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Analytical novel solutions to the fractional optical dynamics in a medium with polynomial law nonlinearity and higher order dispersion with a new local fractional derivative. (English)

Zbl 1479.78007
Phys. Lett., A 420, Article ID 127744, 19 p. (2021).

Summary: Novel solutions for the nonlinear dynamics of Schrödinger equation for polynomial law medium with third-order dispersion (TOD), fourth-order dispersion (FOD), and self-steepening are investigated based in a novel local fractional derivative of order α and the Jacobi elliptic function method which are combined into a novel fractional sub-equation method. The Jacobi elliptic function method will provide different types of analytical solutions and not only soliton type solutions for the propagation of ultra-short optical signals through a polynomial law medium. Solutions are illustrated in 3-D graphs, contour plots and 2-D plots under the obtained constraint conditions.

MSC:

78A40 Waves and radiation in optics and electromagnetic theory
78A48 Composite media; random media in optics and electromagnetic theory
35Q55 NLS equations (nonlinear Schrödinger equations)
81U30 Dispersion theory, dispersion relations arising in quantum theory
26A33 Fractional derivatives and integrals
33C45 Orthogonal polynomials and functions of hypergeometric type (Jacobi, Laguerre, Hermite, Askey scheme, etc.)

Keywords:

analytical solutions in medium with polynomial law nonlinearity; fractional-order derivative; fractional sub-equation method

Full Text: DOI

References:

[1] Wang, M. L., Solitary wave solutions for variant Boussinesq equations, Phys. Lett. A, 199, 169-172 (1995) · Zbl 1020.35528

[2] Wang, M. L.; Zhou, Y. B.; Li, Z. B., Applications of a homogeneous balance method to exact solutions of nonlinear equations in mathematical physics, Phys. Lett. A, 216, 67-75 (1996) · Zbl 1125.35401

[3] Parkes, E. J.; Duffy, B. R., An automated tanh-function method for finding solitary wave solutions to non-linear evolution equations, Comput. Phys. Commun., 98, 288-300 (1996) · Zbl 0948.76595

[4] Fan, E. G., Extended tanh-function method and its applications to nonlinear equations, Phys. Lett. A, 277, 4-5, 212-218 (2000) · Zbl 1167.35331

[5] Liu, S. K.; Fu, Z. T.; Liu, S. D., Jacobi elliptic function expansion method and periodic wave solutions of nonlinear wave equations, Phys. Lett. A, 289, 1-2, 69-74 (2001) · Zbl 0972.35062

[6] Fu, Z. T.; Liu, S. K., The JEFE method and periodic solutions of two kinds of nonlinear wave equations, Commun. Nonlinear Sci. Numer. Simul., 8, 2, 67-75 (2003) · Zbl 1018.35066

[7] Gepreel, K. A., Explicit Jacobi elliptic exact solutions for nonlinear partial fractional differential equations, Adv. Differ. Equ., 2014, Article 286 pp. (2014) · Zbl 1346.35211

[8] Kumar, V. S.; Rezazadeh, H.; Eslami, M.; Izadi, F.; Osman, M. S., Jacobi elliptic function expansion method for solving KdV equation with conformable derivative and dual-power law nonlinearity, Int. J. Appl. Comput. Math., 5, 5, 1-10 (2019) · Zbl 1431.35155

[9] Sirendaoreji, X., New exact travelling wave solutions for the Kawahara and modified Kawahara equations, Chaos Solitons Fractals, 19, 1, 147-150 (2004) · Zbl 1068.35141

[10] Wang, M. L.; Li, X. Z.; Zhang, J. L., The \(\frac{ G^\prime}{ G} \)-expansion method and travelling wave solutions of nonlinear evolution equations in mathematical physics, Phys. Lett. A, 372, 4, 417 (2007)

[11] Roshid, H-O.; Kabir, M. R.; Bhowmik, R. C.; Datta, B. K., Investigation of solitary wave solutions for Vakhnenko-Parkes equation via exp-function and Exp \((- \varphi (\xi))\)-expansion method, SpringerPlus, 3, 692 (2014)

[12] Roshid, H-O.; Rahman, M. A., The exp \((- \operatorname{\Phi} (\xi))\)-expansion method with application in the (1+1)-dimensional classical Boussinesq equations, Results Phys., 4, 150-155 (2014)

[13] Hossen, M. B.; Roshid, H-O.; Zulfikar, M., Modified double sub-equation method for finding complexiton solutions to the (1+1) dimensional nonlinear evolution equations, Int. J. Appl. Comput. Math., 3, 679-697 (2017)

[14] Roshid, H-O., Novel solitary wave solution in shallow water and ion acoustic plasma waves in-terms of two nonlinear models via MSE method, J. Ocean Eng. Sci., 2, 2, 196-202 (2017)

[15] Yıldırım, Y.; Biswas, A.; Asma, M.; Ekici, M.; Ntsime, B. P.; Zayed, E. M.E.; Moshokoa, S. P.; Alzahrani, A. K.; Belic, M. R., Optical soliton perturbation with Chen-Lee-Liu equation, Optik, 220, Article 165177 pp. (2020)

[16] Zheng, B.; Feng, Q., The Jacobi elliptic equation method for solving fractional partial differential equations, Abstr. Appl. Anal., 2014, Article 249071 pp. (2014) · Zbl 1470.35106

[17] Zheng, B., A new fractional Jacobi elliptic equation method for solving fractional partial differential equations, Adv. Differ. Equ., 2014, Article 228 pp. (2014) · Zbl 1346.35039

[18] Alharbi, A. R.; Almatra, M. B.; Abdelrahman, M. A.E., An extended Jacobian elliptic function expansion approach to the generalized fifth order KdV equation, J. Phys. Math., 10, 4, 310 (2019)

[19] Song, L.; Wang, W., Approximate rational Jacobi elliptic function solutions of the fractional differential equations via the enhanced Adomian decomposition method, Phys. Lett. A, 374, 31-32, 3190-3196 (2010) · Zbl 1238.34004

[20] Feng, Q., Jacobi elliptic function solutions for fractional partial differential equations, Int. J. Appl. Math., 46, 1, 121-129 (2016)

[21] Sonmezoglu, A., Improved generalized F-expansion method for the time fractional modified KdV(fmKdV) equation, AIP Conf. Proc., 1738, Article 290007 pp. (2016)

[22] Tasbozan, O., New analytical solutions for time fractional Benjamin-Ono equation arising internal waves in deep water, China Ocean Eng., 33, 5, 593-600 (2019)

[23] Fandio Jubgang, D.; Dikandé, A. M.; Sunda-Meya, A., Elliptic solitons in optical fiber media, Phys. Rev. A, 92, Article 053850 pp. (2015)

[24] Feng, Q.; Meng, F., Traveling wave solutions for fractional partial differential equations arising in mathematical physics by an improved fractional Jacobi elliptic equation method, Math. Methods Appl. Sci., 40, 10, 3676-3686 (2017) · Zbl 1370.35073

[25] Zayed, Elsayed M. E.; Al-Nowehy, Abdul-Ghani, New extended auxiliary equation method for finding many new Jacobi elliptic function solutions of three nonlinear Schrödinger equations, Waves Random Complex Media, 27, 3, 420-439 (2016)

[26] Hosseini, K.; Mirzazadeh, M.; Osman, M. S.; Al Qurashi, M.; Baleanu, D., Solitons and Jacobi elliptic function solutions to the complex Ginzburg-Landau equation, Front. Phys., 8, 225 (2020)

[27] Sarwar, A.; Gang, T.; Arshad, M.; Ahmed, I., Construction of bright-dark solitary waves and elliptic function solutions of space-time fractional partial differential equations and their applications, Phys. Scr., 95, 4, Article 045227 pp. (2020)

[28] Gepreel, K. A.; Mahdy, A. M.S., Algebraic computational methods for solving three nonlinear vital models fractional in mathematical physics, Open Phys., 19, 1, 152-169 (2021)

[29] Çulha Ünal, Sevil; Daşcioğlu, Ayşegül; Varol, Dilek, Jacobi elliptic function solutions of space-time fractional symmetric regularized long wave equation, Math. Sci. Appl. E-Notes, 9, 2, 53-63 (2021) · Zbl 1481.35378

[30] Yépez-Martínez, H.; Gómez-Aguilar, J. F., M-derivative applied to the dispersive optical solitons for the Schrödinger-Hirota equation, Eur. Phys. J. Plus, 134, 93 (2019)

[31] Zhou, Q.; Zhu, Q., Optical solitons in medium with parabolic law nonlinearity and higher order dispersion, Waves Random Complex Media, 25, 1, 52-59 (2014) · Zbl 1375.35076

[32] Zhou, Q., Optical solitons in the parabolic law media with high-order dispersion, Optik, 125, 18, 5432-5435 (2014)

[33] Biswas, A.; Mirzazadeh, M.; Eslami, M., Dispersive dark optical soliton with Schrödinger-Hirota equation by \(G\^\prime / G\)-expansion approach in power law medium, Optik, 125, 16, 4215-4218 (2014)

[34] Lu, D.; Seadawy, A.; Arshad, M., Applications of extended simple equation method on unstable nonlinear Schrödinger equations, Optik, 140, 136-144 (2017)

[35] Najafi, M.; Arbabi, S., Traveling wave solutions for nonlinear Schrödinger equations, Optik, 126, 23, 3992-3997 (2015)

[36] Ali, A.; Seadawy, A. R.; Lu, D., Soliton solutions of the nonlinear Schrödinger equation with the dual power law nonlinearity and resonant nonlinear Schrödinger equation and their modulation instability analysis, Optik, 145, 79-88 (2017)

[37] Zhou, Q.; Yao, D. Z.; Cui, Z., Exact solutions of the cubic-quintic nonlinear optical transmission equation with higher-order dispersion terms and self-steepening term, J. Mod. Opt., 59, 1, 57-60 (2012) · Zbl 1356.35076

[38] Al Qurashi, M. M.; Baleanu, D.; Inc, M., Optical solitons of transmission equation of ultra-short optical pulse in parabolic law media with the aid of Backlund transformation, Optik, 140, 114-122 (2017)

[39] Jawad, A. J.M.; Kumar, S.; Biswas, A., Soliton solutions to a few nonlinear wave equations in engineering sciences, Sci. Iran. Trans. D, Comput. Sci. Eng. Electr. Eng., 21, 3, 861-869 (2014)

[40] Savescu, M.; Alshaery, A. A.; Bhrawy, A. H.; Hilal, E. M.; Moraru, L.; Biswas, A., Optical solitons with coupled Hirota equation and spatial-temporal dispersion, Wulfenia, 21, 1, 35-43 (2014)

[41] Oldham, K. B.; Spanier, J., The Fractional Calculus (1974), Academic Press: Academic Press London · Zbl 0428.26004

[42] Miller, K. S.; Ross, B., An Introduction to the Fractional Calculus and Fractional Differential Equations (1993), Wiley: Wiley New York · Zbl 0789.26002

[43] Caputo, M.; Mainardi, F., A new dissipation model based on memory mechanism, Pure Appl. Geophys., 91, 134-147 (1971)

[44] Caputo, M.; Fabricio, M., A new definition of fractional derivative without singular kernel, Prog. Fract. Differ. Appl., 1, 2,

73-85 (2015)

[45] Atangana, A.; Baleanu, D., New fractional derivatives with nonlocal and non-singular kernel. Theory and application to heat transfer model, Therm. Sci., 20, 2, 763-769 (2016)

[46] Atangana, A.; Secer, A., A note on fractional order derivatives and table of fractional derivatives of some special functions, Abstr. Appl. Anal., 2013, Article 279681 pp. (2013) · Zbl 1276.26010

[47] Malomed, B. A., Optical solitons and vortices in fractional media: a mini-review of recent results, Photonics, 8, 9, 353 (2021)

[48] Zeng, L.; Mihalache, D.; Malomed, B. A.; Lu, X.; Cai, Y.; Zhu, Q.; Li, J., Families of fundamental and multipole solitons in a cubic-quintic nonlinear lattice in fractional dimension, Chaos Solitons Fractals, 144, Article 110589 pp. (2021)

[49] Zeng, L.; Shi, J.; Lu, X.; Cai, Y.; Zhu, Q.; Chen, H.; Long, H.; Li, J., Stable and oscillating solitons of PT-symmetric couplers with gain and loss in fractional dimension, Nonlinear Dyn., 103, 2, 1831-1840 (2021)

[50] Khalil, R.; Al Horani, M.; Yousef, A.; Sababheh, M., A new definition of fractional derivative, J. Comput. Appl. Math., 264, 65-70 (2014) · Zbl 1297.26013

[51] Atangana, A.; Baleanu, D.; Alsaedi, A., New properties of conformable derivative, Open Math., 13, 1, 889-898 (2015) · Zbl 1354.26008

[52] Cenesiz, Y.; Baleanu, D.; Kurt, A.; Tasbozan, O., New exact solutions of Burgers' type equations with conformable derivative, Waves Random Complex Media, 27, 1, 103-116 (2017) · Zbl 1375.35595

[53] He, S.; Sun, K.; Mei, X.; Yan, B.; Xu, S., Numerical analysis of a fractional-order chaotic system based on conformable fractional-order derivative, Eur. Phys. J. Plus, 132, 1, 36 (2017)

[54] Abdeljawad, T., On conformable fractional calculus, J. Comput. Appl. Math., 279, 57-66 (2015) · Zbl 1304.26004

[55] Chung, W. S., Fractional Newton mechanics with conformable fractional derivative, J. Comput. Appl. Math., 290, 150-158 (2015) · Zbl 1336.70033

[56] Cenesiz, Y.; Kurt, A., The new solution of time fractional wave equation with conformable fractional derivative definition, J. New Theory, 7, 79-85 (2015)

[57] Atangana, A.; Baleanu, D.; Alsaedi, A., Analysis of time-fractional Hunter-Saxton equation: a model of neumatic liquid crystal, Open Phys., 14, 1, 145-149 (2016)

[58] Yusuf, A.; Inc, M.; Aliyu, A. I.; Baleanu, D., Beta derivative applied to dark and singular optical solitons for the resonance perturbed NLSE, Eur. Phys. J. Plus, 134, 433 (2019)

[59] Yépez-Martínez, H.; Gómez-Aguilar, J. F., Fractional sub-equation method for Hirota-Satsuma-coupled KdV equation and coupled mKdV equation using the Atangana's conformable derivative, Waves Random Complex Media, 29, 4, 678-693 (2019)

[60] Gurefe, Y., The generalized Kudryashov method for the nonlinear fractional partial differential equations with the beta-derivative, Rev. Mex. Fis., 66, 771-781 (2020)

[61] Guzman, P. M.; Langton, G.; Motta Bittencurt, L. M.L.; Medina, J.; Napoles Valdes, J. E., A new definition of a fractional derivative of local type, J. Math. Anal., 9, 2, 88-98 (2018)

[62] Yépez-Martínez, H.; Rezazadeh, H.; Inc, M.; Akinlar, M. A., New solutions to the fractional perturbed Chen-Lee-Liu equation with a new local fractional derivative, Waves Random Complex Media, 1-36 (2021)

[63] Almeida, R.; Guzowska, M.; Odzijewicz, T., A remark on local fractional calculus and ordinary derivatives, Open Math., 14, 1122-1124 (2016) · Zbl 1355.26005

[64] Sousa, J. V.D. C.; de Oliveira, E. C., A new truncated M-ractional derivative type unifying some fractional derivative types with classical properties, Int. J. Anal. Appl., 16, 1, 83-96 (2018) · Zbl 1399.26013

[65] Zhang, S.; Zhang, H. Q., Fractional sub-equation method and its applications to nonlinear fractional PDEs, Phys. Lett. A, 375, 1069-1073 (2011) · Zbl 1242.35217

[66] Zhang, S.; Wang, W.; Tong, J-L., A generalized \((\frac{ G^\prime}{ G})\)-expansion method and its application to the (2 +1)-dimensional Broer-Kaup equations, Appl. Math. Comput., 209, 2, 399-404 (2009) · Zbl 1165.35457

[67] Ebaid, A.; Aly, E. H., Exact solutions for the transformed reduced Ostrovsky equation via the F-expansion method in terms of Weierstrass-elliptic and Jacobian-elliptic functions, Wave Motion, 49, 296-308 (2012) · Zbl 1360.35039

[68] Hong, B.; Lu, D., New exact Jacobi elliptic function solutions for the coupled Schrodinger-Boussinesq equations, J. Appl. Math., 2013, Article 170835 pp. (2013) · Zbl 1397.35273

[69] Liu, W. J.; Han, H. N.; Zhang, L.; Wang, R.; Wei, Z. Y.; Lei, M., Breathers in a hollow-core photonic crystal fiber, Laser Phys. Lett., 11, 4, Article 045402 pp. (2014)

[70] Yaşar, E.; Yıldırım, Y.; Yaşar, E., New optical solitons of space-time conformable fractional perturbed Gerdjikov-Ivanov equation by sine-Gordon equation method, Results Phys., 9, 1666-1672 (2018)

[71] Sirisubtawee, S.; Koonprasert, S.; Sungnul, S., Some applications of the \((G^\prime / G, 1 / G)\)-expansion method for finding exact traveling wave solutions of nonlinear fractional evolution equations, Symmetry, 11, 8, 952 (2019)

[72] Yépez-Martínez, H.; Gómez-Aguilar, J. F., Optical solitons solution of resonance nonlinear Schrödinger type equation with Atangana's-conformable derivative using sub-equation method, Waves Random Complex Media, 31, 3, 573-596 (2021)

[73] Gómez-Aguilar, J. F.; Yépez-Martínez, H.; Calderón-Ramón, C.; Cruz-Orduña, I.; Escobar Jiménez, R. F.; Olivares-Peregrino, V. H., Modeling of a mass-spring-damper system by fractional derivatives with and without a singular kernel, Entropy, 17, 9, 6289-6303 (2015) · Zbl 1338.70026

[74] Di Paola, M.; Pinnola, F. P.; Zingales, M., Comput. Math. Appl., 66, 5, 608-620 (2013), Fractional differential equations and related exact mechanical models · Zbl 1381.74038

[75] Li, H. M.; Xu, Y. S.; Lin, J., New optical solitons in high-order dispersive cubic-quintic nonlinear Schrödinger equation, Commun. Theor. Phys., 41, 829 (2004) · Zbl 1167.35517

[76] Yépez-Martínez, H.; Gómez-Aguilar, J. F.; Baleanu, Dumitru, Beta-derivative and sub-equation method applied to the optical solitons in medium with parabolic law nonlinearity and higher order dispersion, Optik, 155, 357-365 (2018)

[77] El, G. A.; Geogjaev, V. V.; Gurevich, A. V.; Krylov, A. L., Decay of an initial discontinuity in the defocusing NLS hydrodynamics, Physica D, 87, 186-192 (1995) · Zbl 1194.35407

[78] Fujioka, J.; Cortés, E.; Pérez-Pascual, R.; Rodríguez, R. F.; Espinosa, A.; Malomed, B. A., Chaotic solitons in the quadratic-cubic nonlinear Schrödinger equation under nonlinearity management, Chaos, Interdiscip. J. Nonlinear Sci., 21, Article 033120 pp. (2011) · Zbl 1317.35232

[79] Seadawy, A. R.; Dianchen, Lu D.; Nasreen, N.; Nasreen, S., Structure of optical solitons of resonant Schrödinger equation with quadratic cubic nonlinearity and modulation instability analysis, Physica A, 534, Article 122155 pp. (2019)

[80] Liu, X. Q.; Jiang, S.; Fan, W. B.; Liu, W. M., Soliton solutions in linear magnetic field and time-dependent laser field, Commun. Nonlinear Sci. Numer. Simul., 9, 361-365 (2004) · Zbl 1109.78321

[81] Huang, W.-H.; Mao, J.-W.; Qiu, W.-G., Exact solutions of Bose-Einstein condensate in linear magnetic field and time-dependent laser field, Acta Phys. Pol. A, 119, 3, 294-297 (2011)

[82] Hua-Mei, L., New exact solutions of nonlinear Gross-Pitaevskii equation with weak bias magnetic and time-dependent laser fields, Chin. Phys., 14, 2, 251-256 (2005)

[83] Hua-Mei, L., Dynamics of periodic waves in Bose Einstein condensate with time-dependent atomic scattering length, Commun. Theor. Phys., 47, 1, 63-68 (2007) · Zbl 1355.35174