Physical Review A 2018 vol.98 N4

Application of harmonic and anharmonic frequency crystals for manipulation with quantum states

Shakhmuratov R.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2018 American Physical Society. Filtering of weak pulses through a medium with infinite periodic structure in the absorption and/or transmission spectrum is analyzed. Two types of filters are considered. The first, named harmonic frequency crystal (HFC), is the filter whose periodic structure is harmonic and described by the sine or cosine function of frequency with the fundamental period. The second, named anharmonic frequency crystal (AHFC), also has a periodic structure with one fundamental period but it is described by the function containing many harmonics of the fundamental period. AHFC demonstrates properties quite similar to those of a high-finesse atomic frequency comb (AFC) with a limited number of absorption peaks separated by transparency windows. Filtering of the pulse through AHFC produces a prompt pulse accompanied by a few delayed pulses. Time spacing T of the delayed pulses is inversely proportional to the comb period. On the contrary, HFC transforms the input pulse into a train of many delayed pulses, generated at times nT, where n is an integer. Maximum amplitudes of the delayed pulses follow a wide bell-shaped envelope. Both HFC and AHFC are extensions of AFC, which was proposed to implement quantum memory protocols for single photons. In this paper, it is proposed to create time-bin qubits with the help of a short pulse filtering through HFC. HFC is also proposed to implement tomography of these quantum states. Another promising application of HFC is the optical detection of ultrasound in biological tissues for ultrasound-modulated optical tomography. Since HFC allows one to generate pulses with longer delay with respect to the excitation pulse, one could obtain higher discrimination between weak acoustically generated sidebands and the carrier.

http://dx.doi.org/10.1103/PhysRevA.98.043851

References

[1] F. Wilczek, Phys. Rev. Lett. 109, 160401 (2012). PRLTAO 0031-9007 10.1103/PhysRevLett.109.160401

[2] K. Sacha, Phys. Rev. A 91, 033617 (2015). PLRAAN 1050-2947 10.1103/PhysRevA.91.033617

[3] V. Khemani, A. Lazarides, R. Moessner, and S. L. Sondhi, Phys. Rev. Lett. 116, 250401 (2016). PRLTAO 0031-9007 10.1103/PhysRevLett.116.250401

[4] D. V. Else, B. Bauer, and C. Nayak, Phys. Rev. Lett. 117, 090402 (2016). PRLTAO 0031-9007 10.1103/PhysRevLett.117.090402

[5] C. W. von Keyserlingk, V. Khemani, and S. L. Sondhi, Phys. Rev. B 94, 085112 (2016). 2469-9950 10.1103/PhysRevB.94.085112

[6] N. Y. Yao, A. C. Potter, I.-D. Potirniche, and A. Vishwanath, Phys. Rev. Lett. 118, 030401 (2017). PRLTAO 0031-9007 10.1103/PhysRevLett.118.030401

[7] S. Choi, Nature 543, 221 (2017). 10.1038/nature21426

[8] H. de Riedmatten, M. Afzelius, M. U. Staudt, C. Simon, and N. Gisin, Nature (London) 456, 773 (2008). NATUAS 0028-0836 10.1038/nature07607

[9] M. Afzelius, C. Simon, H. de Riedmatten, and N. Gisin, Phys. Rev. A 79, 052329 (2009). PLRAAN 1050-2947 10.1103/PhysRevA.79.052329

[10] M. Bonarota, J. Ruggiero, J.-L. Le Gouët, and T. Chanelière, Phys. Rev. A 81, 033803 (2010). PLRAAN 1050-2947 10.1103/PhysRevA.81.033803

[11] T. Chanelière, J. Ruggiero, M. Bonarota, M. Afzelius, and J.-L. Le Gouët, New J. Phys. 12, 023025 (2010). NJOPFM 1367-2630 10.1088/1367-2630/12/2/023025

[12] M. Bonarota, J.-L. Le Gouët, S. A. Moiseev, and T. Chanelière, J. Phys. B 45, 124002 (2012). JPAPEH 0953-4075 10.1088/0953-4075/45/12/124002

[13] N. Gisin, G. Ribordy, W. Tittel, and H. Zbinden, Rev. Mod. Phys. 74, 145 (2002). RMPHAT 0034-6861 10.1103/RevModPhys.74.145

[14] J. Brendel, N. Gisin, W. Tittel, and H. Zbinden, Phys. Rev. Lett. 82, 2594 (1999). PRLTAO 0031-9007 10.1103/PhysRevLett.82.2594

[15] I. Marcikic, H. de Riedmatten, W. Tittel, V. Scarani, H. Zbinden, and N. Gisin, Phys. Rev. A 66, 062308 (2002). PLRAAN 1050-2947 10.1103/PhysRevA.66.062308

[16] R. T. Thew, A. Acin, H. Zbinden, and N. Gisin, Phys. Rev. Lett. 93, 010503 (2004). PRLTAO 0031-9007 10.1103/PhysRevLett.93.010503

[17] P. C. Humphreys, B. J. Metcalf, J. B. Spring, M. Moore, X.-M. Jin, M. Barbieri, W. S. Kolthammer, and I. A. Walmsley, Phys. Rev. Lett. 111, 150501 (2013) PRLTAO 0031-9007 10.1103/PhysRevLett.111.150501

[18] J. M. Donohue, M. Agnew, J. Lavoie, and K. J. Resch, Phys. Rev. Lett. 111, 153602 (2013) PRLTAO 0031-9007 10.1103/PhysRevLett.111.153602

[19] B. R. Nisbet-Jones, J. Dilley, A. Holleczek, O. Barter, and A. Kuhn, New J. Phys. 15, 053007 (2013). NJOPFM 1367-2630 10.1088/1367-2630/15/5/053007

[20] F. Vagizov, V. Antonov, Y. V. Radeonychev, R. N. Shakhmuratov, and O. Kocharovskaya, Nature (London) 508, 80 (2014). NATUAS 0028-0836 10.1038/nature13018

[21] R. N. Shakhmuratov, F. G. Vagizov, V. A. Antonov, Y. V. Radeonychev, M. O. Scully, and O. Kocharovskaya, Phys. Rev. A 92, 023836 (2015). PLRAAN 1050-2947 10.1103/PhysRevA.92.023836

[22] R. N. Shakhmuratov, Phys. Rev. A 95, 033805 (2017). 2469-9926 10.1103/PhysRevA.95.033805

[23] D. L. McAuslan, L. R. Taylor, and J. J. Longdella, Appl. Phys. Lett. 101, 191112 (2012). APPLAB 0003-6951 10.1063/1.4766341

[24] N. Horiuchi, Nat. Photon. 7, 85 (2013). 10.1038/nphoton.2013.20

[25] H. Sõnajalg and P. Saari, J. Opt. Soc. Am B. 11, 372 (1994). JOBPDE 0740-3224 10.1364/JOSAB.11.000372

[26] M. D. Crisp, Phys. Rev. A 1, 1604 (1970). 0556-2791 10.1103/PhysRevA.1.1604

[27] Handbook of Mathematical Functions, edited by M. Abramowitz and I. A. Stegun (Dover, New York, 1965).

[28] S. A. Moiseev, F. F. Gubaidullin, R. S. Kirillov, R. R. Latypov, N. S. Perminov, K. V. Petrovnin, and O. N. Sherstyukov, Phys. Rev. A 95, 012338 (2017). 2469-9926 10.1103/PhysRevA.95.012338

[29] S. A. Moiseev, K. I. Gerasimov, R. R. Latypov, N. S. Perminov, K. V. Petrovnin, and O. N. Sherstyukov, Sci. Rep. 8, 3982 (2018). 2045-2322 10.1038/s41598-018-21941-6

[30] H. Schwerer, D. Erni, and A. Rebane, J. Opt. Soc. Am. B 12, 1083 (1995). JOBPDE 0740-3224 10.1364/JOSAB.12.001083

[31] A. Renn, U. P. Wild, and A. Rebane, J. Phys. Chem. 106, 3045 (2002). JPCAFH 1089-5639 10.1021/jp0138025