

Lattice Solitons in Discrete NLS Equation with Saturation

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We consider standing lattice solitons for discrete nonlinear Schrödinger equation with saturation (NLSS), where so-called transparent points were recently discovered. These transparent points are the values of the governing parameter (e.g., the lattice spacing) for which the Peierls-Nabarro barrier vanishes. In order to explain the existence of transparent points, we study a solitary wave solution in the continuous NLSS and analyse the singularities of its analytic continuation in the complex plane. The existence of a quadruplet of logarithmic singularities nearest to the real axis is proven and applied to two settings: (i) the fourth-order differential equation arising as the next-order continuum approximation of the discrete NLSS and (ii) the advance-delay version of the discrete NLSS. In the context of (i), the fourth-order differential equation generally does not have solitary wave solutions. Nevertheless, we show that solitary waves solutions exist for specific values of governing parameter that form an infinite sequence. We present an asymptotic formula for the distance between two subsequent elements of the sequence in terms of the small parameter of lattice spacing. It is in excellent agreement with our numerical data. In the context of (ii), we also derive an asymptotic formula for values of lattice spacing for which approximate standing lattice solitons can be constructed. The asymptotic formula is in excellent agreement with the numerical approximations of transparent points. However, we show that the asymptotic formulas for the cases (i) and (ii) are essentially different and that the transparent points do not generally imply existence of continuous standing lattice solitons in the advance-delay version of the discrete NLSS.