

Uniformly accurate nested Picard iterative schemes for nonlinear Schrödinger equation with highly oscillatory potential

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The nonlinear Schrödinger equation with a highly oscillatory potential (NLSE-OP) often appears in many multiscale dynamical systems, where the temporal oscillation causes the major numerical difficulties. Recently, the splitting schemes (Su et al., 2020) were analyzed rigorously for solving the NLSE-OP and the error bounds show that they are only uniformly first-order accurate. This obviously can not meet the requirement of high precision in actual calculation. In this paper, in order to obtain a higher uniform convergence order, we study the nested Picard iterative (NPI) schemes for the NLSE-OP with polynomial nonlinearity. Firstly we propose a uniformly accurate first-order exponential wave integrator (EWI) scheme for arbitrary nonlinearity by integrating the potential exactly. Then we construct a uniformly accurate second-order NPI scheme for the NLSE-OP with polynomial nonlinearity. The schemes are fully explicit and very efficient due to the fast Fourier transform (FFT). We give rigorously error analysis and establish error bounds for the numerical solutions without any CFL-type condition constraint. Numerical experiments prove the correctness of our theoretical analysis and the effectiveness of our schemes. Theoretically, our schemes can be extended to uniformly accurate arbitrary high order for the NLSE-OP.

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