

Javed, Amaria; Uthayakumar, T.; Alotaibi, M. O. D.; Al-Marzoug, S. M.; Bahlouli, H.; Al Khawaja, U.

Unidirectional flow of composite bright-bright solitons through asymmetric double potential barriers and wells. (English) [Zbl 1477.35241](#)

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Summary: We investigate the dynamics of two component bright-bright (BB) solitons through reflectionless double barrier and double well potentials in the framework of a Manakov system governed by the coupled nonlinear Schrödinger equations. The objective is to achieve unidirectional flow and unidirectional segregation/splitting, which may be used in the design of optical data processing devices. We observe how the propagation of composite BB soliton is affected by the presence of interaction coupling between the two components passing through the asymmetric potentials. We consider Gaussian and Rosen-Morse double potential barriers in order to achieve the unidirectional flow. Moreover, we observe a novel phenomenon which we name “*Polarity Reversal*” in the unidirectional flow. In this situation, the polarity of the diode is reversed. To understand the physics underlying these phenomena, we perform a variational calculation where we also achieve unidirectional segregation/splitting using an asymmetric double square potential well. Our comparative study between analytical and numerical analysis lead to an excellent agreement between the two methods.

MSC:

- [35Q55](#) NLS equations (nonlinear Schrödinger equations)
- [35Q60](#) PDEs in connection with optics and electromagnetic theory
- [78A60](#) Lasers, masers, optical bistability, nonlinear optics
- [78A45](#) Diffraction, scattering
- [35C08](#) Soliton solutions
- [37K40](#) Soliton theory, asymptotic behavior of solutions of infinite-dimensional Hamiltonian systems

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Keywords:

optical solitons; Manakov system; unidirectional flow; optical data processing

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References:

- [1] Scott, A., Encyclopedia of nonlinear science (2005), Routledge · [Zbl 1177.00019](#)
- [2] Hasegawa, A.; Kodama, Y., Solitons in optical communications (1995), Oxford: Oxford Univ. Press · [Zbl 0840.35092](#)
- [3] Mollenauer, L.; Gordon, J., Solitons in optical fibers (2006), Academic Press: Academic Press Boston
- [4] Akhmediev, N.; Ankiewicz, A., Solitons: nonlinear pulses and beams (1997), Chapman and Hall: Chapman and Hall London
- [5] Agrawal, G., Nonlinear fiber optics (2001), Academic Press: Academic Press San Diego
- [6] Kivshar, Y. S.; Agrawal, G. P., Optical solitons: from fibers to photonic crystals (2003), Academic Press: Academic Press San Diego
- [7] Keil, R.; Heinrich, M.; Dreisow, F.; Pertsch, T.; Tünnermann, A.; Nolte, S.; Christodoulides, D.; Szameit, A., All-optical routing and switching for three-dimensional photonic circuitry, *Sci Rep*, 1, 94 (2011)
- [8] Politi, A.; Cryan, M.; Rarity, J.; Yu, S.; O’Brien, J., Silica-on-silicon waveguide quantum circuits, *Science*, 320, 646 (2008)
- [9] Sabini, J.; Finlayson, N.; Stegeman, G., All optical switching in non linear x junctions, *Appl Phys Lett*, 55, 1176 (1989)
- [10] Chu, P.; Kivshar, Y.; Malomed, B.; Peng, G.; Quiroga-Teixeiro, M., Soliton controlling, switching, and splitting in nonlinear fused-fiber couplers, *J Opt Soc Am B*, 12, 898 (1995)
- [11] Peccianti, M.; Conti, C.; Assanto, G.; De Luca, A.; Umeton, C., All-optical switching and logic gating with spatial solitons in liquid crystals, *Appl Phys Lett*, 81, 3335 (2002)
- [12] Piccardi, A.; Alberucci, A.; Bortolozzo, U.; Residori, S.; Assanto, G., Soliton gating and switching in liquid crystal light valve, *Appl Phys Lett*, 96, 071104 (2010)
- [13] Królikowski, W.; Kivshar, Y., Soliton-based optical switching in waveguide arrays, *J Opt Soc Am B*, 13, 876 (1996)

- [14] Wu, Y., All-optical logic gates by using multibranch waveguide structure with localized optical nonlinearity, *IEEE J Sel Top Quantum Electron*, 11, 307 (2005)
- [15] Wu, Y.; Huang, M.; Chen, M.; Tasy, R., All-optical switch based on the local nonlinear Mach-Zehnder interferometer, *Opt Express*, 15, 9883 (2007)
- [16] Aghdami, K. M.; Golshani, M.; Kheradmand, R., Two-dimensional discrete cavity solitons: switching and all-optical gates, *IEEE Photon J*, 4, 1147 (2012)
- [17] Christodoulides, D. N.; Eugenieva, E. D., Blocking and routing discrete solitons in two-dimensional networks of nonlinear waveguide arrays, *Phys Rev Lett*, 87, 233901 (2001)
- [18] Scheuerand, J.; Orenstein, M., All-optical gates facilitated by soliton interactions in a multilayered kerr medium, *J Opt Soc Am B*, 22, 1260 (2005)
- [19] Javed, A.; Shaheen, A.; Khawaja, U. A., Amplifying optical signals with discrete solitons in waveguide arrays, *Phys Lett A*, 384, 126654 (2020)
- [20] Shaheen, A.; Javed, A.; Al Khawaja, U., Adding binary numbers with discrete solitons in waveguide arrays, *Phys Scr*, 95, 085107 (2020)
- [21] Vinayagam, P. S.; Javed, A.; Khawaja, U. A., Stable discrete soliton molecules in two-dimensional waveguide arrays, *Phys Rev A*, 98, 063839 (2018)
- [22] Forinash, K.; Peyrard, M.; Malomed, B., Interaction of discrete breathers with impurity modes, *Phys Rev E*, 49, 3400 (1994)
- [23] Cao, X.; Malomed, B., Soliton-defect collisions in the nonlinear Schrödinger equation, *phys. lett. a*, 206, 177 (1995) · [Zbl 1020.78505](#)
- [24] Frantzeskakis, D. J.; Theocharis, G.; Diakonou, F. K.; Schmelcher, P.; Kivshar, Y. S., Interaction of dark solitons with localized impurities in Bose-Einstein condensates, *Phys Rev A*, 66, 053608 (2002)
- [25] E. Miroshnichenko, A.; Flach, S.; Malomed, B., Resonant scattering of solitons, *Chaos*, 13, 874 (2003) · [Zbl 1080.35538](#)
- [26] Ahufinger, V.; Mebrahtu, A.; Corbalan, R.; Sanpera, A.; Phys, J., Quantum switches and quantum memories for matter-wave lattice solitons, *New*, 9, 4 (2007)
- [27] Weiss, C.; Castin, Y., Creation and detection of a mesoscopic gas in a nonlocal quantum superposition, *Phys Rev Lett*, 102, 010403 (2009)
- [28] Streltsov, A. I.; Alon, O. E.; Cederbaum, L. S., Scattering of an attractive Bose-Einstein condensate from a barrier: formation of quantum superposition states, *J Phys B*, 42, 091004 (2009)
- [29] Kivshar, Y. S.; ZhangFei; Vázquez, L., Resonant soliton-impurity interactions, *Phys Rev Lett*, 67, 1177 (1991)
- [30] Goodman, R. H.; Holmes, P. J.; Weinstein, M. I., Strong NLS soliton defect interactions, *Physica D*, 192, 215 (2004) · [Zbl 1061.35132](#)
- [31] Sakaguchi, H.; Tamura, M., Scattering and trapping of nonlinear Schrödinger solitons in external potentials, *J Phys Soc Jpn*, 73, 503 (2004)
- [32] Stoychev, K. T.; Primatarowa, M. T.; Kamburova, R. S., Resonant scattering of nonlinear Schrödinger solitons from potential wells, *Phys Rev E*, 70, 066622 (2004)
- [33] Morales-Molina, L.; Vicencio, R. A., Trapping of discrete solitons by defects in nonlinear waveguide arrays, *Opt Lett*, 31, 966 (2006)
- [34] Lee, C.; Brand, J., Enhanced quantum reflection of matter-wave solitons, *Europhys Lett*, 73, 321 (2006)
- [35] Ernst, T.; Brand, J., Resonant trapping in the transport of a matter-wave soliton through a quantum well, *Phys Rev A*, 81, 033614 (2010)
- [36] Aceves, A. B.; Moloney, J. V.; Newell, A. C., Theory of light-beam propagation at nonlinear interfaces. i. equivalent-particle theory for a single interface, *Phys Rev A*, 39, 1809 (1989)
- [37] Kivshar, Y. S.; Kosevich, A. M.; Chubykalo, O. A., Radiative effects in the theory of beam propagation at nonlinear interfaces, *Phys Rev A*, 41, 1677 (1990)
- [38] Cornish, S. L.; Parker, N. G.; Martin, A. M.; Judd, T. E.; Scott, R. G.; Fromhold, T. M.; Adams, C. S., Quantum reflection of bright matter-wave solitons, *Physica D*, 238, 1299 (2009) · [Zbl 1167.82322](#)
- [39] Pasquini, T. A.; Shin, Y.; Sanner, C.; Saba, M.; Schirotzek, A.; Pritchard, D. E.; Ketterle, W., Quantum reflection from a solid surface at normal incidence, *Phys Rev Lett*, 93, 223201 (2004)
- [40] Pasquini, T. A.; Saba, M.; Jo, G. B.; Shin, Y.; Ketterle, W.; Pritchard, D. E.; Savas, T. A.; Mulders, N., Low velocity quantum reflection of Bose-Einstein condensates, *Phys Rev Lett*, 97, 093201 (2006)
- [41] Cuevas, J.; Kevrekidis, P. G.; Malomed, B. A.; Dyke, P.; Hulet, R. G.; Phys, J., Interactions of solitons with a gaussian barrier: splitting and recombination in quasi-one-dimensional and three-dimensional settings, *New*, 15, 063006 (2013)
- [42] Al Khawaja, U.; Asad-uz-zaman, M., Directional flow of solitons with asymmetric potential wells: soliton diode, *EPL*, 101, 50008 (2013)
- [43] Liu, W.; Zhu, Y. N.; Liu, M.; Wen, B.; Fang, S.; Teng, H.; Lei, M.; Liu, L. M.; Wei, Z., Optical properties and applications for MoS₂-Sb₂Te₃-MoS₂ heterostructure materials, *Photonics Res*, 6, 220 (2018)
- [44] Liu, W.; Pang, L.; Han, H.; Shen, Z.; Lei, M.; Teng, H.; Wei, Z., Dark solitons in WS₂ erbium-doped fiber lasers, *Photonics Res*, 4, 111 (2016)
- [45] Liu, W.; Pang, L.; Han, H.; Liu, M.; Lei, M.; Fang, S.; Teng, H.; Wei, Z., Tungsten disulfide saturable absorbers for 67 fs

mode-locked erbium-doped fiber lasers, *Opt Express*, 25, 2950 (2017)

- [46] Liu, W.; Pang, L.; Han, H.; Bi, K.; Lei, M.; Wei, Z., Tungsten disulphide for ultrashort pulse generation in all-fiber lasers, *Nanoscale*, 9, 5806 (2017)
- [47] Yan, Y.; Liu, W.; Zhou, Q.; Biswas, A., Dromion-like structures and periodic wave solutions for variable-coefficients complex cubic-quintic Ginzburg-Landau equation influenced by higher-order effects and nonlinear gain, *Nonlinear Dyn*, 99, 1313 (2020)
- [48] Liu, W.; Yu, W.; Yang, C.; Liu, M.; Zhang, Y.; Lei, M., Analytic solutions for the generalized complex Ginzburg-Landau equation in fiber lasers, *Nonlinear Dyn*, 89, 2933 (2017)
- [49] Wang, C.; Nie, Z.; Xie, W.; Gao, J.; Zhou, Q.; Liu, W., Dark soliton control based on dispersion and nonlinearity for third-order nonlinear Schrödinger equation, *Optik*, 184, 370 (2019)
- [50] Fan, X.; Qu, T.; Huang, S.; Chen, X.; Cao, M.; Zhou, Q.; Liu, W., Analytic study on the influences of higher-order effects on optical solitons in fiber laser, *Optik*, 186, 326 (2019)
- [51] Fernandez-de la Garza, J. A.; López-Aguayo, S.; Opt, J., Stable Legendre-Lorentzian solitons in localized optical potentials, *J Opt*, 23, 055501 (2021)
- [52] Cruz-Gomez, M. A.; López-Aguayo, D.; Lopez-Aguayo, S.; Opt, J., Two-dimensional solitons in Laguerre-Gaussian potentials, *J Opt*, 22, 015504 (2019)
- [53] Felix-Rendon, U.; Lopez-Aguayo, S.; Opt, J., Solitons in-symmetric optical Mathieu lattices, *J Opt*, 20, 015606 (2017)
- [54] Khawaja, U. A.; Al-Marzoug, S. M.; Bahlouli, H.; Kivshar, Y. S., Unidirectional soliton flows in PT-symmetric potentials, *Phys Rev A*, 88, 023830 (2013)
- [55] Khawaja, U. A.; Sukhorukov, A., Unidirectional flow of discrete solitons in waveguide arrays, *Opt Lett*, 40, 2719 (2015)
- [56] Khawaja, U. A.; Al-Marzoug, S. M.; Bahlouli, H., All-optical switches, unidirectional flow, and logic gates with discrete solitons in waveguide arrays, *Opt Express*, 24, 11062 (2016)
- [57] Alotaibi, M. O.D.; Al-Marzoug, S. M.; Bahlouli, H.; Khawaja, U. A., Unidirectional flow of solitons with nonlinearity management, *Phys Rev E*, 100, 042213 (2019)
- [58] Li, S.; Dou, F., Matter-wave interactions in two-component Bose-Einstein condensates, *EPL*, 111, 30005 (2015)
- [59] Grimshaw, C. L.; Gardiner, S. A.; Malomed, B. A., Splitting of two-component solitary waves from collisions with narrow potential barriers, *Phys Rev A*, 101, 043623 (2020)
- [60] Lepri, S.; Casati, G., Asymmetric wave propagation in nonlinear systems, *Phys Rev Lett*, 106, 164101 (2011)
- [61] Lepri, S.; Malomed, B. A., Symmetry breaking and restoring wave transmission in diode-antidiode double chains, *Phys Rev E*, 87, 042903 (2013)
- [62] Bai, X. D.; Malomed, B. A.; Deng, F. G., Unidirectional transport of wave packets through tilted discrete breathers in nonlinear lattices with asymmetric defects, *Phys Rev E*, 94, 032216 (2016)
- [63] Sakaguchi, H.; Malomed, B. A.; Phys, J., Matter-wave soliton interferometer based on a nonlinear splitter, *New J Phys*, 18, 025020 (2016) · [Zbl 1456.35074](#)
- [64] Maor, O.; Dror, N.; Malomed, B. A., Holding spatial solitons in a pumped cavity with the help of nonlinear potentials, *Opt Lett*, 38, 5454 (2013)
- [65] Manakov, S., On the theory of two-dimensional stationary self-focusing of electromagnetic waves, *JETP*, 38, 248 (1974)
- [66] Bondeson, A.; Lisak, M.; Anderson, D., Soliton perturbations: A variational principle for the soliton parameters, *Phys Scr*, 20, 479 (1979) · [Zbl 1063.35528](#)
- [67] Anderson, D., Variational approach to nonlinear pulse propagation in optical fibers, *Phys Rev A*, 27, 3135 (1983)

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