Imperfect Fabry-Perot resonators

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Bibliography

[1] J. M. Vaughan, *The Fabry-Perot interferometer* (Adam Hilger, Bristol, 1989).

[2] A. O'Keefe and D. A. G. Deacon, 'Cavity ring-down optical spectrometer for absorption measurements using pulsed laser sources', Rev. Sci. Instrum **59**, 2544–2551 (1988).

[3] G. Berden, R. Peeters, and G. Meijer, 'Cavity ring-down spectroscopy: Experimental schemes and applications', Int. Rev. Phys. Chem **19**, 565–607 (2000).

[4] S. Haroche and D. Kleppner, 'Cavity quantum electrodynamics', Phys. Today **42**, 24–30 (1989).

[5] D. W. Vernooy, A. Furusawa, N. P. Georgiades, V. S. Ilchenko, and H. J. Kimble, 'Cavity QED with high-Q whispering gallery modes', Phys. Rev. A **57**, R2293 (1998).

[6] D. K. Armani, T. J. Kippenberg, S. M. Spillane, and K. J. Vahala, 'Ultra-high-Q toroid microcavity on a chip', Nature **421**, 925 (2003).

[7] http://www.ligo.caltech.edu.

[8] http://www.cascina.virgo.infn.it.

[9] http://tamago.mtk.nao.ac.jp.

[10] D. Kleckner, W. Marshall, M. J. A. de Dood, K. N. Dinyari, B. J. Pors, W. T. M. Irvine, and D. Bouwmeester, 'High finesse opto-mechanical cavity with a movable thirty-micron-size mirror', Phys. Rev. Lett. **96**, 173091 (2006).

[11] W. Demtröder, *Laser-spektroskopie* (Springer-Verlag, Berlin, 1993).

[12] A. E. Siegman, *Lasers* (University Science Books, Sausalito, CA, 1986).

[13] E. D. Palik, H. Boukari, and R. W. Gammon, 'Experimental study of the effect of surface defects on the finesse and contrast of a Fabry-Perot interferometer', Appl. Opt. **35**, 38–50 (1996).

[14] M. Born and E. Wolf, *Principles of Optics* (Cambridge University Press, Cambridge, 1999).

[15] M. Bernardini, S. Braccini, C. Bradaschia, G. Cella, E. Cuoco, E. D'Ambrosio, V. Dattilo, R. de Salvo, A. di Virgilio, F. Fidecaro, A. Gaddi, A. Gennai, A. Giassi, A. Giazotto, P. L. Penna, M. Lyablin, G. Losurdo, M. Maggiore, S. Mancini, H. B. Pan, A. Pasqualetti, D. Passuello, R. Poggiani, P. Popolizio, D. Shabalin, A. Viceré, and

Z. Zhang, 'Plane parallel mirrors Fabry-Perot cavity to improve Virgo superattenuators', Phys. Rev. A **243**, 187–194 (1998).

[16] G. Rempe, R. J. Thompson, H. J. Kimble, and R. Lalezari, 'Measurement of ultralow losses in an optical interferometer', Opt. Lett **17**, 363–365 (1992).

[17] M. Hercher, 'Spherical mirror Fabry-Perot interferometer', Appl. Opt. **7**, 951–966 (1968).

[18] J. M. Bennet and L. Mattsson, *Introduction to Surface Roughness and Scattering* (Optical Society of America, Washington, D. C., 1999).

[19] M. Hercher, 'The spherical Fabry-Perot interferometer', in 'The Fabry-Perot Interferometer', (J. M. Vaughan, ed.), 184–212 (Adam Hilger, Bristol, 1989).

[20] D. J. Bradley and C. J. Mitchell, 'Comments on the spherical mirror Fabry-Perot interferometer', Appl. Opt **8**, 707–709 (1969).

[21] D. R. Herriot, H. Kogelnik, and R. Kompfner, 'Off-axis paths in spherical mirror interferometers', Appl. Opt. **3**, 523–526 (1964).

[22] C. J. Hood, H. J. Kimble, and J. Ye, 'Characterization of high-finesse mirrors: Loss, phase shifts, and mode structure in an optical cavity', Phys. Rev. A **64**, 033804 (2001).

[23] K. D. Skeldon, J. Mackintosh, M. von Gradowski, S. Thieux, and R. Lee, 'Qualification of supermirrors for ring-laser-gyros based on surface roughness and scatter measurements', J. Opt. Soc. Am. A **3**, 183–187 (2001).

[24] N. Uehara and K. Ueda, 'Accurate measurement of ultralow loss in a high-finesse Fabry-Perot-interferometer using the frequency-response functions', Appl. Phys. B **61**, 9–15 (1995).

[25] R. Mavaddat, D. E. McClelland, P. Hellos, and J. Y. Vinest, 'Dual recycling laser interferometer gravitational-wave detectors simulating the performance with imperfect mirrors', J. Opt. **26**, 145–149 (1995).

[26] S. Sato, S. Miyoki, M. Ohashi, M. K. Fujimoto, T. Yamazaki, M. Fukushima, A. Ueda, K. Ueda, K. Watanabe, K. Nakamura, K. Etoh, N. Kitajima, K. Ito, and I. Kataoka, 'Loss factors of mirrors for a gravitational wave antenna', Appl. Opt. **38**, 2880–2885 (1999).

[27] D. G. Blair, M. Notcutt, C. T. Taylor, E. K. Wong, C. Walsh, A. Leistner, J. Seckold, J. M. Mackowski, P. Ganau, C. Michel, and L. Pinard, 'Development of low-loss sapphire mirrors', Appl. Opt. **36**, 337–341 (1997).

[28] N. Uehara, A. Ueda, and K. Ueda, 'Ultralow-loss mirror of the parts-in-10^6 level at 1064 nm', Opt. Lett. **20**, 530–532 (1995).

[29] J. C. Stover, *Optical Scattering: Measurement and Analysis* (SPIE, Bellingham, 1995).

[30] E. L. Church, 'Fractal surface finish', Appl. Opt. **27**, 1518–1526 (1988).

[31] TNO Science and Industry, Business Unit Opto-Mechanical Instrumentation (OMI), Delft, The Netherlands.

[32] S. Jakobs, A. Duparre, and H. Truckenbrodt, 'Interfacial roughness and related scatter in ultraviolet optical coatings: experimental approach', Appl. Opt. **37**, 1180–1193 (1998).

[33] W. M. Bruno, J. A. Roth, P. E. Burke, W. B. Hewitt, R. E. Holmbeck, and D. G. Neal, 'Prediction of the bidirectional reflectance-distribution function from atomic-force and scanning-tunneling microscope measurements of interfacial roughness', Appl. Opt. **34**, 1229–1238 (1995).

[34] J. M. Elson, J. P. Rahn, and J. M. Bennett, 'Light-scattering from multilayer optics: comparison of theory and experiment', Appl. Opt. **19**, 669–679 (1980).

[35] J. Poirson, F. Breetanker, M. Vallet, and A. le Floch, 'Analytical and experimental study of ringing effects in a Fabry-Perot cavity. Application to the measurement of high finesses', J. Opt. Soc. Am. B **14**, 2811–2817 (1997).

[36] P. Domokos and H. Ritsch, 'Mechanical effects of light in optical resonators', J. Opt. Soc. Am. B **20**, 1098–1130 (2003).

[37] D. J. Heinzen, J. J. Childs, J. E. Thomas, and M. S. Feld, 'Enhanced and inhibited visible spontaneous emission by atoms in a confocal resonator', Phys. Rev. Lett. **58**, 1320–1323 (1987).

[38] J. C. Bergquist, W. M. Itano, and D. J. Wineland, 'Laser stabilization to a single ion', in 'Frontiers in Laser Spectroscopy', (T. W. Hänsch and M. Inguscio, eds.), 359–376 (North-Holland Publishing Co, Amsterdam, 1994).

[39] J. T. Hodges, J. P. Looney, and R. D. van Zee, 'Response of a ring-down cavity to an arbitrary excitation', J. Chem. Phys. **105**, 10278–10288 (1996).

[40] D. H. Lee, Y. Yoon, B. Kim, J. Y. Lee, Y. S. Yoo, and J. W. Hahn, 'Optimization of the mode matching in pulsed cavity ring-down spectroscopy by monitoring non-degenerate transverse mode beating', Appl. Phys. B **74**, 435–440 (2002).

[41] C. A. Schrama, D. Bouwmeester, G. Nienhuis, and J. P. Woerdman, 'Mode-dynamics in optical cavities', Phys. Rev. A **51**, 641–645 (1995).

[42] H. J. Stöckmann, *Quantum chaos, an introduction* (Cambridge University Press, Cambridge, 1999).

[43] E. Hecht, *Optics* (Addison Wesley, San Francisco, 2002).

[44] F. L. Pedrotti and L. S. Pedrotti, *Introduction to Optics* (Prentice Hall, New Jersey, 1993).

[45] D. J. Bradley and C. J. Mitchell, 'Characteristics of the defocused spherical Fabry-Perot interferometer as a quasi-linear dispersion instrument for high resolution spectroscopy of pulsed laser sources', Phil. Trans. A **263**, 209–223 (1968).

[46] I. A. Ramsay and J. J. Degnan, 'A ray analysis of optical resonators formed by two spherical mirrors', Appl. Opt. **9**, 385–398 (1970).

[47] J. A. Arnaud, 'Degenerate optical cavities. III: Effect of aberrations', Appl. Opt. **9**, 1192–1200 (1970).

[48] E. Merzbacher, *Quantum Mechanics* (John Wiley & Sons, New York, 1970).

[49] D. Herriot, H. Kogelnik, and R. Kompfer, 'Folded optical delay lines', Appl. Opt. **3**, 523–526 (1964).

[50] T. Klaassen, J. de Jong, M. P. van Exter, and J. P. Woerdman, 'Transverse mode coupling in an optical resonator', Opt. Lett. **30**, 1959–1961 (2005).

[51] P. Harihan, 'Interferometers', in 'Handbook of Optics', (M. Bass, ed.), 21.1 – 21.8 (McGraw-Hill, New-York, 1995).

[52] M. Françon, *Optical Interferometry* (Academic Press, New York, 1966).

[53] S. Tolansky, *An Introduction to Interferometry* (Longmans, Green and Co, London, 1955).

[54] B. Kells, 'LIGO-Caltech', Private communication.

[55] J. Dingjan, E. Altewischer, M. P. van Exter, and J. P. Woerdman, 'Experimental observation of wave chaos in a conventional optical resonator', Phys. Rev. Lett. **88**, 064101 (2002).
[56] N. Uehara and K. Ueda, 'Accurate measurement of the radius of curvature of a concave mirror and the power dependence in a high-finesse Fabry-Perot interferometer', Appl. Opt. **34**, 5611–5619 (1995).
[57] H. Laabs and A. T. Friberg, 'Nonparaxial eigenmodes of stable resonators', IEEE J. Quant. Elec. **35**, 198–207 (1999).
[58] H. A. Buchdahl, *An Introduction to Hamiltonian Optics* (Cambridge University Press, Cambridge, 1970).
[59] V. N. Mahajan, *Optical Imaging and Aberrations* (SPIE Press, Bellingham, 1998).
[60] D. L. Dickensheets, 'Imaging performance of off-axis planar diffractive lenses', J. Opt. Soc. Am. A **13**, 1849–1858 (1996).
[61] M. H. Dunn and A. I. Ferguson, 'Coma compensation in off-axis laser resonators', Opt. Comm. **20**, 214–219 (1977).
[62] J. Visser and G. Nienhuis, 'Spectrum of an optical resonator with spherical aberration', J. Opt. Soc. Am. A **22**, 2490–2497 (2005).
[63] J. Dingjan, *Multi-mode optical resonators and wave chaos*, Ph.D. thesis, Universiteit Leiden (1996).
[64] G. Nienhuis, 'Huygens Laboratorium, Universtiteit Leiden, The Netherlands', Private communication.
[65] M. Lax, W. H. Louisell, and W. B. McKnight, 'From Maxwell to paraxial wave optics', Phys. Rev. A **11**, 1365–1370 (1975).
[66] A. Wünsche, 'Transition from the paraxial approximation to exact solutions of the wave equation and application to Gaussian beams', J. Opt. Soc. Am. A **9**, 765–774 (1992).
[67] G. M. Sanger, 'Perspective on precision machining, polishing and optical requirements', in 'Contemporary methods of optical fabrication', volume 306, 46–51 (SPIE, San Diego, 1981).
[68] E. R. Marsh, B. P. John, J. A. Couey, J. Wang, R. D. Grejda, and R. R. Vallance, 'Predicting surface figure in diamond turned calcium fluoride using in-process force measurement', J. Vac. Sc. and Techn. B **23**, 84–89 (2005).
[69] Philips Research, Eindhoven, The Netherlands.
[70] J. W. Yan, K. Syoji, and J. Tamaki, 'Crystallographic effects in micro/nanomachining of single-crystal calcium fluoride', J. Vac. Sc. and Techn. B **22**, 46–51 (2004).
[71] LASEROPTIK, Garbsen, Germany.
[72] M. V. Berry, 'Quantal phase factors accompanying adiabatic changes', Proc. R. Soc. London A **392**, 54–57 (1984).
[73] J. Anandan, J. Christian, and K. Wanelik, 'Order Resource Letter GPP-1: Geometric phases in physics', Am. J. of Phys. **65**, 180–185 (1997).
[74] N. Hodgson and H. Weber, *Optical Resonators* (Springer, New York, 1997).
[75] A. W. Snyder and J. D. Love, *Optical Waveguide Theory* (Chapman and Hall, London, 1983).
[76] C. Degen, I. Fischer, and W. Elsäßer, 'Transverse modes in oxide confined VCSELs: Influence of pump profile, spatial hole burning, and thermal effects', Opt. Lett. **5**, 38–47 (1999).

[77] C. Degen, I. Fischer, W. Elsäßer, L. Fratta, P. Debernardi, G. P. Bava, M. Brunner, R. Hövel, M. Moser, and K. Gulden, 'Transverse modes in thermally detuned oxide-confined vertical-cavity surface-emitting lasers', Phys. Rev. A **63**, 023817 (2001).
[78] A. Yariv, *Quantum electronics* (John Wiley and Sons, New York, 1988), third edition.
[79] A. Aiello, M. P. van Exter, and J. P. Woerdman, 'Ray chaos in optical cavities based upon standard laser mirrors', Phys. Rev. E **68**, 046208 (2003).
[80] M. Abramowitz and I. Stegun, *Handbook of Mathematical Functions* (Dover, New York, 1974).
[81] N. J. van Druten, S. S. R. Oemrawsingh, Y. Lien, C. Serrat, M. P. van Exter, and J. P. Woerdman, 'Observation of transverse modes in a microchip laser with combined gain and index guiding', J. Opt. Soc. Am. B **18**, 1793–1804 (2001).
[82] G. R. Hadley, 'Effective-index model for vertical-cavity surface-emitting lasers', Opt. Lett. **20**, 1483–1485 (1995).
[83] C. Serrat, M. P. van Exter, N. J. van Druten, and J. P. Woerdman, 'Transverse mode formation in microlasers by combined gain- and index-guiding', IEEE J. Quant. Elec. **35**, 1314–1321 (1999).
[84] W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, *Numerical Recipes* (Cambridge University Press, Cambridge, 1987).
[85] G. R. Fowles and G. L. Cassiday, *Analytical Mechanics* (Thomson Learning, Belmont, USA, 1999), sixt edition.
[86] J. D. Jackson, *Classical Electrodynamics* (Wiley, New York, 1998).
[87] S. B. Shaklan, 'Selective mode injection and observation for few-mode fiberoptics', Appl. Opt. **30**, 4379–4383 (1991).
[88] E. G. Neumann, *Single-mode fibers* (Springer-Verlag, Berlin, 1988).
[89] G. P. Agrawal, *Nonlinear fiber optics* (Academic Press, San Diego, 1989).
[90] J. T. Verdeyen, *Laser Electronics* (Prentice Hall, Upper Saddle River, New Jersey, 2000), third edition.
[91] H. J. Stöckmann and J. Stein, "'Quantum" chaos in billiards studied by microwave absorption', Phys. Rev. Lett. **64**, 2215 (1990).
[92] D. L. Kaufman, I. Kosztin, and K. Schulten, 'Expansion method for stationary states of quantum billiards', Am. J. of Phys. **67**, 133–141 (1999).
[93] B. W. Li, M. Robnik, and B. Hu, 'Relevance of chaos in numerical solutions of quantum billiards', Phys. Rev. E **57**, 4095–4105 (1998).
[94] F. Haake, *Quantum Signatures of Chaos* (Springer, Berlin, 1991).
[95] A. Aiello, unpublished.
[96] M. Bennett, M. F. Schatz, H. Rockwood, and K. Wiesenfeld, 'Huygens' clocks', Proc. Roy. Soc. A **458**, 563–579 (2002).
[97] R. J. C. Spreeuw, R. C. Neelen, N. J. van Druten, E. R. Eliel, and J. P. Woerdman, 'Mode coupling in a He-Ne ring laser with backscattering', Phys. Rev. A **42**, 43154324 (1990).
[98] P. Pellandini, R. P. Stanley, R. Houdré, U. Oesterle, M. Ilegems, and C. Weisbuch, 'Dual-wavelength laser emission from a coupled semiconductor microcavity', Appl. Phys. Lett. **71**, 864–866 (1997).