature Physics **6**, 213 (2010).

[27] J. Suh, A. J. Weinstein, C. U. Lei, E. E. Wollman, S. K. Steinke, P. Meystre, A. A. Clerk, and K. C. Schwab, Science **344**, 1262 (2014).

[28] E. E. Wollman, C. U. Lei, A. J. Weinstein, J. Suh, A. Kronwald, F. Marquardt, A. A. Clerk, and K. C. Schwab, Science **349**, 6251, p.952 (2015).

[29] F. Lecocq, J. B. Clark, R. W. Simmonds, J. Aumentado, and J. D. Teufel, Physical Review X **5**, 041037 (2015).

[30] J. M. Pirkkalainen, E. Damskägg, M. Brandt, F. Massel, and M. A. Sillanpää, Physical Review Letters **115**, 243601 (2015).

[31] A. Vinante and P. Falferi, Physical Review Letters **111**, 207203 (2013).

[32] M. Poot, K. Y. Fong, and H. X. Tang, New Journal of Physics **17**, 043056 (2015).

[33] A. Pontin, M. Bonaldi, A. Borrielli, F. S. Cataliotti, F. Marino, G. A. Prodi, E. Serra, and F. Marin, Physical Review Letters **112**, 023601 (2014).

[34] R. W. Drever, J. L. Hall, F. V. Kowalski, J. Hough, G. M. Ford, A. J. Munley, and H. Ward, Applied Physics B Photophysics and Laser Chemistry **31**, 97 (1983).

[35] B. Hu and Y. Zhang, Modern Physics Letters A **8**, 37, 3575 (1993).

[36] P. Pillet, Physical Review A - Atomic, Molecular, and Optical Physics **48**, 845 (1993).

[37] J. L. Sørensen, D. Møller, T. Iversen, J. B. Thomsen, F. Jensen, P. Staanum, D. Voigt, and M. Drewsen, New Journal of Physics **8**, 261 (2006).

[38] K. S. Kumar, A. Vepsälaïnen, S. Danilin, and G. S. Paraoanu, Nature Communications **7**, 10628 (2016).

[39] H. Goto and K. Ichimura, Physical Review A - Atomic, Molecular, and Optical Physics **75**, 033404 (2007).

[40] D. A. Golter and H. Wang, Physical Review Letters **112**, 116403 (2014).

[41] S. Longhi, Laser and Photonics Reviews **3**, 243 (2009).

[42] J. Simon, H. Tanji, S. Ghosh, and V. Vuletic, Nature Physics **3**, 765 (2007).

[43] H.-S. Chang, Y. Zhong, A. Bienfait, M.-H. Chou, C. R. Conner, É. Dumur, J. Grebel, G. A. Peairs, R. G. Povey, K. J. Satzinger, et al., Physical Review Letters **124**, 240502 (2020).

[44] K. Toyoda, K. Uchida, A. Noguchi, S. Haze, and S. Urabe, Physical Review A - Atomic, Molecular, and Optical Physics **87**, 052307 (2013).

[45] Y. D. Wang and A. A. Clerk, Physical Review Letters **108**, 153603 (2012).

[46] L. Tian, Physical Review Letters **108**, 153604 (2012).

[47] D. Garg, A. K. Chauhan, and A. Biswas, Physical Review A **96**, 023837 (2017).

[48] L. F. Buchmann and D. M. Stamper-Kurn, Physical Review A - Atomic, Molecular, and Optical Physics **92**, 013851 (2015).

[49] A. Noguchi, R. Yamazaki, M. Ataka, H. Fujita, Y. Tabuchi, T. Ishikawa, K. Usami, and Y. Nakamura, New Journal of Physics **18** (2016).

[50] C. F. Ockeloen-Korppi, E. Damskägg, J. M. Pirkkalainen, M. Asjad, A. A. Clerk, F. Massel, M. J. Woolley, and M. A. Sillanpää, Nature **556**, 478 (2018).

[51] S. Kotler, G. A. Peterson, E. Shojaee, F. Lecocq, K. Cicak, A. Kwiatkowski, S. Geller, S. Glancy, E. Knill, R. W. Simmonds, et al., Science **372**, 622 (2021).

[52] L. Mercier de Lépinay, C. F. Ockeloen-Korppi, M. J. Woolley, and M. A. Sillanpää, Science **372**, 625 (2021).

[53] C. Dong, V. Fiore, M. C. Kuzyk, and H. Wang, Science **338**, 1609 (2012).

[54] J. D. Thompson, B. M. Zwickl, A. M. Jayich, F. Marquardt, S. M. Girvin, and J. G. Harris, Nature **452**, 72 (2008).

[55] S. Schmid, K. D. Jensen, K. H. Nielsen, and A. Boisen, Physical Review B - Condensed Matter and Materials Physics **84**, 165307 (2011).

[56] A. Kuhn, G. W. Coulston, G. Z. He, S. Schiemann, K. Bergmann, and W. S. Warren, The Journal of Chemical Physics **96**, 4215 (1992).

[57] M. Dupont-Nivet, M. Casiulis, T. Laudat, C. I. Westbrook, and S. Schwartz, Physical Review A - Atomic, Molecular, and Optical Physics **91**, 053420 (2015).

[58] H. K. Xu, C. Song, W. Y. Liu, G. M. Xue, F. F. Su, H. Deng, Y. Tian, D. N. Zheng, S. Han, Y. P. Zhong, et al., Nature Communications **7**, 11018 (2016).

[59] J. Klein, F. Beil, and T. Halfmann, Physical Review A - Atomic, Molecular, and Optical Physics **78**, 033416 (2008).

[60] H. Theuer and K. Bergmann, European Physical Journal D **2**, 279 (1998).

[61] P. Marte, P. Zoller, and J. L. Hall, Physical Review A **44**, 4118 (1991).

[62] R. Unanyan, M. Fleischhauer, B. W. Shore, and K. Bergmann, Optics Communications **155**, 144 (1998).

[63] M. Rossi, D. Mason, J. Chen, Y. Tsaturyan, and A. Schliesser, Nature **563**, 53 (2018).

[64] R. W. Peterson, T. P. Purdy, N. S. Kampel, R. W. Andrews, P. L. Yu, K. W. Lehnert, and C. A. Regal, Physical Review Letters **116**, 063601 (2016).

[65] M. Underwood, D. Mason, D. Lee, H. Xu, L. Jiang, A. B. Shkarin, K. Børkje, S. M. Girvin, and J. G. Harris, Physical Review A - Atomic, Molecular, and Optical Physics **92**, 061801(R) (2015).

[66] I. Galinskiy, Y. Tsaturyan, M. Parniak, and E. S. Polzik, Optica **7**, 718 (2020).

[67] Y. Zhai, Z. X. Chen, and Q. Lin, Journal of the Optical Society of America B **37**, 956 (2020).

[68] J. Johansson, P. Nation, and F. Nori, Computer Physics Communications **183**, 1760–1772 (2012).

[69] N. V. Vitanov, K.-A. Suominen, and B. W. Shore, J. Phys. B: At. Mol. Opt. Phys. **32**, 4535–4546 (1999).

[70] T. P. Purdy, R. W. Peterson, P. L. Yu, and C. A. Regal, New Journal of Physics **14**, 115021 (2012).

[71] A. G. Kuhn, J. Teissier, L. Neuhaus, S. Zerkani, E. Van Brackel, S. Deléglise, T. Briant, P. F. Cohadon, A. Heidmann, C. Michel, et al., Applied Physics Letters **104**, 044102 (2014).

[72] E. Verhagen, S. Deléglise, S. Weis, A. Schliesser, and T. J. Kippenberg, Nature **482**, 63 (2012).

[73] F. Fogliano, B. Besga, A. Reigue, L. Lépinay, P. Heringlake, C. Gouriou, E. Eyraud, W. Wernsdorfer, B. Pigeau, and O. Arcizet, Nature Communications **12**, 4124 (2021).

[74] R. Riedinger, S. Hong, R. A. Norte, J. A. Slater, J. Shang, A. G. Krause, V. Anant, M. Aspelmeyer, and S. Gröblacher, Nature **530**, 313 (2016).

[75] V. Fedoseev, F. Luna, I. Hedgepeth, W. Loffler, and D. Bouwmeester, Physical Review Letters **126**, 113601 (2021).

[76] M. J. Weaver, D. Newsom, F. Luna, W. Löffler, and D. Bouwmeester, Physical Review A **97**, 063832 (2018).

[77] R. W. Peterson, PhD thesis, University of Colorado at Boulder (2017), URL `https://ui.adsabs.harvard.edu/abs/2017PhDT.....47P/abstract`.

[78] F. Buters, PhD thesis, Leiden University (2017), URL `https://hdl.handle.net/1887/58471`.

[79] M. De Wit, G. Welker, K. Heeck, F. M. Buters, H. J. Eerkens, G. Koning, H. Van der Meer, D. Bouwmeester, and T. H. Oosterkamp, Review of Scientific Instruments **90**, 015112 (2019).

[80] S. L. D. t. Haaf, MSc thesis, Leiden University (2021), URL `https://hdl.handle.net/1887/3166726`.

[81] O. T. Huisman, BSc thesis, Leiden University (2021), URL `https://hdl.handle.net/1887/3194937`.

[82] R. Claessen, MSc thesis, Leiden University (2021), URL `https://scholarlypublications.universiteitleiden.nl/handle/1887/58471`.

[83] C. M. Natarajan, M. G. Tanner, and R. H. Hadfield, Superconductor Science and Technology **25**, 063001 (2012).

[84] F. Marsili, V. B. Verma, J. A. Stern, S. Harrington, A. E. Lita, T. Gerrits, I. Vayshenker, B. Baek, M. D. Shaw, R. P. Mirin, et al., Nature Photonics **7**, 210 (2013).

[85] A. J. Weinstein, C. U. Lei, E. E. Wollman, J. Suh, A. Metelmann, A. A. Clerk, and K. C. Schwab, Physical Review X **4**, 041003 (2014).

[86] M. Yuan, M. A. Cohen, and G. A. Steele, Applied Physics Letters **107**, 263501 (2015).

[87] M. J. Weaver, PhD thesis, UCSB (2018), URL https://www.proquest.com/openview/7bf96a761685c167f976f0d94a445176/1?pq-origsite=gscholar&cbl=18750.

[88] S. Chakram, Y. S. Patil, L. Chang, and M. Vengalattore, Physical Review Letters **112**, 127201 (2014).

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List of publications

1. **V. Fedoseev**, M. Fisicaro, H. van der Meer, W. Löffler and D. Bouwmeester, *Realignment-free cryogenic macroscopic optical cavity coupled to an optical fiber*, Rev. Sci. Instrum. 93, 013103 (2022)
   (Chapter 5 of this thesis)

2. **V. Fedoseev**, F. Luna, I. Hedgepeth, W. Löffler and D. Bouwmeester, *Stimulated Raman Adiabatic Passage in Optomechanics*, Phys. Rev. Lett. 126, 113601 (2021)
   (Chapters 3 and 4 of this thesis)

3. D. C. Newsom, F. Luna, **V. Fedoseev**, W. Löffler and D. Bouwmeester, *Optimal optomechanical coupling strength in multimembrane systems*, Phys. Rev. A 101, 033829 (2020)

4. S. Sonar, **V. Fedoseev**, M. J. Weaver, F. Luna, E. Vlieg, H. van der Meer, D. Bouwmeester and W. Löffler, *Strong thermomechanical squeezing in a far-detuned membrane-in-the-middle system*, Phys. Rev. A 98, 013804 (2018)
   (Chapters 2 of this thesis)

5. I. Battisti, **V. Fedoseev**, K. M. Bastiaans, A. de la Torre, R. S. Perry, F. Baumberger, and M. P. Allan, *Poor electronic screening in lightly doped Mott insulators observed with scanning tunneling microscopy*, Phys. Rev. B 95, 235141 (2017)

6. I. Battisti, K. M. Bastiaans, **V. Fedoseev**, A. de la Torre, N. Iliopoulos, A. Tamai, E. C. Hunter, R. S. Perry, J. Zaanen, F. Baumberger and M. P. Allan, *Universality of pseudogap and emergent order in lightly doped Mott insulators*, Nature Physics 13, 21–25 (2017)

7. V. Dremov, **V. Fedoseev**, P. Fedorov and A. Grebenko, *Fast and reliable method of conductive carbon nanotube-probe fabrication for scanning probe microscopy*, Rev. Sci. Instrum. 86, 053703 (2015)

Acknowledgements

During my PhD studies I learnt so much about optics, mechanics, electronics. Now I perceive myself as a researcher. For sure, that would not be possible without the effort of many people who supported me these years.

I am particularly grateful to my promotor Dirk Bouwmeester for guiding me. Thank you for your patience and letting me accomplish risky ideas.

I would like to thank Wolfgang Löffler for teaching me optics in the lab, day to day supervision and tackling all kinds of technical problems.

Many experiments would not be possible without technical expertise of Harmen van der Meer from Fine Mechanics Department. I was often amazed how Harmen was able to find practical solutions for our crazy projects.

I would like to thank Kier Heeck, Raymond Koehler and Harry Visser for support in electronics. I thank our secretary Henriette van Leeuwen.

I thank Frank Buters, Fernando Luna and Matthew Weaver for introducing me to the optical lab and the setups. I am grateful to Ian Hedgepeth for fruitful discussions. I thank Xinrui Wei and Leon Raabe who worked with me in the lab as well as Sameer Sonar, Matteo Fisicaro, Tim Fuchs, Remi Claessen, Bas ten Haaf, Owen Huisman.

Finally, I am indebted to my wife Nastya for supporting me and my son Yakov for inspiration.