Wannier Solitons in Spin-Orbit-Coupled Bose-Einstein Condensates in Optical Lattices with a Flat-Band

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We investigate families of soliton solutions in a spin-orbit coupled Bose-Einstein condensate embedded in an optical lattice, which bifurcate from the nearly flat lowest band. Unlike the conventional gap solitons the obtained solutions have the shape well approximated by a Wannier function (or a few Wannier functions) of the underlying linear Hamiltonian with amplitudes varying along the family and with nearly constant widths. The Wannier solitons (WSs) sharing all symmetries of the system Hamiltonian are found to be stable. Such solutions allow for the construction of Wannier breathers, that can be viewed as nonlinearly coupled one-hump solitons. The breathers are well described by a few-mode model and manifest stable behavior either in an oscillatory regime with balanced average populations or in a self-trapping regime characterized by unbalanced atomic populations of the local potential minima (similarly to the conventional boson Josephson junction), with the frequencies controlled by the inter-atomic interactions.