Coupled system of Dirac Fermions with different Fermi velocities via composites of SUSY operators.

Summary: We use the framework of supersymmetric transformations in the construction of coupled systems of Dirac fermions. Its energy operator is a composite of the generators of the associated superalgebra, and the two coupled Dirac fermions acquire different Fermi velocities. We discuss in detail the peculiar spectral properties of the new system. The emergent phenomena like level crossing or generation of bound states in the continuum (BICs) are illustrated in two explicit examples.

MSC:
81V74 Fermionic systems in quantum theory
81Q60 Supersymmetry and quantum mechanics
70F05 Two-body problems
17A70 Superalgebras
47A10 Spectrum, resolvent

Keywords:
Dirac fermions; Dirac materials; coupled systems; supersymmetry; Fermi velocity; bound states in the continuum

Software:
DLMF

Full Text: DOI

References:
[1] Neto, A. H. Castro; Guinea, F.; Peres, N. M.R.; Novoselov, K. S.; Geim, A. K., The electronic properties of graphene, Rev. Mod. Phys., 81, 109 (2009)
[2] McCann, E.; Koshino, M., The electronic properties of bilayer graphene, Rep. Prog. Phys., 76, Article 056503 pp. (2013)
[3] McCann, E.; Abergel, D. S.L.; Fal’ko, V. I., Electrons in bilayer graphene, Solid State Commun., 143, 110 (2007)
[4] Kane, C. L.; Mele, E. J., Quantum spin Hall effect in graphene, Phys. Rev. Lett., 95, Article 226801 pp. (2005)
[5] Huertas-Hernando, D.; Guinea, F.; Brataas, A., Spin-orbit coupling in curved graphene, fullerences, nanotubes, and nanotube caps, Phys. Rev. B, 74, Article 155426 pp. (2006)
[6] Avsar, A.; Ochoa, H.; Guinea, F.; Özyilmaz, B.; van Wees, B. J.; Vera-Marun, I. J., Colloquium: spintronics in graphene and other two-dimensional materials, Rev. Mod. Phys., 92, Article 021003 pp. (2020)
[7] Wang, Zhe, Strong interface-induced spin-orbit interaction in graphene on WS2, Nat. Commun., 6, 8339 (Sep 2015)
[8] Altland, A., Low-energy theory of disordered graphene, Phys. Rev. Lett., 97, Article 236802 pp. (2006)
[9] Ando, T.; Nakanishi, T., Impurity scattering in carbon nanotubes: absence of back scattering, J. Phys. Soc. Jpn., 67, 1704 (1998)
[10] Fräsdorf, Ch.; Trifunovic, L.; Bogdanoff, N.; Brouwer, P. W., Graphene p n junction in a quantizing magnetic field: conductance at intermediate disorder strength, Phys. Rev. B, 94, Article 195439 pp. (2016)
[11] Ando, T., Crossover between positive and negative magnetoresistance in graphene: roles of absence of backscattering, J. Phys. Soc. Jpn., 90, Article 044712 pp. (2021)
[12] Koshino, M.; Ando, T., Splitting of the quantum Hall transition in disordered graphenes, Phys. Rev. B, 75, Article 033412 pp. (2007)
[13] Beenakker, C. W.J., Specular Andreev reflection in graphene, Phys. Rev. Lett., 97, Article 067007 pp. (2006)
[14] Beenakker, C. W.J., Colloquium: Andreev reflection and Klein tunneling in graphene, Rev. Mod. Phys., 80, 1337-1354 (2008)
[15] Titov, M.; Beenakker, C. W.J., Josephson effect in ballistic graphene, Phys. Rev. B, 74, Article 041401 pp. (2006)
[16] Cooper, F.; Khare, A.; Sukhatme, U., Supersymmetry in Quantum Mechanics (2001), World Scientific: World Scientific Singapore · Zbl 0988.81001
[17] Junker, G., Supersymmetric Methods in Quantum and Statistical Physics (1996), Springer: Springer Berlin - Zbl 0867.00011

[18] Nieto, L. M.; Pecheritsin, A. A.; Samsonov, B. F., Intertwining technique for the one-dimensional stationary Dirac equation, Ann. Phys., 305, 151 (2003) - Zbl 1028.81011

[19] Pecheritsyn, A. A.; Pozdeeva, E. O.; Samsonov, B. F., Darboux transformation of the nonstationary Dirac equation, Russ. Phys. J., 48, 365 (2005) - Zbl 1156.81376

[20] Pozdeeva, Ekaterina; Schulze-Halberg, Axel, Darboux transformations for a generalized Dirac equation in two dimensions, J. Math. Phys., 51, Article 113501 pp. (2010) - Zbl 1314.81078

[21] Castillo-Celeita, M.; Jakubský, V.; Zelaya, K., Form-preserving Darboux transformations for \((4 \times 4)\) Dirac equations

[22] Junker, G., Supersymmetry of relativistic Hamiltonians for arbitrary spin, Entropy, 12, 1590 (2020)

[23] Schulze-Halberg, A., First-order Darboux transformations for Dirac equations with arbitrary diagonal potential matrix in two dimensions, Eur. Phys. J. Plus, 136, 790 (2021)

[24] Jakubský, V., Spectrally isomorphic quantum systems, Phys. Rev. D, 91, Article 045039 pp. (2015)

[25] Correa, Francisco; Plyushchay, Mikhail S., Peculiarties of the hidden nonlinear supersymmetry of Poschl-Teller system in the light of Lane equation, J. Phys. A, Math. Theor., 40, Article 14403 pp. (2007) - Zbl 1127.81015

[26] Correa, Francisco; Jakubský, Vít; Plyushchay, Mikhail S., Aharonov-Bohm effect on \((A d S_2, )\) and nonlinear supersymmetry of reflectionless Poschl-Teller system, Ann. Phys., 324, 1078 (2009) - Zbl 1162.81014

[27] Correa, Francisco; Dunne, Gerald V.; Plyushchay, Mikhail S., The Bogoliubov/de Gennes system, the AKNS hierarchy, and nonlinear quantum mechanical supersymmetry, Ann. Phys., 324, 2522 (2009) - Zbl 1179.81085

[28] Díaz-Fernández, A.; Chico, Leonor; González, J. W.; Domínguez-Adame, F., Tuning the Fermi velocity in Dirac materials with an electric field, Sci. Rep., 7, 8058 (2017)

[29] Correa, F.; Jakubský, V., Twisted kinks, Dirac transparent systems and Darboux transformations, Phys. Rev. D, 90, Article 125003 pp. (2014)

[30] Nikiforov, A. F.; Uvarov, V. B., Special Functions of Mathematical Physics: A Unified Introduction with Applications (1988), Birkhäuser: Birkhäuser Basel, Germany - Zbl 0624.33001

[31] (Olver, F. W.J.; etal., NIST Handbook of Mathematical Functions (2010), Cambridge University Press: Cambridge University Press New York) - Zbl 1198.00002

[32] Bagchi, Bijan, Exceptional point in a coupled Swanson system

[33] Hsu, Chia Wei, Bound states in the continuum, Nat. Rev. Mater., 1, Article 16048 pp. (2016)

[34] Pappademos, J.; Sukhatme, U.; Pagnamenta, A., Bound states in the continuum from supersymmetric quantum mechanics, Phys. Rev. A, 48, 3525-3531 (1993)

[35] Petrović, J. S., Bound states in continuum of complex potentials generated by supersymmetric quantum mechanics, Phys. Lett. A, 300, 595-602 (2002) - Zbl 0976.81006

[36] Pankin, P. S., One-dimensional photonic bound states in the continuum, Commun. Phys., 3, 91 (2020)

[37] Duclos, P.; Exner, P.; Meller, B., Open quantum dots: resonances from perturbed symmetry and bound states in strong magnetic fields, Rep. Math. Phys., 47, 253-267 (2001) - Zbl 0967.81006

[38] Cortés, N.; Chico, L.; Pacheco, M.; Rosales, L.; Orellana, P. A., Bound states in the continuum: localization of Dirac-like fermions, Europhys. Lett., 108, Article 46008 pp. (2014)

[39] Jakubský, V.; Kuru, Ş.; Negro, J., Dirac fermions in armchair graphene nanoribbons trapped by electric quantum dots - Zbl 1290.82040

[40] Robnik, M., A simple separable Hamiltonian having bound states in the continuum, J. Phys. A, 19, 3845-3848 (1986) - Zbl 0617.58035

[41] Nickel, J. U., Resonances in quantum-dot transport, Phys. Rev. B, 46, Article 15348 pp. (1992)

[42] Gustafsson, S. J.; Sigal, I. M., Mathematica Concepts of Quantum Mechanics (2011), Springer: Springer Berlin

This reference list is based on information provided by the publisher or from digital mathematics libraries. Its items are heuristically matched to zbMATH identifiers and may contain data conversion errors. It attempts to reflect the references listed in the original paper as accurately as possible without claiming the completeness or perfect precision of the matching.